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CREATION IN SCIENCE AND TECHNIQUE - A GENERAL APPROACH

Dr. R.E.Goot,1, M.B.A Student Eng.V.M.Goot,2
Holon Institute of Technology, Holon, Israel1
Tel Aviv University, Tel Aviv, Israel 2
gootrom@gmail.com1, gootvld@gmail.com2

Abstract: As applied to science and technique a creative problem is defined as stemming from the resolution of a contradiction. The concept of state space for the problem is introduced and the abstract model for the problem as an element of the state space is proposed. Then the solving consists in extension of the space dimension. The contradiction is resolved by separation of the required contradictory properties into different coordinates. We present examples from different science and technique fields (mathematics, physics, biology, medicine and communications). It is noted that the proposed concept can serve as the basis for developing of practical methodology for creative problems solving.

Keywords: creative problem, contradiction, separation method

1. Introduction

1.1 In the paper we consider the creative process as a thought process only. Thereby we restrict ourselves by science and technique, and will not elaborate on creative processes related to art. Along the paper the term “creation” will thus be used in the sense of scientific and technique creation.

1.2 Two types of thinking – two types of sciences

“There are two kinds of people in the world, those who believe there are two kinds of people in the world and those who don’t.” Robert Benchley

There are two well-established, types of thinking: rational (logical, analytical) and figurative (synthetic), relating to two cerebral hemispheres of the brain. In accordance with that, the knowledge can also be divided into the two (although with indistinct bounds) groups – logical and figurative (non-logical). The typical example for the first type is mathematics and the examples for the second type are art criticism and descriptive sciences. Naturally the real man’s thought (as well as knowledge fields) possesses the both type features; however it tends to a greater or lesser extent to one of these poles. As for the sciences, it is because of that thought typization, they are also separated into the groups. So named descriptive sciences are being such because the subjects of their interests are often complicated and have so immense number of interior connections that only those possessing possibility to entire coverage (scope) could investigate them. That is the reason why the analytical type investigators could not approach to them for a long time.

2. Creative problem

“We know that the problem has no solution, but we wish to learn how to solve it.”

A. and B. Strugatsky,
“Monday begins on Saturday”

In order to discuss creativity problem, firstly we would like to determine what creation is.

As it was shown in [1] any psychological investigation includes irremovable act of introspection, so, strictly speaking, each researcher can produce his own personal conception. Correspondingly, the definition of creation given by psychologists is, as a rule, descriptive nature, due to their figurative thinking. Such typical, “averaged over set” determination [2,3,4 and references therein.] is approximately as follows:

definition 1: Creation (creative process) is a productive intellectual activity producing a non-trivial (non-obvious) result.

Accordingly to this approach, the creative process is represented as some “black box” with a new nontrivial result at the output. Without any attempts to belittle the importance of such definitions, we note, nevertheless, that they cannot satisfy investigators and practical workers with analytical way of thinking. They are more interested in definitions, characterizing the occurrence “inside the box”. The break-through in this direction was performed in [5,6] as applied to technical inventions. There was shown that the invention process is resolving of a contradiction in a technical object. Following to [5,6] and expanding the field of application we give the

definition 2: Creation (creative process) is productive intellectual activity, allowing to reach a new result by resolution of a contradiction.

It follows from here the

definition 3: Creative problem is the problem of some contradiction resolution.

Claims 2 and 3 state indeed that contradiction and its resolution are necessary and sufficient tests for creativity. Thus, these claims allow to clearly distinguish between creative and non-creative thought independently of any subjective or objective novelty of the result. However, it yields necessity to explain what a contradiction is. We provide the following, suitable for our aim:

definition 4: Contradiction is the necessity for an object to possess two properties, each one excluding the other.

3. Model of creative problem and solution of creative task (creative process)

3.1 The space of states

The concept of state, as it seems, relates to primaries, irreducible concepts which are impossible to characterize by means of more elementary concepts. They are usually introduced descriptively with appeal to professional and worldly experience. The state of an object is usually determined with the number of generalized coordinates $q_1, \ldots, q_N$, which can be numbers, functions and other objects. The set of the possible states is named states space. For example, the state of chess game is determined by the position of the pieces on the board, and the set of the possible positions is the state space. The concept of state space is widely used in numerous fields such as automatic control, pattern recognition and other.
3.2 The method of separation to solve of creative problem

Assume that a creative problem (as defined in the previous definition) applied to a given object A exists. Suppose that a N-dimensional states space \( Q_N = \{q_n\}_{n=1}^N \) is associated to A. The object A possesses the feature B and the requirement is imposed to endow A with the property C, which is incompatible with B, holds for A. Consequently the following contradiction exists: there is the necessity for A to possess both B and C but it is impossible. As applied to the states space \( Q_N \), it means that the generalized coordinate \( q_n \), holding the property B exists in \( Q_N \). As for C, the contradiction exists because this property cannot have an associated coordinate in \( Q_N \). Should any coordinate of the state hold C, the problem would be non-creative and could be solved with known methods, possibly requiring some corresponding qualification. The natural resolution of the contradiction lies in that the space \( Q_N \) should be expanded to \( Q_{N+1} \) by introducing an additional coordinate \( q_{N+1} \), which would be able to hold C. Thus \( Q_{N+1} \) will be new states space for the new object, possessing the both properties B and C. We summarize the following principle for solving of creative problem:

Contradiction is resolved by introduction a new generalized coordinate into the state space and the separation of the contradictory properties into the different coordinates.

4. Examples

We provide below examples illustrating the applications of the presented principle. The examples belong to the several fields of science and technique.

4.1 Mathematics:

Complex numbers

The well-known elementary example, is the solution of the quadratic equation \( x^2 - \alpha = 0 \). The equation is solved by means of real numbers for the case \( \alpha \geq 0 \). The state space for the solutions is one-dimensional, it is a real numbers axis \((-\infty < x < \infty)\). The contradiction arises when \( \alpha < 0 \). On the one hand, the solution must exist, on the other hand it is not able to exist in the current state space. As it well known, the contradiction is resolved by introducing a second coordinate (the axis of imaginary numbers). Thus, one-dimensional space is expanded and turned in the regular two-dimensional complex plane.

4.2 Physics:

Helium superconductivity

Liquid helium flows through narrow capillaries (tubes) and slots without viscosity at ultra-low temperature. Thus the contradictory lies in both the presence and absence of viscosity. The contradiction was explained by construction of two component model, when the temperature is below \( T = 2.17°K \), the second component arises, so that helium has two components at the same time (two generalized coordinates) – normal (He-I) and super-fluid (He-II), existing independently one from the other) [7].

4.3 Communication techniques:

4.3.1 Difference phase shift keying (DPSK)

Development of communication systems has caused a permanent demand to increase capacity and performance under the bounding frequency and power resources. One of intermediate stages on the development way of modern communication systems was to use the phase of harmonic signal as the modulated parameters. It promised the essential improvement for performance without increasing of the transmission power and frequency band. However it required the reference signal with constant phase but it was not a success to extract of it from the information bearing modulation (DPSK). The new parameter was introduced into the signal - difference between phases of two consecutive signals and it was used as modulated parameter. Thus the dimension of parameters space was expanded from three-dimension (amplitude, frequency and phase) for four-dimension (amplitude, frequency phase and difference of phases) [8].

4.3.2 Reception of signals under near-zone fields interferences

The receiving antennas for radio signals very often have to be displayed close to transmitting antennas of several local radio stations (including piratical) and far from the source of information bearing signals. The contradiction consists in that it is necessary to receipt signals (useful) and do not receipt signals (harmful). The contradiction was resolved by the usage of the well-known effect – distinction between electrical and magnetic components of electromagnetic field. For the far-zone field these components are in phase and for the near-zone field the phase shift between the components is half period. The receiving antenna is at the far-zone field for the transmitting antenna of information bearing signals (transmitter) and it is placed at the near-zone field for the antennas of harmful signals transmitters. The common used receiving antennas respond to electrical component of electromagnetic field. Thus, the space of states has only generalized coordinate. We introduce the second coordinate – magnetic component. The component is receipted by the additional magnetic antenna. Owing to the difference between phases for near- and far-zone fields, the interfering and information signals can be separated and successful reception of the information signal is performed [9].

4.4 Biology:

4.4.1 Sexual division

During the evolution process of highly organized animals, the Nature had had to solve the following contradictory problem: to follow environment changes, organisms must be provided with the property of variability in order to adopt itself to the changes. On the other hand, it needs stability for preservation of useful changes. The contradiction was resolved by two-sexual nature of organisms. The nature assays variants of the changes on males by the random search method. The useful properties are fixed in females.

4.4.2 Dolphin sleeping

Like any other living creature, sleeping is necessary for Dolphins in order to rest and accumulate energy; on the other hand the Dolphin is not able to sleep because it has to be conscious in order to look out for possible predators (like sharks). Thus the following contradiction occurs: it has to sleep and it does not have to sleep. The contradiction is resolved as follows: dolphins have a unique ability called Unihemispheric slow-wave sleep which allows them to shut down only one hemisphere of its brain at a time giving it a possibility to rest. During this time the opposite eye is closed and the other hemisphere of the brain monitors the environment and controls breathing functions. In this case the contradiction is resolved by introducing an additional coordinate (the object performing the sleeping and consciousness functions).
4.5 Medicine:

4.5.1 Intracavity irradiation treatment of tumor disease

Malignant tumors of uterine body are one of the most severe diseases for woman. Intracavity irradiation is widely used for treatment of the disease. The medical procedure of the treatment consists in introducing of hollow bar into the uterine cavity through its cervical channel. Then a capsule with radioactive preparation is delivered pneumatically from the storage into the bar. After the procedure ending the capsule is returned to the storage. The main disadvantage of the method is its painfulness, caused by the bar size (1-1.5 cm diameter). The advantage is the possibility for intracavity radioactive irradiation. Thus the contradiction lies in the necessity for irradiation (for treatment) and impossibility of the irradiation (because painfulness). The contradiction was resolved by division in time: initially the size must be small (for painless introducing into the cavity), and afterwards the size must be large (for delivery treatment). It was realized with use of elastic (rubber, for example) balloon. Firstly the balloon is in a deflated state. It is introduced into the cavity through the cervical channel and then blown by radioactive gas, filling up the cavity. The extraction is performed in the inverse order [10].

4.5.2 Clinical research – placebo substances

The process of a new drug development includes several phases: Discovery and development, Preclinical research and Clinical Research – all those followed by a process of federal approval. After the preliminary development of the drug there is a need to test its efficiency such as its effect. This kind of testing is usually performed on a group of people who have the disease or condition that the medicine is developed for. One of the methods that are used to examine the effect of the drug is comparing several medical indicators between two groups: treatment (people who receive the drug) and control (people who do not receive the drug) groups. The participants of the experiment are assigned to one of these groups without being aware of the identity of the group they were assigned to - in order to neutralize any subjective psychological influence of the participants on the results of the experiment. This condition creates a contradiction – the participants that are selected for the control group have to receive medicine (in order to preserve the conditions of the experiment) but on the other hand they cannot receive the medicine (since the effect of the medicine is examined by comparing their medical indicators to the indicator of those in the treatment group). This contradiction is resolved by adding an additional coordinate – the degree of influence of the medicine. In this kind of experiments the people in the control group usually receive a Placebo medicine, which looks exactly like the drug given to the other group except that it excludes the active material of the drug itself and contains another substance that does not effects the medical condition of the participant.

5. The influence of inertia of thinking on creative process

Consider the following elementary training problem, which appears in many psychological books as the test for creative thinking.

Nine points are on a sheet, disposed at the angles, in the middle of sides and in the center of an imaginary square. It is required to trace the continuous line, composed of no more than four straight segments so that the line would pass over all the nine points. Emphasize that it must be done without lifting the pencil from the sheet and returning along the line. The solution is given in Figure 1. Once the solution is presented, it becomes apparent that the difficulties were caused by the attempts to remain in the bound of the square. It means that we tried to solve not the stated problem, but another one, imposed by thinking inertia. The starting problem contained no contradiction. The contradictions aroused only in the models for the problem, formed by imagination (must be in the square and impossible to be in the square). This new problem turned out to be creative, and solved by expansion of the states space from the square to the whole plane. In essence we dealt with no contradiction, but rather with a kind of pseudo contradiction. As a rule, pseudo contradictions superimpose on real contradictions, hampering the solving.

Now we propose to continue the solving of the same problem, but instead of broken line it is required to draw only a straight line (one!). One of the authors carried out the experiment many times. The problem was insoluble before and was immediately solved after the familiarization with the content of the sections 2 and 3. The solution is presented in Figures 1 and 2.

If you solved also this problem, you are suggested to solve the same problem (only one straight line!) in the case of points disposed on a classroom board.

6. Discussion

6.1 First of all it is necessary to emphasize the difference between separation as a general principle for resolution of contradictions and the concrete applications of that principle that in the specific techniques for resolving specific contradictions. When creating inventions, the authors resolved contradictions without perception that they performed a specific realization of some general principle, although unknown for them. From this point of view, the known methods and the approaches to elaborate inventive
tasks (brainstorming, TRIZ and other) are, in essence, methods for searching of new coordinates in the corresponding state space.

6.2 Turn now to the issue about provability.

In mathematics and other connected scientific fields, the issue can be resolved perfectly when standard binary logic is used. Even ternary logic ("true-false-unknown") is not employed, so as "unknown" is considered as "false". In the natural sciences, based on experiments and observations, the issue is resolved by the requirement of experimental reproducibility, although it resembles very often the proposition to solve a scientific problem by vote [12]. Indeed only practice is the criterion for "true". In order to confirm or reject the proposed claim, the authors undertook the prolonged experiment, extended near fourteen years. A lot of mathematical, scientific and technical problems, which were undoubtedly creative, were examined. It may be said that the validity was being proved by the attempts of disproof. A resolved contradiction was found every time and it was resolved indeed with use of separation in the corresponding states space. Thus, one can assert that the separation is the general principle for resolution of contradictions in natural sciences, mathematics and technique.

7. Conclusion

"All generalizations are false, including this one"

Mark Twain

So:

7.1 Any creative problem is the problem for resolution of some contradiction.

7.2 Any contradiction is resolved by separation method, including the expansion of the problem's states space.

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Introduction

The research on the technology transfer and its practical application is becoming ever more important due to its potential positive impact on the development of the organizations, which are applying it. The technology transfer as well as its results can be considered as an innovation of a certain grade. The multilateral interrelation of these concepts is best illustrated by the Venn diagram [7]. The systematic literature search [7] identified a variety of researches [27; 37] focusing on the classification of the technology transfer. Depending on the viewpoint the technology transfer is defined as a technology, technique or knowledge that has been developed in a given organization and transferred to another where it is adopted and used [22 cited in 26]; an adoption of innovation made by another organization [28 cited in 30] or an application of technology to a new use or user [11 cited in 30]. The results of the focus group discussion [7] indicate that the technology transfer should be viewed as a systematic process of transformation in which a variety of stakeholders from individual (people), organizational (University-Industry) and macro (Industry-Science-Society) levels may be involved. The university-industry cooperation is an often studied form of technology transfer in the scientific literature (see, e.g., 15; 23; 24) and often is analysed in the context with the government, thus creating the so called Triple Helix model [see e.g. 9]. The university-industry cooperation holds the potential to create reciprocal benefits for the involved stakeholders as well as the general society, thus gaining increased importance [25 cited in 10].

The term technology can be referred to both a physical item and the information or knowledge [see e.g., 19; 26; 32]. The Paper analyses the Lean management techniques know-how transfer from the industry (manufacturer of vehicles) to the university. As suggested [8] the process of know-how transfer can be best implemented by using a learning outcomes oriented approach and the performance of know-how transfer is affected by the accuracy of the stated learning outcomes, applied teaching, learning and assessment methods and both internal and external environment characteristics of the stakeholders involved in the process. The aim of this Paper is to identify the drivers of and barriers to the know-how transfer. Accordingly, the research question is – which are the drivers of and barriers to the know-how transfer and foreign origin, and the publicly available information on the university-industry cooperation models. As a result 90 factors were determined, both the drivers of and barriers to the cooperation between the university and the industry [6]. Using the pair-comparison method the following 14 factors affecting university-industry cooperation were chosen and adapted for this know-how transfer case study:

1. Clarity and concreteness of the stated outcomes of the skill acquisition process;
2. Existence of a common goal among all stakeholders participating in the skill acquisition process (industry representatives, academics, students);
3. Mutual trust among the stakeholders involved (industry representatives, academics, students) in the skill acquisition process;
4. The students’ prior knowledge for the skill acquisition process;
5. The students’ ability to absorb the skills acquired as a result of the cooperation initiative;
6. Interest of the universities to learn and help provide solutions to the existing problems of the companies;
7. Capacity of the industry representatives to define the achievable outcomes of the resulting skill acquisition process;
8. Motivation of the industry representatives participating in the cooperation initiative;
9. Motivation of the academics to promote the skill acquisition process;
10. Motivation of the students to acquire new skills while cooperating with the companies;
11. Availability of rooms and equipment for students during their skill acquisition process;
12. Participation of other institutions (local municipalities, NGOs, business incubators, university career centres, etc.) in the skill acquisition process;
13. Positive legal framework regulation for the skill acquisition process in the companies;

Methods

Quantitative and qualitative data collection was carried out by surveying students (hereinafter respondents) participating in the know-how transfer project. The questionnaire included the previously indicated drivers of and barriers to university-industry cooperation. In most cases the limitations in the attitude researches are related to the fact that there are significant differences in the subjective perspectives, attitudes and feelings of the respondents in the absence or existence of a certain criteria. In order to acquire more accurate response, for the categorization of the factors, a modified Kano methodology [14] was applied, which is often used to determine the consumer needs and for quality assurance.
purposes. This method allows to analyse the aspects in a more detailed way similar to Herzberg et al. (1966), etc. [2; 3; 4; 13; 17; 18; 35 cited in 1]. The methodology of the Kano model [14] prescribes formulating the research aspects into two groups – functional and dysfunctional. The functional is a positively formulated assumption, i.e., the given aspect applies, while the dysfunctional is a negatively formulated assumption, i.e., the given aspect does not apply. Different possible options of the answers are available [see e.g. 36]; however, the following formulations have been adapted:

1) I like it;
2) I expect it;
3) I am neutral;
4) I can tolerate it;
5) I do not like it at all.

The importance (category) of any given aspect can be determined according to a modified evaluation matrix of the Kano methodology (see Table 1).

### Table 1: Modified Kano evaluation matrix, based on [31]

<table>
<thead>
<tr>
<th>Functional form of the question</th>
<th>Dysfunctional form of the question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I like it very much</td>
<td>Q</td>
</tr>
<tr>
<td>2. I expect it</td>
<td>A</td>
</tr>
<tr>
<td>3. I am neutral</td>
<td>A</td>
</tr>
<tr>
<td>4. I can tolerate it</td>
<td>A</td>
</tr>
<tr>
<td>5. I do not like it at all</td>
<td>P</td>
</tr>
<tr>
<td>1. Like it very much</td>
<td>Rₐ</td>
</tr>
<tr>
<td>2. I expect it</td>
<td>Q</td>
</tr>
<tr>
<td>3. I am neutral</td>
<td>I</td>
</tr>
<tr>
<td>4. I can tolerate it</td>
<td>I</td>
</tr>
<tr>
<td>5. I do not like it at all</td>
<td>M</td>
</tr>
<tr>
<td>1. Like it very much</td>
<td>Rₐ</td>
</tr>
<tr>
<td>2. I expect it</td>
<td>I</td>
</tr>
<tr>
<td>3. I am neutral</td>
<td>I</td>
</tr>
<tr>
<td>4. I can tolerate it</td>
<td>Q</td>
</tr>
<tr>
<td>5. I do not like it at all</td>
<td>M</td>
</tr>
</tbody>
</table>

The survey – the categorization or the importance of the factors tested in the research are shown in Table 2.

### Table 2: Categorization of factors affecting university-industry cooperation

<table>
<thead>
<tr>
<th>Factor</th>
<th>Number of Respondents (n=10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Category</td>
</tr>
<tr>
<td>M</td>
<td>1</td>
</tr>
<tr>
<td>P</td>
<td>2</td>
</tr>
<tr>
<td>A</td>
<td>3</td>
</tr>
<tr>
<td>Rₐ</td>
<td>0</td>
</tr>
<tr>
<td>Rₚ</td>
<td>0</td>
</tr>
<tr>
<td>Rₐ</td>
<td>0</td>
</tr>
<tr>
<td>I</td>
<td>1</td>
</tr>
<tr>
<td>Q</td>
<td>0</td>
</tr>
<tr>
<td>1. I like it very much</td>
<td>Q</td>
</tr>
<tr>
<td>2. I expect it</td>
<td>A</td>
</tr>
<tr>
<td>3. I am neutral</td>
<td>A</td>
</tr>
<tr>
<td>4. I can tolerate it</td>
<td>A</td>
</tr>
<tr>
<td>5. I do not like it at all</td>
<td>P</td>
</tr>
<tr>
<td>1. Like it very much</td>
<td>Rₐ</td>
</tr>
<tr>
<td>2. I expect it</td>
<td>Q</td>
</tr>
<tr>
<td>3. I am neutral</td>
<td>I</td>
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<tr>
<td>4. I can tolerate it</td>
<td>I</td>
</tr>
<tr>
<td>5. I do not like it at all</td>
<td>M</td>
</tr>
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<td>1. Like it very much</td>
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<td>Q</td>
</tr>
<tr>
<td>5. I do not like it at all</td>
<td>M</td>
</tr>
</tbody>
</table>

The survey results indicate that in most cases the respondents' attitude towards the importance of the aspects is rather heterogeneous, except for factors as follows:

- The students' ability to learn and use skills acquired as a result of the cooperation initiative;
- The students' prior knowledge for the skill acquisition process within the company;
- Interest of the universities to learn and help provide solutions to the existing problems of the companies.

According to the Kano methodology it is clear that the final two factors are evaluated as rather unimportant, while the ability of the students to learn and use skills acquired as a result of the cooperation initiative is considered as the performance aspect or rather important, because if it is met or if it isn’t, the satisfaction and dissatisfaction increases proportionally accordingly. The ability to acquire and use the skills (absorptive capacity) both on the individual, group and organizational level has been analysed within the Learning organization concept [see, e.g., 21]. The ability of a company to recognize the value of external information, to assimilate it, and apply it to commercial ends is critical to its innovative capabilities [5].

Although the students’ prior knowledge is believed to be an important factor [see, e.g., 12; 16; 33; 34], respondents found it as relatively indifferent. This could be explained by the fact that in this project the students were not required to have any additional knowledge thus it was not a defining factor for the skill acquisition. However, the situation unveils the imperfection of the Kano methodology. The evaluation results of other factors are not unambiguous, however according to the proportion of the answers, separate groups can be identified. Among them factors which are not relatively important to the respondents themselves:

- Participation of other institutions (local municipalities, NGOs, business incubators, university career centres, etc.) in the skill acquisition process;


1. Positive legal framework regulation for the skill acquisition process in the companies;
The following factors were defined as rather important:
2. Availability of rooms and equipment for students during their skill acquisition process;
3. Mutual trust among the stakeholders (industry representatives, academics, students) in the skill acquisition process;
4. Motivation of the students to acquire new skills while cooperating with the companies;
5. Motivation of the academics to promote the skill acquisition process;
6. Existence of a common goals among all stakeholders participating in the skill acquisition process (industry representatives, academics, students);
7. Capacity of the industry representatives to define the achievable outcomes of the resulting skill acquisition process;
8. Motivation of the industry representatives participating in the cooperation initiative;
9. Clarity and concreteness of the stated outcomes;

The evaluation of the tested factors according to the respondents’ opinion indicates that in the majority of cases they strongly agree or rather agree to the provided criteria. With the exception of the following criteria:

1. Interest of the universities to learn and help provide solutions to the existing problems of the companies;
2. Participation of other institutions (local municipalities, NGOs, business incubators, university career centres, etc.) in the skill acquisition process;

When evaluating the interest of the universities to learn and to provide solutions to the existing problems of the companies, the respondents have provided the following comments: “It is not in the interests of the university to solve the most significant problems of a given company, but rather to educate the students thus improving their understanding about the possible problems and solutions to them in the business environment.”; “The university is interested in helping the companies to solve their problem, because by such means the university is creating closer interrelationships between the both sectors and thus creates highly valuable internship placements in the given companies for the students to enrol in”. The provided quotes provide an example of the difference in the respondents’ attitudes. The evaluation results of the factors related to the other institutions’ involvement in the skill acquisition process is related to the fact that such other institutions were not present. Most of the respondents (9 out of 10) strongly agree that the factor clarity and concreteness of the stated outcome is important within the skill acquisition process. The respondents provided the following comments: “All tasks are clear”, “The achievable tasks were clearly defined”, “The outcomes were defined already in the beginning of the study course, before our visit to the company.”, “We were introduced to the tasks and how to conduct them well in advance as well as the possibility to approach the lecturer or the head of the company in case we had any uncertainty”. The results of the evaluation as well as the fact that the given aspect is believed to be rather important, it can be suggested that in this case the factor is a technology transfer driver of the most importance.

Additional factors which importance were highly evaluated (more than half of the 10 respondents strongly agreed), are the:

1. Motivation of the industry representatives participating in the cooperation initiative;
2. Availability of rooms and equipment for students during their skill acquisition process;
3. Existence of a common goals among all stakeholders participating in the skill acquisition process (industry representatives, academics, students);
4. Capacity of the industry representatives to define the achievable outcomes of the resulting skill acquisition process;
5. Motivation of the students to acquire new skills while cooperating with the companies.

Respondents provided the following comments regarding the aforementioned factors:

“All representatives of the company (…) were cooperative and replied to all of the questions by students, thus I believe they were motivated”; “For the students to acquire the skills and to effectively cooperate with the company, it is highly important to have access to rooms and equipment, which is the only way how to see and understand the real situation as well as the possible problems.”; “The company was highly involved in the process of educating and informing the students. The aim of the students is to gain new knowledge and understanding about the actual processes in the companies. The same involved aim applies to the companies which are eager to provide the necessary information to the students, thus attracting them as the new employees!”; “All of the participating parties had common goal, since everyone benefited from our visit”; “If the company is participating in this process, it has to be able to define what particularly important skills they would like to disseminate and what are the achievable outcomes.”; “We were motivated to fulfil the given tasks as good as we could, so the company may gain the largest possible benefit from our cooperation.”

### 5. Conclusions

The research results indicate that in most cases the opinion of the student groups on the factor importance is not homogenous. Nonetheless, it allows drawing conclusions. However, the factor significance evaluation indicates that the given case from the perspective of the tested factors can be defined as successful. It can be concluded that out of the tested factors the most important is the ability of the students to learn and use skills acquired as a result of the cooperation initiative, meanwhile the most success-defining factor - clarity and concreteness of the stated outcomes in the skill acquisition process. It can be concluded, that tested factors are the drivers of technology transfer. Although the sample of the case study was quantitatively limited, the results indicate the usefulness of the Kano methodology, because from the perspective of the respondents factors can be divided into multiple categories. The specificity of the research defines its limitations and limits the generalisation of the results; however, it can be used complementary with other case studies. The novelty of the research...
is defined by the use of Kano methodology for categorization of factors, thus proving that the application of Kano methodology is not limited to determining of consumer needs and quality assurance purposes.

6. Acknowledgments

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7. References

Abstract: Planning the innovative products includes both a technical and commercial evaluation. Suppose, an organization is looking for a new product and has several alternatives that finish initial screening at the same time. Sometimes the organization will have enough resources to develop and market all of these innovations, but usually resources are limited and one product is being chosen above the others. So we need some simple methods to compare products and choose the best. There are several ways of comparing the products, one of this is Quality function deployment QFD and Break even point BEP method. The goal of this paper is commercial evaluation with Break even point method as method for comparing the products and QFD method usage on the theory and practice base.

Keywords: BEP - BREAK EVEN POINT, QFD - QUALITY FUNCTION DEPLOYMENT, NEW PRODUCTS

1. Introduction

All organizations make products. These products might be goods - like a car, computer, house or clothes - or they might be services - like transport, a holiday, health care or insurance. An organization can only be successful if it makes the products that customers want. So an organization must find that kind of products that customers really demand, and then it must make the products to satisfy this demand.

Introducing a new product is expensive and needs careful planning. The planning for a new product goes through a number of stages. These start with the generation of ideas, and end when the product is actually sold to customers. The details of the planning depend on the organization and the product, but a common approach has next stages: generation of ideas - initial screening of ideas - conceptual and detailed design - development and testing - market and economic analysis - final product development - launch of product.

Most organizations continuously search for new ideas they can exploit. Some of these ideas come from within the organization - a research department may develop a new product, or the operations people may suggest a change to an existing product. Many ideas come from outside the organization - a competitor's product might be adapted to fit into a company's range, customers may demand a product that is not currently available, or new regulations make a new product essential.

Introducing a new product is expensive and needs careful planning. The planning for a new product goes through a number of stages. The generic product development process consists of six phases, as illustrated in figure 1. The process begins with a planning phase, which is the link to advanced research and technology development activities. The output of the planning phase is the project's mission statement, which is the input required to begin the concept development phase and which serves as a guide to the development team. The last stage of the product development process is the product launch, when the product becomes available for purchase in the marketplace.

One way of looking at the development process is as the initial creation of a wide set of alternative product concepts and then the subsequent narrowing of alternatives and increasing specification of the product until the product can be reliably and repeatable produced by the production system.

Another way of looking at the development process is as an information-processing system. The process begins with inputs such as the corporate objectives and the capabilities of available technologies, product platforms, and production systems. Various activities process the development information, formulating specifications, concepts, and design details. The process concludes when all the information required to support production and sales has been created and communicated.

In the early phases of product development, various risks are identified and prioritized. As the process progresses, risks are reduced as the key uncertainties are eliminated and the functions of the product are validated. When the process is completed, the team should have substantial confidence in the product, working correctly and being well received by the market.

Figure 1 identifies the key activities and responsibilities of the different function of the organization during each development phase. Because of their continuous involvement in the process, we choose to articulate the roles of marketing, design, and manufacturing. Representatives from other functions, such as research, finance, field service, and sales, also play key roles at particular points in the process.

A key component of market success is to recognize the customer, meet and exceed customer requirements. Not surprisingly, quality function deployment (QFD) had begun in Japan as a quality system for creating new innovative products to satisfy customer's wishes. To efficiently deliver value to customers it is necessary to listen to the voice of the customer throughout the product or service development. Quality experts in Japan developed
the tools and techniques and organized them into a comprehensive system to assure quality and customer satisfaction in new and even innovative products and services.

A lot of companies are looking for new innovative products, but only few have alternatives that customers really demand. So we need some methods to compare products and choose the best. Break-even method is very useful for the obvious purpose of seeing how many units must be sold to make a profit, but they also help us with choices between alternative products. Figure 2 presents steps in design of products and well-known procedure methods from definition of the customer needs to the conceptual design.

In this paper I present both methods, which usage is very simple, but essential for success in the marketplace.

![Steps in design of products](Image)

**Simple procedure methods**

- Definition of the customer needs
  - Marketing information
- Conceptual design:
  - Evaluation and feasibility study
- Break even point
  - (BEP)

**Fig. 2 Steps and well-known procedure methods in Design of Innovative Product from Definition to the Conceptual design**

2. Two simple, but important methods in design of innovative products

2.1 QFD - simple method for market success

QFD links the needs of the customer (and user) with design, development, engineering, manufacturing, and service functions. It helps organizations seek out both spoken and unspoken needs, translate these into actions and designs, and focus various business functions toward achieving common goal. QFD empowers organizations to exceed normal expectations and provide a level of unanticipated excitement that generates valued "QFD uses a series of interlocking matrices that translates customer needs into product and process characteristics."

In QFD method, product development translates customer expectations on function requirements into specific engineering and quality characteristics. Quality function deployment has four phases. Phase 1 gathers the voice of the customer puts it in words accurately understood by the producing organizations and analyzes it versus the capability and strategic plans of the organizations. Phase 2 identifies the area of priority breakthrough that will have a result in dramatic growth in market share for the producer. Phase 3 represents the breakthrough to new technology. Phase 4 represents the production of the new product and new technology at the highest possible quality standards.

QFD uses a series of matrices to document information collected and developed and represent the team's plan for a product. The QFD methodology is based on a systems engineering approach consisting of the following general steps:

- Derive top-level product requirements or technical characteristics from customer needs (product planning matrix).
- Develop product concepts to satisfy these requirements.
- Evaluate product concepts to select the optimum one (concept selection matrix).
- Partition system concept or architecture into subsystems or assemblies and flow-down higher level requirements or technical characteristics to these subsystems or assemblies.
- Derive lower level product requirements (assembly or part characteristics) and specification from subsystem/assembly requirements (assembly/part deployment matrix).

- For critical assemblies or parts, flow-down lower level product requirements (assembly or part characteristics) to process planning.
- Determine manufacturing process steps to meet these assembly or part characteristics.
- Based in these process steps, determine set-up requirements, process controls and quality control to assure achievement of these critical assembly or part characteristics.

The following methodology has been suggested for implementing QFD. The following steps are important in QFD. However, there is a very specific process that should be followed when building the House of Quality - a complex graphical tool for product planning matrix (see Fig. 3). These steps are provided as an introduction.

![Fig. 3 The expanded house of Quality QFD](Image)

**Key to interrelationship matrix symbol**

- Strong interrelationship
- Medium interrelationship
- Weak interrelationship

Quality function deployment and the house of quality serve as a living document and a source of ready reference for related products, processes, and future improvements. Their purpose is to serve as a method for strengthening communications and tearing down internal and external walls. Through customer’s needs and competitive analysis, QFD helps to identify the critical technical components that require change. Issues are addressed that may never have surfaced before. These critical issues are then driven to identify the critical parts, manufacturing operations, and quality control measures needed to produce a product that fulfills both customer needs and producer needs within a shorter development cycle time. Tools such as designed experiments assist in the improvement of processes to meet those needs.

2.2 BEP - simple method for market success

Before introducing a new product, an organization must know if demand will be high enough to make a profit. The income generated must cover the cost of producing each unit, but it must also recover the money which was spent on development before the product was launched. This includes the costs of research, tooling, prototypes, market surveys, trial runs, and so on.
We can define the profit from selling a product as:

Profit = Income - Total costs

In this equation the total costs come from a number of sources and can be classified as:

- Fixed costs, which are constant regardless of the number of units made and
- Variable costs, which depend on the number of units made.

Research and development costs, for example, are fixed regardless of the number of units made. Other fixed costs come from marketing, administration, lighting, heating, rent, debt repayments and a range of overheads. On the other hand, the cost of raw materials, direct labour, maintenance and some other costs are directly affected by output - a doubling of output will double these costs. You have probably met this when running a car.

Then:
Total costs = fixed cost + variable cost
Total costs = fixed cost + number of units made × cost per unit
Total costs = \( CF + n \times CU \)

where:
\( n \) = number of units sold
\( CF \) = fixed cost
\( CU \) = variable cost per unit

The income is much simpler and comes from:
Income = number of units sold × price charged per unit
Income = \( n \times P \)

where:
\( P \) = price charged per unit

We now have an income and total costs that both rise linearly with the number of units made, as shown in Figure 4. The break-even point occurs when the income equals the total costs, and is the point where these lines cross each other.

The break-even point is the number of units that must be sold before an organization covers all costs and begins to make a profit.

\[ n = \frac{CF}{P - CU} \]

For each product we have Break even point:

- **A**: \( n = \frac{120,000}{12 - 9.5} = 48,000 \)
- **B**: \( n = \frac{260,000}{23.5 - 19} = 57,778 \)
- **C**: \( n = \frac{280,000}{25 - 22} = 93,334 \)

If the company wants the lowest break-even point it would choose product A. But the company must be interest in the time taken to break point. For each product this gives:

- **A**: 48,000 / 12,000 = 4 years
- **B**: 57,778 / 16,500 = 3.5 years
- **C**: 93,334 / 16,500 = 5 years

In this case product B is the first to start making the profit. Another objective might be to maximize long-term profit. For each product the lifetime profit is:

- **A**: \( (3 \times 12,000 \times 12) - (3 \times 12,000 \times 9.5) - 120,000 = -30,000 \) €
- **B**: \( (5 \times 16,500 \times 23.5) - (5 \times 16,500 \times 19) - 260,000 = +111,250 \) €
- **C**: \( (6 \times 18,500 \times 25) - (6 \times 18,500 \times 22) - 280,000 = +53,000 \) €
Product A makes a net loss over its expected life, while product B gives the best total profit. Overall, the best decision on the objectives of our case-study company is production of product B. Aluminium swing arm – product B passes the feasibility study and it moves to final design and testing. This is where the product changes from a prototype or concept model, to the form that will be sold to customer.

3.2 Case study of QFD

We can not imagine economy without continuous development, innovation and creativity. We show the design, solution and product development - the mechanism of building fittings with Quality Function Deployment method. QFD is a method of quality assurance based on pre-defined customer requirements, which reinforces the characteristics of the product, some of which depend on fulfillment of all the requirements, defines the critical points in the product and its manufacturing.

The introduction of QFD methods in the new products development phase is one of the most difficult steps. At this stage, we have to choose a large number of important information such as customer requirements, weight of importance and direction of improvements, that define the future steps of the project for the end-product.

Building a house of quality QFD looks simple. Good construction of this house depends on good cooperation between the project team with a group of potential buyers of a new innovative product. Complexity of the house depends on the number of customer requirements and quality characteristics of R&D team.

Figure 5 shows the QFD house of quality for mechanism of building fittings.

4. Conclusions

The economic success of manufacturing firms depends on their ability to identify the needs of customers and to quickly create products that meet these needs and can be produced at low cost. Achieving these goals is not solely a marketing problem, nor is it solely a design problem or a manufacturing problem; it is a product development problem involving all of these functions.

Product development process is the sequence of different steps or activities which enterprise employs to conceive, design, and commercialize a product. Before the start of the mass production of a new product it is necessary to use several calculation and technical methods. Companies can use in their strategy a few simple methods and skills for success in the market. QFD and BEP are methods that can be a significant extent affect the performance of the product in the market.

Quality function deployment and the house of quality serve as a living document and a source of ready reference for related products, processes, and future improvements. Their purpose is to serve as a method for strengthening communications and tearing down internal and external walls. Through customer needs and competitive analysis, QFD helps to identify the critical technical components that require change.

The main advantage of break-even analysis is that it points out the relationship between cost, production volume and returns. It can be extended to show how changes in fixed cost-variable cost relationships, in commodity prices, or in revenues, will affect profit levels and break-even points.

Calculation of break-even point is important for every business because it tells business owners and managers how much sales are needed to cover all fixed as well as variable expenses of the business or the sales volume after which the business will start generating profit.

5. References


Fig. 5 QFD - Mechanism of building fittings
CASE STUDY – INNOVATION AND BUSSINESS EXCELENCE

Prof. Dr Mitreva E. 1, Prof. Dr Krivokapić Z. 2
University "Goce Delcev", Skopje, Macedonia, elizabeta.mitreva@ugd.edu.mk 1
University of Montenegro, Podgorica, Montenegro, zdrrvok@ac.me 2

Abstract: Success in the market can only be achieved if the business processes are designed and realized with the optimum use of the resources in order to do the best job for the first time, without any disadvantages, without waste of time and to the satisfaction of all the interested parties. Sustainable success can only be left out if innovations are being promoted and innovated. That is why this paper is based on innovations in correlation with the European Quality Award, so we are evaluating the state of innovativeness of the relationship with the model of business excellence. The enterprises have been analyzed through the questionnaire in accordance with the criteria for obtaining the international quality award.

The obtained data have united the experience and reality of significance of a number of certified organizational systems in Montenegro. The analysis of data, principles and strategies that would be resulted from this research should help and provide useful directives in developing of a model for improving of organizational performance, in defining of measures to achieve a sustainable business systems, for increase of innovation, to contribute the strengthening of links among the enterprises, scientific research and Innovation.

Keywords: Business Excellence, European Quality Award, Standardization, Business Processes, Innovations

1. Introduction

The subject of this paper includes enterprises from Montenegro, and their impact on the global market where there is a global increase in claims related to quality. The main objective of this paper is that, to make the analysis of the situation by applying modern scientific approaches and their application in business environments. This will affect the performance improvement of business processes, particularly in the promotion and development of innovation and entrepreneurship in companies with certified management systems, and those who have not done it.

The European Quality Award model quality with its criteria enables organizations to realize a picture of themselves on the basis of clear criteria. Most of the countries on the basis of this model have their own national awards. Montenegro has no national quality award and there is no one company that is applying for the European Quality Award. Therefore, the paper is oriented towards organizations with certified management system (ISO 9001, ISO 14001 or any others), because such systems are arranged, using a planned approach, possess the necessary dose of persistence and have defined rights, obligations and responsibilities of each individual.

The results stemming from this research for these companies can be taken as a benchmark for all others, because the rules for certification of management systems are unambiguous, which leads to the conclusion that the results are widely used.

2. Business excellence

The concept of business excellence (BE) should be seen as an expression of the highest quality and reliability. For superior organizations is characterized to continuously improve their operations and adapt to changes in time and space, and simultaneously cause changes on their own. Organizations that seek business excellence are characterized by superior business results - at the same time in their business inevitably involve a wider social responsibility. [1]

Today, the business excellence is evidenced on the basis of national and regional awards, which play a particularly important role in the development of quality in each country which are extensively applied on the basis of established quality awards. The three most famous model of business excellence are: the Deming Award in Japan, the US National Quality Award Malcolm Baldrige and the European Quality Award - EFQM. The paper discusses the EFQM - European model. Many countries in the world have their own national award,. All these awards were declared for models of excellence, and the criteria which change over time, are used to compare organizations or self-assessment in the process of continuous improvement of business.

The EFQM Excellence Model is based on nine criteria. Five of these are "Enablers" and four are "Results". The "Enabler" criteria cover what an organisation does and how it does it. The "Results" criteria cover what an organisation achieves (Figure 2).

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**Fig. 1 The Fundamental Concepts EFQM.**

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---

**Fig. 2 EFQM Excellence Model.**
As shown in Figure 2, the model reflects the causal-consequential relationship between the actuator and the results of the criteria. Correlation of the left and right hand side consists of the causal-consequential relation between the mover and the results, as well as the feedback of the results in the form of learning and innovation.[4]

Confirmation of a causal-consequential link between the actuator and the result is of fundamental importance in self-assessment, where the assessor should always check the Log file consistency between the given results and data collected on the basis of relevant criteria and driving sub-criteria. Such consistency is sometimes difficult to verify in view of the holistic character of the organization, because different drivers react to each other in the creation of the result. [5,6]

3. Innovation

Innovation is introduction of a new, previously unknown product or process or significant improvement of already existing organization scheme which leads to the development of a new generation of products and their distribution.

Understanding the significance of innovation and reengineering of products/services, innovation strategy and activities of organization in that field is one of the preconditions for achieving competitive advantage and survival in dynamic market. Business system that tends to be successful and to make a progress in market aspect needs to be innovative. Creation of the new market or new category of product is the most efficient way of competing in mature markets. Innovations and innovative strategies, constant improvements and application of knowledge bring a series of advantages and their significance is reflected in the following [7,8]:

- Innovation encourages the economic growth and makes profit,
- Growth in innovations of 1% contributes to the growth of income per a citizen of about 0,05%,
- Innovation directly influences the increase of employment and indirectly contributes to economic efficiency and profit,
- Innovative products provide the winning and retaining of a share in the market, as well as the increase of profitability in markets.

The concept of innovation can best be observed through the definition of innovation as the implementation of a new and improved idea, procedure, good, service, process which brings new benefits or quality in implementation. The most accepted is classification by OECD: [9,10]

1) Innovations of products/services,
2) Innovations of process,
3) Innovations of organization,
4) Innovations of marketing.

Innovation of product – some product or service which is new or significantly improved. This includes significant improvement in technical specifications, components and materials, improvement in the sense of approaching users’ requirements and suitability for use or some other functional characteristics.

Innovation of process – new or significantly improved method of production or delivery. This includes significant changes in techniques, equipment and/or software.

Innovation of organization represents the implementation of a new method of the organization within the enterprise, organization in the workplace or organization of external relations.

Innovation of marketing – new method in marketing that includes significant changes in product’s design and packaging, placement of the product, promotion of the product or price formation.

4. Research methodology and results

Research was carried out by interview method. Questionnaire that is used in that occasion consisted of 91 questions, 33 of which referred to innovativeness in correlation with the criteria elements of the European Quality Award.

From the set of all Montenegrin business systems, we performed a survey on the sample of 120 business systems as following:

1) Statistical set: 425 business systems, from 15 Montenegrin cities;
2) Sample: 120 business systems;
3) Unit of research (entity): small, medium or large Montenegrin enterprise;
4) Instrument of research: INTERVIEW – filling in the survey questionnaire by the interviewer;
5) Manner of selecting the respondents: Systematic.

<table>
<thead>
<tr>
<th>Elements</th>
<th>Montenegro</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statistical group</td>
<td>125</td>
</tr>
<tr>
<td>Sample size</td>
<td>60</td>
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<tr>
<td>Standard utilization</td>
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<tr>
<td>size</td>
<td></td>
</tr>
<tr>
<td>One standard</td>
<td>24 (40%)</td>
</tr>
<tr>
<td>Integrated standard</td>
<td>36 (60%)</td>
</tr>
<tr>
<td>Micro</td>
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<tr>
<td>Small</td>
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<tr>
<td>Medium</td>
<td>45%</td>
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<tr>
<td>Big</td>
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<td>70%</td>
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<tr>
<td>state</td>
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<tr>
<td>Education</td>
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<tr>
<td>Utilization of quality tools</td>
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<td>Innovation orientation</td>
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<td>R&amp;D investment</td>
<td>1,62% of revenue 33,33% without investment</td>
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<td>Employee training investment</td>
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<tr>
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<td>Own inno activities</td>
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<td>Profitability improvement</td>
<td>-</td>
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</tbody>
</table>

For the purpose of this study a comparison was based on seven issues, which the authors believe that in terms of the goals are the most important and can contribute to obtaining the most beneficial results [11]. The following table gives a comparative view on all items.
Table 1: Investment in modernization of business systems.  
Question 1a: Do you have invested in the business systems modernization in the last 3 years?  
<table>
<thead>
<tr>
<th>Option</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Yes</td>
<td>98.17%</td>
</tr>
<tr>
<td>No</td>
<td>1.83%</td>
</tr>
</tbody>
</table>

Table 1: Investment in modernization of business systems.  
Question 1b: What type of investments is made?  
<table>
<thead>
<tr>
<th>Category</th>
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</tr>
</thead>
<tbody>
<tr>
<td>New machines</td>
<td>17.33%</td>
</tr>
<tr>
<td>New equipment</td>
<td>42.40%</td>
</tr>
<tr>
<td>Training of employees</td>
<td>11.18%</td>
</tr>
<tr>
<td>Other</td>
<td>7.00%</td>
</tr>
</tbody>
</table>

Table 2: The existence of the person or team responsible for innovation.  
Question 2: Is there a person or team responsible for innovation?  
<table>
<thead>
<tr>
<th>Existence</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formally exists</td>
<td>30.18%</td>
</tr>
<tr>
<td>Informally exists</td>
<td>54.17%</td>
</tr>
<tr>
<td>Does not exist</td>
<td>15.99%</td>
</tr>
</tbody>
</table>

Table 3: The frequency of innovation related meetings.  
Question 3: How often are held meetings related to innovation?  
<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don't hold meetings</td>
<td>15.99%</td>
</tr>
<tr>
<td>Half-yearly or yearly</td>
<td>8.17%</td>
</tr>
<tr>
<td>Quarterly</td>
<td>12.00%</td>
</tr>
<tr>
<td>Monthly</td>
<td>26.67%</td>
</tr>
<tr>
<td>Weekly or more often</td>
<td>35.64%</td>
</tr>
</tbody>
</table>

Table 4: The funds allocated to innovation.  
Question 4: How many funds are annually allocated for innovation?  
<table>
<thead>
<tr>
<th>Percentage</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than 5%</td>
<td>19.18%</td>
</tr>
<tr>
<td>3% - 5%</td>
<td>9.18%</td>
</tr>
<tr>
<td>1% - 3%</td>
<td>22.60%</td>
</tr>
<tr>
<td>Less than 1%</td>
<td>17.60%</td>
</tr>
<tr>
<td>Do not set aside</td>
<td>31.64%</td>
</tr>
</tbody>
</table>

Table 5: Place of innovation in the strategy of the operating system.  
Question 5: What priority is given to innovation in business strategy?  
<table>
<thead>
<tr>
<th>Priority</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovations are not a priority</td>
<td>8.33%</td>
</tr>
<tr>
<td>Due attention is paid to them</td>
<td>42.50%</td>
</tr>
<tr>
<td>Among top 10 priorities</td>
<td>20.00%</td>
</tr>
<tr>
<td>Among top 3 priorities</td>
<td>26.67%</td>
</tr>
<tr>
<td>The highest priority</td>
<td>2.50%</td>
</tr>
</tbody>
</table>

Table 6: Documents that involve innovation.  
Question 6: Documents that involve innovation?  
<table>
<thead>
<tr>
<th>Document</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract</td>
<td>0.01%</td>
</tr>
<tr>
<td>Milestone that defines a system</td>
<td>36.38%</td>
</tr>
<tr>
<td>Statement of submission</td>
<td>18.00%</td>
</tr>
<tr>
<td>Financial reports</td>
<td>12.82%</td>
</tr>
<tr>
<td>Promotion materials</td>
<td>17.24%</td>
</tr>
<tr>
<td>Innovations not included in documents</td>
<td>35.95%</td>
</tr>
</tbody>
</table>

Table 7: Share of innovation in the total income of business systems.  
Question 7: What is the share of revenues from new - improved products / services developed in the last 3 years, the total income of the business system?  
<table>
<thead>
<tr>
<th>Share</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Did not make any profit from innovation</td>
<td>20.00%</td>
</tr>
<tr>
<td>Up to 5%</td>
<td>54.17%</td>
</tr>
<tr>
<td>From 5% to 10%</td>
<td>16.67%</td>
</tr>
<tr>
<td>From 10% to 15%</td>
<td>5.00%</td>
</tr>
<tr>
<td>More than 15%</td>
<td>4.24%</td>
</tr>
</tbody>
</table>

With this defined results and views, we enter into the analysis and conclusions presented in the next section work.

4. Conclusion

The study was conducted based on data that are selected so as to be fully comparable and give a true picture of the state of innovation in Montenegrin organizations. Samples provide a picture of the real business environment and are therefore significant results and applicable in realistic conditions. It should also be noted that the method of collecting data through surveys and interviews, tended to reduce subjectivity and to create an objective view of the situation in our organizations.

We performed a survey in 120 Montenegrin organizations and found that there are a lot of fields for improving its innovation. Based on that survey we found that even, organizations invested in the modernization of their business system (mostly in equipment), most of them don’t have person or team responsible for innovation. Most organizations allocated less than 5% of funds per year to the innovation while just 19.18% allocated more than 5%. The very serious fact is that more than 30% organizations don’t allocate any funds for innovation. There were also found that innovation is important for organizations but they mostly don’t include innovation in their documents.

However, increasing the innovation capacity and improving business processes innovation system, create a predisposition for the development of a number of new products/services, and thus greater chance of their commercialization. In order to improve innovation in organizations they need to: develop a strategy for the company which will be an integral part of innovation activities and to develop organizational structures and processes that support innovation activities.

The most important aspect of any business sistem is a learning organization. From all this follows the conclusion that a successful business is only possible with a well-functioning system of innovation that develop TQM strategies and weight meet the criteria of the European Quality Award.

5. References

BASIC TECHNOLOGICAL PROCESSES REQUIRED TO CREATE MECHATRONIC SYSTEMS TO MEET TODAY’S NEEDS AND PROBLEMS OF THEIR INSTRUMENTAL SUPPORT OF “INDUSTRY 4.0” CHALLENGES

Doctor of science, Prof. Turmanidze R.1(*), Senior laboratory assistant Bachanadze V.2 Master Popkhadze G.3
Faculty of Transportation and Mechanical Engineering1,2 – Georgian Technical University (GTU) – Georgia1,2,3,
inform@gtu.ge 1,2, popxadzegiorgi@gmail.com 3

Abstract: In the presented work investigated the changes of power characteristics of deep drilling package of printed circuit board’s hard metal micro drills depending on the drilling depth, cutting data and geometry of the drill. In particular studied the nature of changes in axial efforts and torque depending on the drilling depth drill with different inclinations of the spiral grooves using specially designed highly sensitive devices, enabling direct measurement method. Based on the analysis of the results of the study, changes in the geometry of existing standard drills. Proposed new construction of micro drills vary-angle spiral grooves in such a way that the angle is the maximum value at the top of the drill and uniformly decreases towards the end of the working parts. The drills are manufactured with different inclinations of the spiral grooves. Based on the analysis of the experiments of them chosen more for its near standing power rates to the standard drill bit and its comparative test with a standard drill bit, bringing them up to the breakage, thanks to which the proven advantages of drills new design. Taking into account the results of the experiments proposed drill elongated structures to improve performance by increasing the processing drilling depth and accordingly the number of plates in the package of printed circuit boards.

Key words: Drill, Gradient of spiral groove, Variable angle, Device.

1. INTRODUCTION

It is impossible to imagine modern equipment without electronic knots, starting from household and ending with space equipment. Printed circuit board’s production, basic parts of electronic equipment associated with drilling process vast quantities of small diameter holes (about 1 mm or less). Carry out drilling of micro carbide drill geometry, which has multiple experiments and experiences relevant production. In particular: the optimum cutting angle and spiral angle grooves respectively is 30°, and the rear angle 180. They are refaced through each hole and 1000 are designed for 3-4 regrinding costs.

Production of printed circuit boards is mass production, where performance is carried out with the aim of increasing the drilling package, composed of several plates, it has a place of deep-hole drilling, where the drill depth exceeds the diameter of 8-10 times.

Downtimes of expensive technological equipment, especially in mass production are associated with significant economic losses. In the production of printed circuit boards easy connected not only with the replacement of the tool with the aim of reshaping, but unexpected, caused by fragile destruction even before the first reshaping. Probability of brittle fracture grows significantly during deep drilling package of printed circuit boards. When this zone is located in the near destruction of the end of the spiral grooves.

Providing the best mass production processes for manufacture of printed circuit boards, at least a slight increase in resistance, including fragile resistance micro drills and consequently increasing productivity processes, can provide significant economic benefits.

2. THE MAIN PART

Research work with a view to enhancing the resistance of tungsten carbide micro drills and deep hole drilling process performance package of printed circuit boards were held in the laboratory precision micro instrumental Department “Industrial Technologies Engineering

Fig. 1. Instrument for measuring axial efforts.
Experiments were conducted with drills from solid alloy VK60M diameter φ 0.9mm long spiral groove l=10mm. Rake angle and spiral angle grooves respectively ω=30°, rear angle was 18°.

Drilling was carried out a package of printed circuit boards of fiberglass thickness 1.6mm composed of 5 plates with a total thickness of 8mm (see fig. 3).

Drilling of blanks is carried out on different modes of cutting depth up to 7 mm and 1 mm the depth of the recorded testimony every depth controlled readings. Experimental results are shown in fig. 4 and 5.

From this results, clearly shows that the load power with increasing depth progressively increasing. If the axial thrust is growing, approximately 1.5 times the amount of torque is increased 3-4 times.

Question, what caused this increase in power? Cutting conditions at the cutting edge of drills with increasing depth does not change. The only reason for this could be the increased contact area abrasive chips with the surface of the hole and emerged from it frictional forces.

You need to note that the sharp fall in axial efforts on areas of depth 2-3 and 5-6 (see fig. 5.) on these sites due to the lack of the work piece (fig. 3.) the copper layer.

The main factor increase the likelihood of brittle fracture of the cutting tool of these two power indicators may not increase the axial effort and more progressive increase in torque because the strength properties of carbide materials on the compression significantly exceed indicators of torsion.

Accelerating the process of chips from the cutting zone would contribute to the reduction of the force of friction and, consequently, improve the reliability of the drilling process. The problem of removal of chips when drilling deep hole in different cases decide in different ways. For example, when drilling drills dimensions solid this exercise method of leaching using a coolant, which is supplied, into the hole through, done in the body of the drill. In other cases, when the drill bit sizes do not give possibility of coolant above method to remove shavings used drilling method intermittent, where after a certain depth drilling is carried out periodically by the disqualification of drills from holes fast running.

The application of these techniques in our case nepriemlim. In the first case we have with micro drills. The use of coolant in the manufacture of printed circuit boards is not allowed. Design and method of intermittent drilling, because it led to the strong performance. When processing deep eyelet micro drills accelerating factor could be an increase in chip removal step spiral grooves, i.e. reducing the angle, but it would have led to a deterioration of the cutting conditions, so-as will decrease the cutting angle drills.

In the design of the drills carried out in a way that at the top of the save the desired cutting angle, and toward the end of the spiral grooves reduce its angle, IE a spiral groove cut into a vary-angle [1, 3, 4, 5, 6] and gradually increase its step, it would accelerate the process of chip and facilitate conditions for drilling.
Fig. 6 shows the scheme of drills with vary-angle spiral grooves where the angle of the grooves at the top of the drill \( \omega_0 \), and at the end of the working part of \( \omega_1 \). The width of the grooves in the normal section \( B_n \) on all length does not change, but the change in the front section and at the top is \( B_{T_0} = \frac{B_n}{\cos \omega_0} \), and at the end of the working parts \( B_{T_1} = \frac{B_n}{\cos \omega_1} \).

Changing and useful mechanical drill section. Useful section at the top: \( S_n = \frac{\pi d^2}{4} - \frac{2S_n}{\cos \omega_0} \) and at the end of the working parts: \( S_1 = \frac{\pi d^2}{4} - \frac{2S_n}{\cos \omega_1} \) where \( S_n \) - square grooves in the normal section, \( d \) - is the diameter of the drill.

If you take into account that \( \omega_0 > \omega_1 \), it turns out that toward the end of the working part of the useful cross-section drills intensifies. Then there are drills compared to standard must withstand stress.

Production of such drills associated with certain difficulties. At production of standard drills with a constant tilt angle of a spiral flute the special adaptation carries out the mutually agreement two movement – rotations of preparation of a drill and its movement in the axial direction at a size of a step of a spiral flute. Thus, this interrelation is defined by linear function. In case of a variable step, this interrelation is defined by difficult tangential function. Because of it was necessary to modernize the equipment and its mechanism of axial giving of an element with the Archimedean spiral to replace elements with a tangential spiral, made by our special calculations [2, 3].

Besides, because of a variable tilt angle of a spiral flute, at you - polishing of these flutes should change orientation of a grinding wheel relatively to an axis of preparation of a drill respectively to change of a tilt angle of a flute. It can be carried out in two ways: at a motionless axis of a grinding spindle to turn a preparation spindle axis round a point of intersection of these axes at a corner size \( \omega = \omega_0 - \omega_1 \) (see figs. 7), or motionless to leave an axis of a spindle of preparation and to turn an axis of a grinding spindle (see figs. 8) [4, 5].

![Fig. 6. Drill scheme with vari-angle spiral grooves.](image)

![Fig. 7. Schemes of change of orientation of axes of a spindle of preparation of a drill and grinding spindle. Method of turn of an axis of a spindle of preparation.](image)

![Fig. 8. Schemes of change of orientation of axes of a spindle of preparation of a drill and grinding spindle. Method of turn of a grinding spindle.](image)
of rotation of an axis of preparation, \( \ell_x \) - the current coordinate of length of the cutting part of a drill, \( K_{\omega} \) - the size of change of a tilt angle of a spiral flute per unit length the cutting part of a drill.

Schematic diagram of the upgraded device with a lever turning mechanism shown in Fig. 9. It should be noted that with the purpose to achieve higher precision in return lever mechanism can be used rack and pinion pair.

Device for polishing spiral grooves in the side of the work piece 1 is mounted on the drill axis of rotation 2, mounted on a grinding machine table - 3D642. In this case, the axis of rotation adaptation must take place at the point "O" crossing the axis of the drill blanks and the vertical axis of symmetry of the grinding wheel 3. The other end of the device is based on a circular guide 4. Rotate lever mechanism is carried out, the reference axis 5 which is fixedly mounted on the basis of 6 devices. When the axial movement of the upper slide 7 and, accordingly, drill blanks rigidly associated finger 8 turns right shoulder of the lever 9. The left lever arm is connected to finger 10 fixedly mounted on the machine table. Thus, the rotation of the lever causes the whole structure adjustment. Thus, the linkage elements are designed so that the axial feeding blanks on a drill length value helical cutting tool is rotated by the movement of the spiral groove inclination angle \( \Delta \omega = \omega_0 - \omega_1 \).

For this calculated distance between the left finger and fixedly pivot device formula:

\[
R = l_x \cdot \frac{L_s}{L_n} \cdot \frac{360}{2\pi \Delta \omega}
\]

Where:
- \( l_x \) - the length of the spiral cutting drill, mm;
- \( L_s \) - left lever arm length;
- \( L_n \) - the right lever arm length;
- \( \Delta \omega \) - amount of change in the angle of the spiral grooves of the drill

We have designed constructed prototypes of drills with vary-angle \( \omega = 30 – 17^\circ \), \( \omega = 35 – 20^\circ \), \( \omega = 40 – 22^\circ \) and \( \omega = 43 – 23^\circ \).

All of these included circuit boards same experiments as the standard. Experimental results for drills \( \omega = 30 – 17^\circ \) and \( \omega = 35 – 20^\circ \) are shown on fig. 10 – 13.

Analysis of these graphs shows the following: for drills \( \omega = 30 – 17^\circ \) performance of axial efforts almost indistinguishable from a standard drill bit \( \omega = 30^\circ \), so, it was expected, because these same drill front angle and cutting conditions respectively at the cutting edge. With regard to indicators of torque, they drill \( \omega = 30 – 17^\circ \) depending on the cutting was understated by 12-16%.
For drills $\omega = 35 - 20^0$ performance of axial efforts relatively understated, as rake angle increased by 5% and this facilitated the process of cutting, but indicators of torque with increasing depth drilling grows more intensively and exceed indicators of both previous designs. It is clear that the understatement of torque to drills $\omega = 30 - 17^0$ compared with standard drills $\omega = 30^0$, due to the gradual increase in step spiral grooves and accordingly reduced contact area formed by chips with processed apertures. Increasing the angle of inclination and therefore a decrease in pitch of spiral drills $\omega = 35 - 20^0$ again causes the reverse-torque figures intensively promoted.

When drilling by drills of $\omega = 40 - 22^0$ and $\omega = 43 - 23^0$ these power indicators are rather underestimated (see figs. 13-16) that is explained by improvement of conditions of cutting because of considerable ($5-8^0$) increases in a forward corner at the cutting edge. However, reduction of a corner of a point at further operation causes increase in intensity of wear, and they without repoint reach only 600-800 openings.
Obviously, to get a clearer picture further experiment need to keep standard drills \( \omega = 30^\circ \) and drills with vari-angle spiral grooves \( \omega = 30 - 17^\circ \). Experiments were continued until the breakdown drills. Through each hole 200 checked power indicators, with increasing cutting edge wear gradually increases. After 1000 holes check carried out through every 100 holes, as increasing the likelihood of breakage of drill. Throughout a series of experiments for both types of drills, \( \omega = 30^\circ \) nearly identical indicators remain innovative wear and axial efforts. As for torque, its value on the standard drills always exceed the value of drills with variable angle of the spiral grooves \( \omega = 30 - 17^\circ \).

Statistics showed that the breakage of the standard drills \( \omega = 30^\circ \) going from 1200 to 1300 holes and drill with vari-angle \( \omega = 30 - 17^\circ \) from – 1400 to – 1500. Performance torque values before breakdown indicating the number of drilled holes \( N \) traversed the path \( L \) and size of wear on back surface drills \( f \) shown in Fig. 17 and 18.

3. CONCLUSIONS

Solid Carbide micro drills with vary-angle spiral grooves in deep drilling package provides improved chip control process intensity of hole, promoting this underestimates the force of friction and consequently the torque on the axis of the drill.

Implementation of the spiral grooves with a gradual lowering of the \( \alpha \)-angle from the top of the drill toward the end of the working part provides useful cross-section reinforcement drills, increasing the reliability of the brittle.

On the basis of the foregoing, it becomes possible to manufacture drills with elongated working part at 2-2,5mm and in the package circuit boards add another plate, which will make it possible to improve the performance of drilling process on 20%.

REFERENCES


AN INNOVATIVE METHOD OF POLIMERIC SAWDUST BOARDS PRODUCTION

Bialasz Sebastian, Klepka Tomasz.
Department of Technology and Polymer Processing, Faculty of Mechanical Engineering – Lublin University of Technology, Poland
Sebastian.bialasz@gmail.com; t.klepka@pollub.pl

Abstract: The paper summarizes studies pertaining to an innovative method of polymeric chips and sawdust boards production. RD boards are manufactured from post-production waste in the form of chips. The chips are heated and pressed under small pressure in metal forms. The product is characterized with good sound and thermal insulation, small mass, and low manufacturing cost. As a consequence, it can be applied in several types of products as a filler.

Keywords: POLYMERIC BOARDS, PRESSING, INNOVATION, INSULATION, RECYCLING, WINDOWS, DOORS

1. Introduction

At present, the inner space of window and door frames is filled with PVC, mineral wool, wood, cardboard, cellulose, polystyrenes, etc.

Insulation is a critical feature of products constituting a moving partition between the interior and exterior. Figure 1 presents several zones with negative heat transfer. In order to minimize heat loss and improve sound insulation, the development of insulating material improving insulating properties and the material’s application in the production of doors, windows and stairs, has been undertaken.

The material constitutes a filler of inner spaces of such products in order to decrease the need for high-quality material in production of frame profiles, and to boost the attractiveness of end products by improving specific properties.

![Heat Transfer Through a Window](image)

Fig.1. Heat transfer zones in a window frame

In case of doors, solid wood, chipwood, or cardboard can play the role of the filler. Stairs are made of solid or glued wood. No fillers are known to be applied in this case.

The new material must be characterized with: low mass, high sound and thermal insulation, low manufacturing cost, high availability of manufacturing components, ecology (recycling), ability to form any size of product. The material is to be applied as: a filler of inner spaces in cantilevered stairs in order to provide sound insulation and reduce mass, sound insulation for internal doors made of wood encased by plywood, sound insulation or back/side panel of wardrobes or cases which divide rooms into sleeping and living rooms, and in classic stairs.

Under patent description no. PL191 427, current state of the art contains a lamination method by pressing composite board made of slag wool, and a method for manufacturing objects by low-temperature sintering in which components are mixed to obtain a homogenous mass whereof objects are made, dried and kilned in low-temperature (PL 162 322). The two technologies may be considered similar to the one described in the present paper.

Based on the current state of the art, a product innovation was developed in the form of a polymeric structural board named “RD Board” (RD for Reduced Density). The manufacturing process was patent claimed in PL218877. The board is characterized with a layered structure, low mass, good sound and thermal insulation. Therefore, it may be applied as a thermal or sound insulation.

Owing to the fact that the new product is manufactured with post-production waste, it results in the waste’s quantity being reduced. On the one hand, it leads to the reduction of economic costs for manufacturers (less waste to be utilized) and public administration, and those associated with environment protection (e.g. necessity of maintaining and creating new waste disposal sites). On the other hand, such mode of production will contribute to environment protection. Another aspect significant from the point of view of the general public can be seen in the product’s unique sound and thermal insulation properties.

2. Materials and methods

The material used for manufacturing RD boards may be sawdust, polymeric, or polymeric-wood chips (figure 2) constituting post-production waste e.g. originating from machining of pipes or composite boards.

![Materials used for the production of RD boards](image)

Fig.2. Materials used for the production of RD boards: a) polypropylene chips, b) sawdust

In the manufacturing process, chips are introduced into a metal form comprised of a socket and a stamp and placed in a vertical press. Subsequently, external walls of the socket are heated to a temperature lower than the softening temperature of the polymer. The top part of chips introduced into the forming socket is pressed with the pressure between 0.2 to 25kN. The pressure is introduced by the stamp moving vertically. After between 20 and 240 seconds has elapsed, the bottom of the forming socket is heated to between 70% and 100% of the softening temperature of the polymer for between 5-45 seconds. Subsequently, the stamp is removed from the board and the socket. Having been formed in the above manner, the board cools in ambient...
temperature or is cooled with water. Figure 3 presents individual steps of the process: introduction of chips- pressing- form opened-board removed from the form.

1. 
2. 
3. 
4.  

Fig.3. Description of RD boards’ manufacturing process

As indicated in Figure 4, the board’s structure is layered. The external layer (1) is of solid structure with improved hardness, and the internal layer (2) is composed of heated chips with air chambers between them.

Fig. 4. Structure of RD boards: 1 – solid external layer, 2 – internal layer composed of heated chips and air chambers between them.

The manufacturing process of RD boards may be realized in three manners:
- Pressing with heating in order to soften polymeric chips (e.g. PP or PVC).
- Pressing with heating in order to soften and bind polymeric chips and sawdust together (e.g. PP/PVC and wood).
- Pressing with heating in order to bind sawdust (wood and thermosetting adhesive).

The board is characterized with layered structure, low mass, good thermal and sound insulation. Therefore, it may be applied in constructions as a thermal and sound insulation.

Manufacturing of the board from chips does not require any additional technological operations. Apart from temperature and pressure, no additional adhesives are required in order for chips in the socket to be bound together. Pressing with heating is not expensive, which offers cost reduction when manufacturing products of original structure and composition.

3. Methodology and results

In order to conduct the study, RD boards were required. Boards were manufactured in three compositions:
- Polypropylene-chip board (PP)
- Polivinyl chloride-chip board (PVC)
- Polypropylene-chip board (PP) combined with sawdust

Studies were made in order to establish the manner and parameters of RD boards’ manufacturing, determine mass and density, sound and thermal insulation properties, so as to evaluate the effectiveness of the new product.

In order to manufacture boards, a form was used. The form’s socket measured 120x200x15 mm. The form was made of aluminum. Heating was independent (both the form and stamp). Manufacturing parameters for individual components were determined.

PVC-chip board was manufactured as the first. It was characterized with low mass (density) and short production time. One of the boards was defective due to improper manufacturing parameters being applied (heating time too long). The board was presented in Figure 5. Having modified these parameters, a quality PVC board was manufactured- featured in Figure 6.

Fig. 5. Defective PVC board  
Fig. 6. PVD RD board

Next, a PP board was manufactured. Mixed chips were used- polypropylene chips containing some impurities (e.g. paper).

The end product was characterized with greater rigidity and strength than the PVC board. Manufacturing conditions were friendlier as well- lower impact of manufacturing temperature and time upon the product. An example PP board was presented in Figure 7.

Next, a composite board made of polymer-wood (polymeric chips and sawdust in 3:2 ratio) was manufactured. The product was presented in Figure 8.

Fig. 7. PP RD board  
Fig. 8. PP-wood RD board

The board was characterized with larger mass than in case of the one made of polypropylene exclusively, and was more porous (see photo).

The board made of sawdust bound with thermosetting adhesive was manufactured last. Manufacturing process was considerably shorter due to the fact that no cooling was required. As a result of the application of the adhesive, sawdust was bound to make a solid external layer and porous internal core of the board.
The assessment of sound insulation was conducted in order to determine insulating properties of RD boards, cardboard (paper), and chipboards, i.e. materials applied as a door fillers.

The assessment measured noise level by means of a digital sound meter positioned in a fixed distance from a PMMA box whose one side was made of the evaluated material. A wireless Bluetooth speaker emitting sound with a constant, known volume was located inside the box.

In order to examine sound insulation, a testing station was developed (Fig. 9.). The station was composed of a table (1), sound level meter (2), PMMA aquarium (3), Bluetooth speaker (4), tested material (5) constituting the front wall of the aquarium.

The following materials were examined: RD board made of PP, RD board made of PP and wood, RD board made of PVC, cardboard (obtained from a door), chipboard, solid oak wood.

The measurement enabled sound insulation properties of these materials to be determined. Results were presented in a table and in chart 1. Sound reduction index [dB] denotes the result of subtracting sound volume with the examined board from the volume without the board (directly from the speaker). The formula for the calculation is presented in formula 1.

**Formula 1.:**

\[
\text{Sound Reduction Index} = \text{Volume A [dB]} - \text{Volume B [dB]},
\]

where A- without board, B- with board.

The greater the index, the more insulation the material offers.

**Table 1: Sound Reduction Index [dB].**

<table>
<thead>
<tr>
<th>Material</th>
<th>Śr. pomiar I</th>
<th>Śr. pomiar II</th>
<th>Śr. pomiar III</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP RD board</td>
<td>27</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>PP+wood RD board</td>
<td>32</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>PVC RD board</td>
<td>25</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Chipboard</td>
<td>24</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Cardboard</td>
<td>4</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Chart 1 compares average sound reduction index values for examined boards.

Measurements of sound insulation were conducted in order to determine insulating properties of RD boards, cardboard (paper), chipboards, and solid wood, i.e. materials applied as door and stairs fillers.

The test measured temperature by means of a pyrometer positioned in a fixed distance from PMMA box whose one side was made of the evaluated material. A heater with a thermostat, which heated the interior of the box and maintained a fixed temperature was located inside the box.

In order to examine thermal insulation a testing station was developed (Fig. 10.). The station was composed analogically as in case of the previous test: a table (1), pyrometer (2), PMMA aquarium (3), heater with a thermostat (4), tested material (5) constituting the front wall of the aquarium.

The following materials were examined: RD board made of PP, RD board made of PP and wood, RD board made of PVC, cardboard (obtained from a door), chipboard, solid oak wood.

The measurement enabled thermal insulation properties of these materials to be determined. Thermal insulation index denotes the result of subtracting temperature of the board’s surface from the temperature of the heater (no board in the box). Heating time equaled 10 minutes (600s). The formula for the calculation is presented in formula 2.

**Formula 2.:**

\[
\text{Thermal Insulation Index} = \text{Temperature A [°C]} - \text{Temperature B [°C]},
\]

where A- without board, B- with board.

The greater the index, the more insulation the material offers.

**Table 2: Thermal Insulation Index [°C].**

<table>
<thead>
<tr>
<th>Material</th>
<th>Śr. pomiar I</th>
<th>Śr. pomiar II</th>
<th>Śr. pomiar III</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP RD board</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>PP+wood RD board</td>
<td>12</td>
<td>11</td>
<td>13</td>
</tr>
<tr>
<td>PVC RD board</td>
<td>16</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Chipboard</td>
<td>8</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Cardboard</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Wood board</td>
<td>9</td>
<td>9</td>
<td>8</td>
</tr>
</tbody>
</table>

Chart 2 compares average thermal insulation index values for examined boards.
Measurements of mass and size of boards were conducted in order to examine these properties for RD boards, cardboard (paper), chipboards, and solid wood, i.e., materials applied as fillers in doors and stairs.

Boards of the same dimensions were weighed, which enabled density to be calculated. Measurements of mass and density were conducted by means of a laboratory weight, slide caliper, and a calculator.

The following materials were examined: RD board made of PP, RD board made of PP and wood, RD board made of PVC, cardboard board (obtained from a door), chipboard, solid oak wood.

Table 3 presents density and mass of these boards.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass [g]</th>
<th>Density [kg/m³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PP RD board</td>
<td>195</td>
<td>540</td>
</tr>
<tr>
<td>PP+wood RD board</td>
<td>250</td>
<td>695</td>
</tr>
<tr>
<td>PVC RD board</td>
<td>173</td>
<td>480</td>
</tr>
<tr>
<td>Chipboard</td>
<td>234</td>
<td>650</td>
</tr>
<tr>
<td>Cardboard</td>
<td>249</td>
<td>690</td>
</tr>
<tr>
<td>Wood board</td>
<td>545</td>
<td>1515</td>
</tr>
</tbody>
</table>

4. Conclusions

Tests and measurements indicated that the application of innovative fillers in the form of RD boards in manufacturing window frames, boards and door frames, and stairs is valid. Example applications of RD boards are presented in Figure 11.

Moreover, the said product innovation offers numerous benefits. What is more, it constitutes a stimulus for the development of social responsibility of the company and product as well. At the same time, it feeds back into CSR (Corporate Social Responsibility), which also motivates the development of innovation. It has been acknowledged by an European Commission report published in 2008 which discussed competitiveness of European economy. The report indicates that CSR may contribute to the development of innovation, and at the same time, boost competitiveness of enterprises.

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NOISE POLLUTION REDUCTION AND CONTROL PROVIDED BY GREEN LIVING SYSTEMS IN URBAN AREAS

MSc.Eng. Dimitrijević D. PhD student¹, Assist. Prof. Živković P. PhD¹, Assist. Prof. Dobrnjac M. PhD², Assist. Prof. Latinović T. PhD²
Faculty of Mechanical Engineering, University of Niš, Serbia¹
Faculty of Mechanical Engineering, University of Banja Luka, Bosnia and Herzegovina²

dragana.dimitrijevic@masfak.ni.ac.rs

Abstract: GREEN living the building envelope is innovative technology in architecture that can regain losses of a natural environment in dense urban areas. Implementation of green living systems, greening horizontal surfaces with intensive and extensive green roofs or using vegetation in vertical greening systems for façades is a strategy that provides ecological, economic and social benefits and it is a sustainable solution for improving the environmental balance of cities limiting the major negative effects of urbanization providing better comfort at both building and urban level. The potential to provide external and internal sound insulation due to their high mass and absorption through the surface, reducing and control of noise pollution in urban areas, was investigated through various studies. There are several situations in which noise reduction due to green living systems’ sound absorption should be considered important, such as buildings near to roads, rail or air traffic noise sources. The configurations of the systems, substrate thickness, and vegetation layer, are important factors affecting the sound absorption and sound propagation properties of these systems.

This review paper presents findings from different research conditions and approaches, to explore the importance of green living systems considering the impact on noise mitigation and acoustic aesthetics of the environment.

Keywords: GREEN LIVING SYSTEMS, GREEN ROOF, GREEN WALL, ACOUSTIC INSULATION, NOISE POLLUTION

1. Introduction

Rapid urbanization increases the energy problem of cities and decreases the proportion of spaces dedicated to green infrastructures due to new building developments amplifying the pollution problems. Greening the building envelope is innovative technology in architecture that can regain losses of a natural environment in dense urban areas. Implementation of green living systems is a strategy that provides ecological, economic and social benefits and it is a sustainable solution for improving the environmental balance of cities limiting the major negative effects of urbanization.

In addition to the creation of a pleasant environment, the aesthetic visual and acoustic impressions, green living systems offer several substantial benefits in comparison to the conventional building envelope. Main environmental benefits that green living systems (GLS) can achieve are energy consumption reduction, a decrease of the urban heat island effect, reduction of carbon footprints, air pollution mitigation, reduction in storm-water runoff and improvement of a storm-water quality, reduction in interior noise levels, noise absorption [1]. Depending on the types of plants and soils, a GLS can provide a natural habitat for animals, insects, and plants and can increase the biodiversity of an urban area [2].

Noise is understood as a sound that is loud, unpleasant, unexpected, or undesired. The primary reasons to decrease noise is to avoid direct damage, but also to increase comfort whilst sleeping, working and socializing. Noise can also cause economic problems through decreased efficiency amongst employees as well as lowered property values due to less demand. GLS have the potential to provide external and internal sound insulation due to their high mass and absorption through the surface, reduce and control of noise pollution in urban areas. In terms of acoustic benefit, vegetation, in general, affects the sound field in urban environments through mechanisms. When a sound wave impinges on the vegetation and is then reflected back sound absorption and diffusion occur; and when a sound wave is transmitted through the vegetation sound level reduction occurs.

2. The Green Living Systems

Living architecture is the integration of the living, organic systems characterized by green walls and green roofs, with the inorganic and lifeless structures that have come to dominate modern architecture. By combining nature and built areas in their designs, architects and urban planners can respond to serious human health and welfare issues and restore the environmental quality of dense urban areas. Green living systems are not only the solution for the new designs. Retrofitting existing buildings by altering the buildings’ surficial properties can reduce buildings' energy and address air and noise pollution.

2.1. The green living walls

Green wall technologies may refer to all forms of vegetated wall surfaces. Two major categories can be identified: Green Facades and Living Walls.

The Green facades are a type of green wall system in which climbing plants or cascading groundcovers are trained to cover specially designed supporting structures (Fig. 1. left). Rooted at the base of these structures, in the ground or in intermediate planters.

Fig. 1 The Green Facade Singapore Changi Airport Terminal 3, Singapore, Singapore (left), The Living Wall Europa Congress Palace Convention Center, Vitoria-Gasteiz, Spain (right)

The Living wall systems are composed of prevegetated panels, vertical modules or planted blankets that are fixed vertically to a structural wall or frame (Fig. 1. right). These panels can be made of plastic, expanded polystyrene, synthetic fabric, clay, metal, and concrete, and support a great diversity and density of plant species.

2.2. The green living roofs

Green roof construction mimics in a few centimeters what normal soil does in a couple meters. The green roof accomplishes the natural balance through several layers depending on its complexity.

The model of the green roof consists of three main components: structural support, a soil layer, and foliage layer. The structural support includes all the layers between the inner plaster and the drainage layer or filter layer. In most cases, the structural layer is considered as a single layer with constant properties. The drainage layer provides water for upper layers in relatively small space and with light weight. The soil layer, or the growing medium, is complex with the solid phase (organic and mineral material), the liquid phase (water) and the gaseous phase (water vapor and air).
The growing medium, filter, drainage layer and protection layer act to support plants and protect lower levels. The foliage layer (canopy) is composed of the leaves and the air within the leaves, and its characteristics depend on the plant selection.

There are two main classifications of green roofs: Extensive Green Roofs (EGR) and Intensive Green Roofs (IGR)

Extensive Green Roofs are lightweight in structure with a thinner substrate and feature succulent plants like sedums that can survive in harsh conditions (Fig. 2. left).

Fig. 2 EGR, Bridgpoint Active Healthcare, Toronto, ON (left), IGR, Aventura Optima Plaza, Aventura, FL (right)

Intensive Green Roofs may require irrigation during dry periods having a thicker soil layer than extensive ones. Because of their thicker soil, these roofs require greater structural support (Fig. 2. right). IGR allow a greater variety and size of plants such as shrubs and small trees but have higher initial costs and maintenance.

3. Evaluation of green living systems on noise pollution reduction and control

The acoustical performance of green living systems involves two different aspects: the outdoor noise absorption and the insulation of indoor environments from outside noise. In street canyons and urban environments, sound propagation through the urban fabric from noisy areas into quiet zones is influenced by a variety of geometrical parameters such as street width and building height, as well as the acoustic characteristics of the materials used in the building envelope. This means that there is important potential for reducing acoustic waves diffracting over building since the envelope is most often made of rigid materials, thus can be improved using the vegetation.

From the previous studies concerning the sound interception provided by vegetation it is known that it can reduce sound levels in three ways:

- Sound can be reflected and diffracted (scattered) by plant elements. Trunks, branches, twig and leaves have the different influence.
- Sound can be absorbed by plant elements. Mechanical vibrations of plant elements caused by sound waves lead to energy dissipation by converting sound energy to heat. There is also a contribution to attenuation by thermo-viscous boundary layer effects at vegetation surfaces.
- Sound levels can be reduced by the destructive interference of sound waves. The presence of soil can lead to destructive interference between the direct contribution from the source to the receiver and a ground-reflected contribution. The presence of vegetation leads to an acoustically very soft soil. This effect is often referred to as the acoustical ground effect or ground dip.

Regarding the urban noise attenuation by vegetation, in their research [3] Dunnet and Kingsbury stated that the hard surfaces of urban areas tend to reflect sound rather than absorb it and that green roofs can absorb sound, with both the substrate and plants contributing. The substrate tends to block lower sound frequencies, whereas plants block higher frequencies.

3.1. Evaluation of green living walls on noise pollution reduction and control

In the study [4], where only the direct transmission of sound through the modular green wall was considered, two different standardized laboratory tests were conducted. The main results were a weighted sound reduction index $R_w$ (which is a value that is expressed as a single number (UNE-EN ISO 717-1)) of 15 dB and a weighted sound absorption coefficient $\alpha$ (defined as the proportion of sound energy that is absorbed by the material from an incident sound) of 0.40. The sound absorption coefficient remained more constant between 0.35 and 0.51, reflecting a good performance of the green wall not only at low frequencies but at high frequencies as well. The capacity of the green wall to reduce airborne noise, which is expressed by the $R$ coefficient, was lower than the other constructive solutions (Fig. 3.)

![Figure 3: Sound reduction coefficient (R) comparison between the green wall (GW) and common constructive solutions: A. Thermal double glazing (6-12-6), timber frame, B. Brick, 100 mm thick, no finish. C. Lightweight aggregate blockwork 215 mm thick with plaster finish both sides. D. Two leaves of 12.5 mm + 19 mm plasterboard on metal studs, separated by 250 mm cavity with 100 mm mineral wool [4].](image)

Researchers concluded that green walls have significant potential as a sound insulation tool for buildings but that some design adjustments should be performed.

An acoustical measurement campaign around a site, located in Cergy, in the Val d'Oise department, near Paris, France, hosting a green wall was carried out to highlight its potential effectiveness in reducing noise pollution in its environment [5]. Measurements showed a decrease in overall sound pressure levels (dBA) generated by road traffic as a result of setting up the green wall on the site. Acoustic gains remained moderate and ranged from 0.6 to 2.5 dBA depending on the measurements day. In the middle frequencies, 400 - 2500 Hz, acoustic gains were moderate (between 0 and 6 dB depending on the configuration and the one-third octave band concerned) with maximum efficiency for configurations where the source was distant from the receiver. These can be attributed to acoustic absorption due to the planting substrate. At high frequencies, 3150 to 20000 Hz, except for close source/receiver configurations, acoustic gains were substantial (between 0 and 10 dB depending on the configuration and the one-third octave band concerned), where a scattering phenomenon caused by the foliage of the development also comes into play.

The interesting paper described the construction of a vertical indoor greenery system (VIGS) on the north side of a wall and assessed the noise mitigation that resulted from the use of a vegetation-covered wall face [6]. Sound level measurements were recorded in dBA. The source content provided a continuous level sound from 55 to 115 dBA with different voices from adults and children. The average decrease in dBA was between 2% with the frequency weightings equivalent to the sound frequencies that the human ear perceives, and 3% for the with the frequency weightings...
equivalent to the sound frequencies perceived by the human ear, excluding extreme frequencies. This may indicate up to a three-fold reduction in energy caused by the green wall. In the case of noise that lasted longer than 1s, which can be considered the most troublesome for human sensitivity, there was a sonic mitigation of 6% to 8% for the selected frequency using those two weightings, respectively.

### 3.2. Evaluation of green living walls on noise pollution reduction and control

Transmission loss (TL) is a measure of how much sound energy is reduced in transmission through a single or multi-layered partition. The green roof as a series of finite layers impedes sound energy as it transmits from the exterior environment through each layer of the system to the interior of the building. Architectural acoustics is most often concerned with the sound transmission in the frequency range of 125–4000 Hz.

The empirical findings on the sound transmission loss of green roofs suggest that the use of green roof technologies may be optimized to increase transmission loss and ameliorate the coincidence effect. The field testing [7] conducted on two 33 m² extensive green roofs indicated an increase of 5 to 13 dB in TL over the low and mid frequency range, 50 Hz to 2000 Hz, and 2 dB to 8 dB increase in TL in the higher frequency range above the reference. It was highlighted that green roofs would provide a higher TL than the additional ceiling element and improve TL throughout the full architectural frequency range, specifically desirable in residential occupancies developed below aircraft flight paths.

The sound transmission loss of a reference roof (conventional type) and two green roofs, identical with the only difference in the depth size of the substrate (75 mm for GR1 and 150 mm for GR2), was measured [8]. The analysis revealed that the increase of TL through GR1 at different frequencies was less consistent while the respective increase of TL through GR2 was more reliable. The findings also demonstrate that deep green roof increased the transmission loss from 5 dB to 13 dB at low and mid frequency bands 50–2000Hz, and of less than 6 dB at higher frequencies.

The Finite-Difference Time-Domain Method was used to study sound propagation over a green roof in an urban situation [9]. Sound propagation between adjacent city canyons was considered, and the focus was on the reduction of the sound pressure level in the non-exposed canyon due to the presence of a green roof. Numerical calculations were conducted for both intensive and extensive green roofs, showing that an important reduction of the sound pressure level in the shielded canyon could be achieved, compared to a rigid roof. In the case of an extensive green roof, there was a strong dependence on the substrate layer thickness; a maximum reduction of 10 dB at the octave band of 1000Hz was found. A good overall efficiency was observed near the maximum layer thickness as found in practice for this type of green roof. For intensive green roofs, the influence of the substrate layer thickness was limited. Both extensive and intensive green roofs significantly reduced the sound levels in the non-exposed canyon. At low frequencies, effects were minimal since the substrate impedance was large. For a typical intensive green roof, more than 6 dB was gained at the octave band of 1000Hz, relative to a fully rigid roof, when the green fraction of the roof was 0.8. In this research, a linear relationship between the green roof effect and the fraction of the roof covered with green, and the slopes increase with the octave band centre frequency was confirmed.

Laboratory study [10], with a series of measurements of Sound Pressure Level (SPL) in the semi-anechoic chamber were carried out to demonstrate the effect of green roof systems on noise abatement at street levels, considering diffracted sound waves propagating through a low profiled structure. For green roof systems, trays which are composed of the Zinco substrate with a depth of 100mm and low growing vegetation were applied. To verify the acoustic effects of the green roof system, four experimental parameters were considered, including the structure, area and position of the green roof system, and the type of vegetation. The experimental results on the effect of the structures of the green roof trays suggest that the trays can disperse sound energy from diffracted sound waves effectively and further theoretical approach could be made to design this to an optimal condition. With different areas of the green roof system, a noise reduction of over 10 dB was observed. The effect on noise reduction was gradually increased with increasing number of rows of the trays. The experimental results with the pruned leaves show that dense leaves have positive effects on noise mitigation mainly at high frequencies above 4000Hz. In terms of the acoustic effects of the position of the green roof system, the measurement results suggest they sensitively affect the pattern of noise reduction at different frequency ranges.

In Flanders, Belgium, measurements were performed just before and after placement of the green roof, with an identical source-receiver configuration in both situations [11]. The results showed what can be expected from current green roof practice for sound diffracting over it, for various building configurations. The first situation involved a building extension with a green roof where the sound was forced to be diffracted over it (shearing sound propagation over the green roof) before reaching a façade or window (single diffraction). The second situation aimed at achieving a silent zone at a non-directly exposed façade while the source was in an adjacent street canyon. In the latter, the green roof was modeled on the main part of the building (double diffraction). Measurements showed that green roofs may lead to consistent and significant sound reduction at locations where only diffracted sound waves arrive. Among the single diffraction cases, acoustic green roof improvements exceeding 10 dB were found, over a wide frequency range. This improvement was measured for a propagation path interacting with the green roof of only 4.5 m. The presence of shearing waves over the green roof (near parallel sound propagation to the roof), and sufficient substrate thickness seemed to be important to have such large positive effects. For the double diffraction cases, positive effects were measured over the full frequency range from 50Hz to 10kHz, at the two fully shielded receiver heights considered in the experiments. Effects seemed to be less-frequency dependent than for the single diffraction cases, and a case with positive effects up to 10 dB was found. It was concluded that small substrate thickness and/or the presence of vegetation was positive for higher frequencies, while for low-frequency noise reduction a larger substrate thickness was needed.

Experimental data on acoustical performances on the sound absorption of the green roof systems were evaluated and discussed in the study [12]. Three green roof systems had been experimentally tested measuring their sound absorption coefficients at normal incidence: extensive green roof (Sample A), semi-intensive green roof (Sample B) and common soil (Sample C). The sound absorption depends on the angle of incidence of the acoustical waves on the surface of the material.

![Fig. 4 Comparison of curves for sound absorption coefficient at random incidence ][12].
The value of the normal incidence absorption coefficient $\alpha_n$ is an important parameter in applications when the sound absorbing material is very close to the sound source. For green roofs relatively far from the sound source, such as a building close to an urban road, the most important parameter results is the random incidence sound absorption coefficient $\alpha_d$. The diagram showed (Fig. 4.) the high advantage in the use of green roofs compared to traditional roof techniques. Results confirmed that, generally, sound absorption of green roofs was higher than the absorption estimated for concrete traditional roofing, demonstrating the effectiveness of the solution. It must be noticed that sound absorption coefficients at random incidence $\alpha_{d,w}$ and $\alpha_{d,m}$ presented higher values than sound absorption coefficients at normal incidence $\alpha_{n,w}$ and $\alpha_{n,m}$ (Tab. 1).

**Table 1: Weighted and average sound absorption coefficients at normal and random incidence [12]**

<table>
<thead>
<tr>
<th>Roof types</th>
<th>$\alpha_{n,w}$</th>
<th>$\alpha_{n,m}$</th>
<th>$\alpha_{d,w}$</th>
<th>$\alpha_{d,m}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample A</td>
<td>0.45</td>
<td>0.75</td>
<td>0.64</td>
<td>0.76</td>
</tr>
<tr>
<td>Sample B</td>
<td>0.60</td>
<td>0.80</td>
<td>0.54</td>
<td>0.80</td>
</tr>
<tr>
<td>Sample C</td>
<td>0.40</td>
<td>0.60</td>
<td>0.44</td>
<td>0.63</td>
</tr>
<tr>
<td>Concrete roof</td>
<td>0.00</td>
<td>0.00</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

4. Conclusion

In street canyons, the amount of sound energy propagating over rooftops from noisy sides to quite sides is mainly determined by the height and width of buildings, and also materials used in building envelope. Green living roofs on the top of buildings can be assumed as absorbers especially for diffracted sound waves between parallel streets. Thus, in the aspect of acoustic advantages, green living systems have been regarded as an important structure to reduce noise pollution in urbanized areas such as street canyons.

Green living systems can absorb sound, with both the substrate and vegetation contributing. The substrate tends to block lower sound frequencies, whereas vegetation blocks higher frequencies. Growing mediums used in green living systems are highly-porous, and allow acoustic waves to enter the medium, which is a necessary property of a sound absorbing material. Due to a large number of interactions between the waves and the solid phase of the substrate attenuation occurs. Also, the typical substrates are known for their high water retention capabilities. The volume of the substrate particles will increase largely by absorbing water, leading to a decreased porosity of the substrate layer. Furthermore, the presence of water reservoirs or the use of rock-wool mats to further enhance water retention is not optimal from the acoustic viewpoint, knowing that porous materials and outdoor ground surfaces can be largely affected by the presence of water usually leading to a decreased sound absorption. On the other hand, such layers could largely improve these aspects under dry conditions. When vegetation is present on building envelope the effectiveness of absorption can be greatly enhanced since there are multiple reflections. In build-up areas the absorption and diffusion effects are also useful for reducing the negative effect of reflections from the ground that often occur in outdoor sound propagation.

The configurations of the systems, substrate thickness and vegetation layer, are important factors affecting the sound absorption and sound propagation properties of these systems. That should be taken into consideration if the green living systems are designed as a means of noise pollution reduction and control.

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NEW METHODS FOR DIAGNOSTIC OF CNC MACHINE TOOLS

Ing. Zajačko I., PhD., prof. Dr. Ing. Kuric I., Ing. Cisar M., PhD.
Department of Automation and Production Systems, Faculty of Mechanical Engineering
University of Žilina, Slovak Republic
ivan.zajaacko@fstroj.uniza.sk

Abstract:

Diagnostic system is very important part of a system for fault prediction and it is very helpful tool to improve efficiency of industry production. If we want to attain an optimalisation of production, have shortest lead times, low costs of production we need accurate information from maximal number of criteria collected from production machines, to setup best process parameters focused on reaching acceptable life time of machine parts.

For this reason, we need improve the power of diagnostic systems with implementation of new methods with new possibilities.

Keywords: MULTICRITERIAL DIAGNOSTIC, ELECTRIC CONSUMPTION, VIBRATION DIAGNOSTIC, DATA MINING

1. Introduction

Today’s trend in factories is to obtain a maximal automation, which corresponds to the ideas of the Idea Industry 4.0 concept. Machines are connected to a collaborative community and people cooperate with machines robots cooperate according to collaborative principles and production is set up to a point with zero faults and zero wasted time. For efficient and precise production management, we need to implement tools and methods to eliminate unpredictable failures and errors that reduce the production performance and cause financial losses. One way is to implement a powerful multi-criteria diagnostic systems that enables us to monitor real-time production facilities while allowing us to analyze collected data online for the diagnostics of manufacturing processes. Multi-criteria diagnostics is very beneficial, based on analysis of the results obtained from manufacturers, exact information about weaknesses in the processes of production and proposed solutions to existing or predictable problems can be made. Usage of modern technologies is needed to gather large amounts of data from multicriterial diagnostic processes. Accurate use of the data, often stored in large databases is used to understand production processes, to achieve optimization of production processes or maintenance, to reduce the cost of maintenance and at the same time to maximize the effectivity of production processes. This is particularly visible in the Industry 4.0 concept. This concept assumes the use of various modern information technologies, such as the Cyber-Physical Systems (CBS) or Internet of Things (IoT) – processing the Big Data. The main idea here is the preparation of a computerized manufacturing environment, which will simply allow us to increase flexibility and efficiency of production through integration of various activities and effective communication between a client and a producer - Customer to Business (C2B), as well as between a producer and a supplier Business to Business (B2B).

In respect of the above, methods of acquisition, gathering, processing and, most of all, exploration and analysis of data become particularly important. It seems that predictions of experts have become true – at the beginning of this millennium they stated that data analysis would be a revolutionary achievement of the following or coming decade.

The reason for the creation of specialized nodes is to ensure the maximum possible level of production quality and optimization of logistic processes. However, this causes a new challenge in the production process, the formation of hierarchical dependence of the manufacturing processes where consecutive stages of production within the company are dependent on the production of the previous stages in the life cycle of production. For this reason, the occurrence of random and sudden interruptions of production or unplanned production decline is undesirable phenomenon with potentially serious consequences for the entire production. Prediction of the problems determined by the analysis of information obtained in production by obtaining measurable data is very beneficial method of eliminating the problems of manufacturing. Production processes are complex in nature with a large number of interacting actors. Results of mono-criteria diagnostics are useful only in analyzing an isolated property of the production process, or in the case of mono-criteria diagnostics of more complex property (e.g. vibrations) the result have broader scope, but are susceptible to errors due to misinterpretation of the analyzed results or the emergence of errors in cases where the process is affected by new actor that did not appeared previously and then "hiddenly" influence the result.

Our aim is to as much as possible get an accurate and comprehensive view of the manufacturing process and obtain measurement results that allow us by their analysis to produce results with high diagnostic value with accurate description of the state of the manufacturing process. Data obtained through multi-criteria diagnosis have a very large content value. Depending on the way in which we look at the data, in way of their further processing and, depending on the interpretation of the results obtained by the analysis of the collected data we can not only predict failures and need of scheduled maintenance, and predict other phenomena related to the production and manufacturing process. With correct data analysis and correct interpretation of data we can create very precise results for optimization of energy requirements and environmental impacts of manufacturing processes, also we can optimize usage of human resources, and material flow, and other important factors. Because of wide application opportunities of the proposed multi-criteria diagnostics, and analysis of the results obtained by it we can apply the research results in a manufacturing companies.

Aim of our research is to ensure the development of analytical tools that process the data obtained through multi-criteria diagnostics to obtain the required answers to specific questions defined by mechanical engineering companies in the topic of increasing efficiency and optimizing production processes. The resulting data set has a very large scope and the maximization of the content value is however dependent on a thorough knowledge of its structure and in particular in accordance with the dependencies observed in gathered data. Production process is a continuous sequence of tasks and the various actions in the production process are not an isolated factors affecting the final product, but are an integral set of mutually interacting factors that have both a direct impact on final product manufacturing, and also often lead to mutual interaction between each parameter by means of a visible but also hidden dependencies that need to be understood before of the processing and interpretation of data obtained thru multi-criteria diagnostics.
2. Design of multicriterial diagnostic system

In order to achieve maximum accuracy of diagnostic of the production machines, we have designed a conceptual design of the hardware of the diagnostic system. The proposed hardware is based on the paradigm of autonomy of the diagnostic system in production: "The functionality of the proposed diagnostic system must be independent from the control system of the diagnosed device."

The necessary conditions for achieving the proposed system is:

- It must work with its own and independent control system.
- It must autonomously collect the data and process them to the required representation without the need for any interaction with the control system of the diagnostic system.
- It must have a separate data transfer channel to the parent system (server).
- It must have separate power supply.

To meet the defined conditions, we designed the following architecture of the diagnostic system:

![Multi-criterial Diagnostic System](image)

Because of the need to process and transmit large amounts of data in a short period of time, the internal communication bus between the process nodes and the central processor unit must have high bandwidth. Due to the possible requirement of placing the entire diagnostic system to proximity of the diagnosed device, interference may occur on the communication bus between processing nodes and central unit, because of that hardened communication bus must be used, and likewise the communication protocol must use checksums and have autocorrecting capabilities.

Process nodes must be connected to individual sensors via lines that can transmit measured data without restricting the production and without loss of transfer speed. The types of lines depend exclusively on a communication pair, that consists of a suitable sensor for measurement and a process node with sufficient power.

Process nodes can be differentiated by several logical criteria mainly the following:

- Position of sensors on the production device.
- Process node performance (defined by volume and type of data collected by sensors).
- The number of sensors connected.
- Type of connected sensors.

The main reason for creating process nodes is to take advantage of the decentralization of the diagnostic system. Decentralization enables us to create topologically large applications, greatly simplifies the cabling structure, reduces aggregate transmission speeds and, in the event of a failure of certain node it allows to continuously monitor all parameters of non-affected nodes.

At the same time, we also enable us to decentralize the necessary computational power to process the acquired data from the sensors through their pre-processing functions on process nodes and then send them in the optimized range and shape to the central processing unit.

The subsystem of sensors designed for the diagnostic system is dependent on specific implementations. The main factor determining their choice is their suitability for the chosen purpose, especially in terms of ranges and speed of data collection. At the same time, sensors must be selected based on the suitability of their application for the particular conditions of the monitored device and the environment in which they will be installed. A prerequisite for choice of sensors is connectivity in digital format or must be able to connect via analog-to-digital converter to a digital format.

3. Processing of collected data

With multi-criteria diagnostics of the production process we are collecting in a relatively short time an extensive set of data. We need very powerful analytical methods and tools to obtain applicable results in real time. Therefore, we will focus our research on the implementation of advanced analytical methods for processing the large data set on powerful computing devices.

The process of obtaining the necessary performance of the diagnostic system is by processing of the data obtained by means of progressive tools designed for the processing of large volumes of data. We consider Big Data Tools or Modified Business Intelligence Tools. Modification of Business Intelligence tools is required primarily because of their primary focus on historical data processing. When BI is applied to the Multi Criteria Diagnostics System, the implementation change is required to process current data.

In our research, we focus on analyzing the data obtained in order to create a system of predictive care for the device - i.e., to predict the occurrence of a potential malfunction with the purpose of timely elimination of the malfunction and thus to prevent the device from failing.

From these approaches, we are focusing on Data mining and Knowledge data discovery. Through these methods, we perform analysis of the data obtained in order to identify correlations between the measured data and evaluate the actual condition of the monitored device by processing the acquired data through modified methods of conventional diagnostic methods.

From the point of view of the user, application of specific Data Mining methods for extraction of knowledge hidden in data is the least laborconsuming stage, in comparison with the often cumbersome and technically complicated preceding stages, related to understanding of a problem, proper data preparation, filtering and converting data with regard to a given task. In the knowledge extraction process the data exploration results can be obtained automatically. However, the preceding and the final stages (the latter focused on the analysis of obtained results) require the user to be familiar with problems of mathematics, statistics, as well as to have specialized knowledge regarding the diagnostic branch.

Knowledge data discovery is used to discover new knowledge in stored data. Data analysis is started by identification of the research problem, while further exploration is conducted on a data sample obtained from a larger data set. Then, relations between data are mostly looked for using data visualization tools and the data set is prepared for modeling. The last stage is the evaluation of obtained results and attempt at their translation into real conditions of company functioning.

Success implementation of data mining is connected with full and correct phases of implementation. The most frequently distinguished tasks are:

- Description.
- Classification.
- Regression.
- Clustering.
- Looking for associations.

Description consists in concise summarizing of analyzed data. During realization of this task, graphs are frequently used alongside one-dimensional or multidimensional tables or rules for data description.

Classification belongs to the so-called supervised ("learning with teacher") group and is aimed at creating a dependency model.
between independent variables describing given objects or phenomenon and a dependent variable in an attribute form. It is done on the basis of the so-called teaching set, containing a set of objects with known values of independent and dependent variables. The purpose is to apply this model for assigning new cases to a selected class of the dependent variable. The most frequently used methods in this area are classification trees, neural networks, support vector machines, the naive Bayesian classifier or Bayesian networks.

Regression also belongs to the supervised group and plays a similar role to classification, but in the dependency model created on the basis of the teaching set, the dependent variable is in a numerical form. Examples of methods used to realize the regression task are neural networks, simple and multiple regression, and regression trees.

Clustering does not use a teacher (there is no dependent variable here) and consists in creating clusters (groups) of objects in a way to ensure the highest possible similarity between objects in one cluster, as regards values of the considered independent variables, with simultaneously maintained maximal possible differences between particular clusters. In this area, two groups of methods are applied: hierarchical ones, building the so-called dendrograms, and non-hierarchical ones, creating entirely separate clusters.

Looking for associations consists in finding dependencies in an analyzed data set. These dependencies do not have a functional character; rather, they are based on coexistence of values of particular variables.

4. Model application example

Our system of multi-criteria diagnostics was applied on the diagnosis of the turning process.

We have tracked:
- Vibration
- Temperature
- Power Consumption parameters

We have fully utilized the described philosophy of the decentralized hardware of the diagnostic system. We have saved and pre-processed data stored in a database created through Microsoft SQL Server.

We performed several repetitive measurements on the device while working without a fault, and then we introduced a model of error that is common in the production process.

The effect of the error in the production process is evident from the following graphs:

The next step was to apply data mining to the obtained data. After applying individual methods of data mining, we found a correlation between the individual parameters of the production process. For clarity, we chose to visualize pairs correlations with graphs.

4. Conclusion

By applying multi-criteria diagnostics to the well-known processes of lathe manufacturing operations, we expected to find hidden relationships between the machine state and the measured parameters, and we also expected to find new connections between the production parameters.

Our assumptions have been fulfilled. The correlations between the monitored characteristics of the production processes have been shown as expected, thus confirming the accuracy of the proposed hardware and methods of processing the obtained data.

In further research, we will continue to look at increasing the implementation capabilities of multi-criteria diagnostics systems and expanding the precise knowledge base and understanding of the processes under examination.
5. References


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INCREASING INFORMATION SECRECY BY JAMMING WITH UNIFORMLY DISTRIBUTED EAVESDROPPERS

Aneta Velkoska PhD.1, M.Sc. Natasha Paunkoska2, Ninoslav Marina PhD.1
Faculty of Communication Networks and Security, University of Information Science and Technology, Ohrid1
Faculty of Information Systems, Visualization, Multimedia and Animation, University of Information Science and Technology, Ohrid2
aneta.velkoska@uist.edu.mk

Abstract: Transmission of confidential messages over wireless networks between a transmitter and a receiver in the presence of illegitimate receivers called eavesdroppers is an active area of research. Cooperation by jamming can improve information-theoretic secrecy in wireless networks. However, randomly chosen jammers can have a negative impact on the secrecy capacity. Our goal is to provide a closed form for positioning the friendly jammers in two-dimensional wireless network with uniformly distributed eavesdroppers while two legitimate partners are communicating.

Keywords: INFORMATION-THEORETIC SECRECY, SECRECY CAPACITY, UNIFORMLY DISTRIBUTED EAVESDROPPERS, JAMMER

1. Introduction

The issues of privacy and security in wireless communication networks have taken on an increasingly important role as these networks continue to flourish worldwide. Traditionally, security is viewed as an independent feature addressed above the physical layer and all widely used cryptographic protocols are designed and implemented assuming the physical layer has already been established and is error free.

In contrast with this framework, there exist both theoretical and practical contributions that support the potential of physical layer security ideas to significantly strengthen the security of digital communication systems. The basic principle of information-theoretic security — widely accepted as the strictest notion of security — calls for the combination of cryptographic schemes with channel coding techniques that exploit the randomness of the communication channels to guarantee that the sent messages cannot be decoded by a third party maliciously eavesdropping on the wireless medium (see Fig. 1).

A suitable metric to assess the secrecy level of a system is the secrecy capacity [1], i.e. the maximum transmission rate at which the source can communicate with the receiver without the eavesdropper being able to acquire any information.

Secrecy capacity can be increased in two ways: (a) by improving the signal-to-noise ratio (SNR) of the legitimate receiver (e.g. by shortening the distance to the transmitter) or (b) by reducing the SNR of the eavesdropper (e.g. by adding controlled interference). Interference then emerges as a valuable resource for wireless security. Friendly jammers, with different levels of channel state information, help the legitimate parties by causing interference to possible eavesdroppers.

Results shows that cooperation can significantly improve information - theoretic secrecy in wireless networks but the randomly chosen relay nodes can have a negative impact on the secrecy capacity. Finding the optimum positions for cooperating jammers which minimize the size of the vulnerability region in order to increase secrecy region is a challenging task. Therefore, our interest is solving this task in a 2D wireless network with two legitimate communication partners, uniformly distributed eavesdroppers and friendly jammers.

The paper is organized as follows. Section 2 presents related work and our goal. Section 3 describes our system model and problem formulation. In Section 4 we present the main result and investigate it in particular scenarios. Section 5 concludes the paper.

2. Related work

Several interference generation schemes have been proposed to improve the secrecy rate of different types of wireless channels. A scheme for generation of artificial noise is proposed in [2] whereby a transmitter with multiple antennas or, alternatively, a set of amplifying relays introduces noise in the system that results in low outage probabilities of secrecy rate. In [3], a cooperative jamming scheme is proposed in which an otherwise disadvantaged user can help improve the secrecy rate by jamming a nearby eavesdropper. [4] presents a set of cooperation strategies for a relay node to improve the achievable secrecy rate. Interference-assisted secret communication in which an interferer improves the secrecy rate by injecting independent interference is considered in [5].

In [6], the secrecy level of two nodes communicating in the presence of eavesdroppers placed anywhere in a confined region is investigated. Friendly jammers, with different levels of channel state information, help the legitimate parties by causing interference to possible eavesdroppers. Results shows that jamming near the legitimate receiver leads to a small secrecy improvement and requires channel state information that may not always be available and multiple jammers are needed to achieve relevant secrecy gains throughout the entire confined region.

Secrecy of a cryptographic system is based on the secrecy of the secret key, and not on the secrecy of the cryptographic algorithm. Secret keys between communicating parties are exchanged in two ways: through physically secure channels e.g. a diplomatic suitcase or through public-key cryptographic protocols. The exchanged secret key is called master key, and is typically used to encrypt and exchange session keys, which are then used to encrypt the data flow between the two parties. In [7] and [8] is examined the possibility to use information-theoretic secrecy to exchange a master-key between the two communicating parties in a wireless network with multiple eavesdroppers via user cooperation. Secrecy capacity determines how quickly the master key will be exchanged between the two parties. Since the two communicating parties usually change the master key very rarely, it is sufficient to transmit it at even very small rates. Once the master key is exchanged, the legitimate parties can start communicating at maximum data rate since their communication channel is cryptographically protected achieving computational secrecy [9].

In order to tackle the unknown eavesdropper locations in [8] the pre-master key message is split into a large number B of data blocks. The two communicating nodes ensure that the entire pre-master key message is received correctly at the receiving node, which is required for the computation of the master key. Each data block is sent for a different network configuration of jammers. As the number of transmitted blocks grows, the eavesdropper is less able to intercept in a network configurations with large number of nodes. The secrecy level is observed in two-dimensional wireless network with two communication nodes: a transmitter at position (0, 0) and a receiver at position (1, 0), N friendly nodes (jammers), and a passive eavesdropper which does not transmit any signal, and tries to intercept the information that is transmitted between the pairs of legitimate nodes, hence reducing the secrecy capability of
the network. Its location is unknown to the two communicating nodes.

The following notation is used:

- $X$ the transmitted signal from the transmitter,
- $Y$ the received signal at the receiver,
- $Z_e$ the received signal at the eavesdropper,
- $J_k$ the received interfering signal from jammer $k$,
- $V, V_e$ the additive noise at receiver and eavesdropper, which are independent zero mean Gaussian random variables with variance $\sigma^2$,
- $[N]$ the set of all positive integers smaller than or equal to $N$,
- $K(x) = \frac{1}{2} \log_2 (1 + x)$,
- $C_s$ secrecy capacity between the transmitter and the receiver,
- $d_{ij}$ the distance between nodes $i$ and $j$,
- $\beta$ the path-loss coefficient [10],
- $\sigma$ the variance in independent zero mean Gaussian random variables with variance $\sigma^2$.

We consider 2D wireless network with two communication nodes: a transmitter at position $(0, 0)$ and a receiver at position $(r_1, r_2)$, $0 \leq r_1, r_2 \leq 1$, in presence of uniformly distributed passive eavesdroppers $\mathcal{E} = \{ E_1, E_2, E_3, \ldots \}$. Our goal is to find closed form for positioning the jammers $\mathcal{J}(a, b)$ in a confined region $[0,1] \times [0,1]$ in order to characterize the secrecy regions in the system.

In the rest of the paper, we assume that the transmitter and all jammers have equal transmitting power $P_j = P$, $j \in [N]$. Since the function $K(x)$ is monotonically increasing, plugging equations (2) in (1), it follows that the secrecy capacity $C_s$ is positive if

$$
\frac{d_{i,r}^\beta}{\sigma^2 + \sum_{j \in [N]} b_j P d_{j,r}^\beta} > \frac{d_{e,r}^\beta}{\sigma^2 + \sum_{j \in [N]} b_j P d_{j,e}^\beta},
$$

Since we want to characterize the secrecy regions in the system by the position of the jammers in a confined $[0,1] \times [0,1]$ region we assume that there is a single jammer. So, plugging $N = 1$, $j = 1$ in (3),

$$
\frac{d_{i,r}^\beta}{\sigma^2 + P d_{j,r}^\beta} > \frac{d_{e,r}^\beta}{\sigma^2 + P d_{j,e}^\beta}.
$$

In order to achieve information theoretic secrecy for the master key in the presence of eavesdroppers, it is sufficient that the signal quality at the eavesdropper is sufficiently degraded by the artificial noise generated by the jamming nodes for at least one configuration. In that case at least one data block out of $B$ data blocks is not intercepted, and consequently the master key cannot be computed at the eavesdropper.

Since the position of the eavesdroppers is unknown, we assume that they are uniformly distributed over the region $[0,1] \times [0,1]$ and for the distances from the transmitter to the eavesdropper $d_{i,r}$, and from the jammer to the eavesdropper $d_{j,e}$ we consider their mean distances.

The mean distance of any fixed point $A(x_a, y_a)$ and some random nodes $\mathcal{E} = \{ E_1, E_2, E_3, \ldots \}$ uniformly distributed over region $[0,1] \times [0,1]$ is:

$$
m(T, \mathcal{E}) = \frac{1}{\int_0^1 \int_0^1 (x - x_a)^2 + (y - y_a)^2 \, dx \, dy}.
$$

If we plugging $x_a = y_a = 0$ in (5), the mean distance from the transmitter to the set of uniformly distributed eavesdroppers over the region $[0,1] \times [0,1]$ is:

$$
d_{i,r} = m(T, \mathcal{E}) = \frac{1}{\int_0^1 \int_0^1 \sqrt{x^2 + y^2} \, dx \, dy} = 0.7652.
$$
4. Main result

Theorem 1. The mean distance between a jammer \( J(a, b) \) and a set of uniformly distributed eavesdroppers over the region \([0,1] \times [0,1]\) is

\[
d_{j,e} = \frac{1}{12} \left[ (1-b)^3 \Omega_1((1-b, 1-a); (1-a, 1-b)) + (1-b)^3 \Omega_2((1-b, a); (1-a, b)) + \frac{a^3}{12} \Omega_3((1-b, a); (b, a)) + \frac{b^3}{12} \Omega_4((b, a); (1-a, b)) \right],
\]

where

\[
\begin{align*}
\Omega_1((x, y); (z, w)) &= \ln(\Phi(x, y)\Theta(z, w)) + \Psi(x, y)\Psi(z, w), \\
\Omega_2((x, y); (z, w)) &= \ln(\Phi(x, y)\Phi(z, w)) + \Psi(x, y)\Psi(z, w), \\
\Phi(x, y) &= b + 1 + x + y - \sqrt{x^2 + y^2}, \\
\Theta(x, y) &= b + 1 + x + y - \sqrt{x^2 + y^2}.
\end{align*}
\]

Proof. Plugging \( x_0 = a, y_0 = b \) in (5), where \( a, b \in [0, 1] \), the mean distance from the jammer to the set of uniformly distributed eavesdroppers over the region \([0,1] \times [0,1]\) is

\[
d_{j,e} = m(J, E) = \int_{0}^{1} \int_{0}^{1} \sqrt{(x-a)^2 + (y-b)^2} \, dx \, dy.
\]

This integral will require the following substitutions,

\[
\begin{align*}
u &= x - a \quad v = y - b \quad dx \, dy = du \, dv \\
x = 0 &\Rightarrow u = -a, \quad x = 1 \Rightarrow u = 1-a \\
y = 0 &\Rightarrow v = -b, \quad y = 1 \Rightarrow v = 1-b
\end{align*}
\]

Plugging these substitutions in (8),

\[
d_{j,e} = m(J, E) = \int_{-a}^{1-a} \int_{-b}^{1-b} \sqrt{u^2 + v^2} \, du \, dv.
\]

This integral is considered in four regions (Fig. 1), A, B, C and D. In all these it requires the following trig substitutions,

\[
u = \rho \cos \theta \quad v = \rho \sin \theta \quad du \, dv = p \rho \, dp \, d\theta
\]

and results in equation (7).

For particular position of the receiver \((r_1, r_2)\) in the region \([0,1] \times [0,1]\) the secrecy regions where the jammer will degrade the signal quality at the eavesdropper by generating artificial noise can be obtained by plugging equation (7) in the inequality (4).

We will consider two different scenarios, first when the receiver is at position \((0, 0.5)\) and second at position \((0.5, 0.5)\).

**First scenario**, 2D wireless network with two communication nodes: a transmitter at position \((0, 0)\) and a receiver at position \((0, 0.5)\), in presence of uniformly distributed passive eavesdroppers \( E = \{ E_1, E_2, E_3, \ldots \} \), (Fig. 2). We use that \( P/\sigma^2 = 10 \), where \( \sigma^2 \) is the noise power, and \( \beta = 3 \).

Since the receiver is at position \((0, 0.5)\),

\[
d_{j,e} = 0.5 \text{ and } d_{j,r} = \sqrt{a^2 + (b - 0.5)^2}
\]

Plugging (6), (7) and (10) in (4) we obtain the secrecy regions presented in Fig.3. Positioning the jammer in the region \([0,1] \times [0,1]\) between the blue line (dot line) and the light blue line; between the green line and the orange line; between the red line and the closed curve in the middle, we will obtain positive secrecy capacity in the system.

**Second scenario**, 2D wireless network with two communication nodes: a transmitter at position \((0, 0)\) and a receiver at position \((0.5, 0.5)\), in presence of uniformly distributed passive eavesdroppers \( E = \{ E_1, E_2, E_3, \ldots \} \), (Fig. 4). We use that \( P/\sigma^2 = 10 \), where \( \sigma^2 \) is the noise power, and \( \beta = 3 \).

Since the receiver is at position \((0.5, 0.5)\),

\[
R((0.5, 0.5))
\]

Fig. 3. Boundaries of secrecy in a confined region \([0,1] \times [0,1]\) with transmitter at \((0, 0)\), receiver at \((0, 0.5)\) and uniformly distributed eavesdroppers.

Fig. 4. Since the receiver is at position \((0.5, 0.5)\),

\[
T((0,0))
\]
\( d_{r} = 0.866 \) and \( d_{j,r} = \sqrt{(a-0.5)^2 + (b-0.5)^2} \).

(11)

Plugging (6), (7) and (11) in (4) we obtain the secrecy regions presented in Fig.5. Positioning the jammer in the region \([0,1] \times [0,1]\) between the dark blue line (dot line) and the blue line (dot line); between the light blue line and the green line; between the orange line and the red line, and outside the dark red line (the largest closed curve) we will obtain positive secrecy capacity in the system.

Fig. 5. Boundaries of secrecy in a confined region \([0,1] \times [0,1]\) with transmitter at (0, 0), receiver at (0.5, 0.5) and uniformly distributed eavesdroppers.

Notice, that in both scenarios the jamming near the legitimate receiver results with small secrecy regions, so once again we confirm that as the jammer is closer to the legitimate receiver the jamming leads to a small secrecy improvement.

5. Conclusion

Positions of cooperating jammers are quite important for the resulting secrecy region. Finding the optimum positions for cooperating jammers which decrease the vulnerability region still is an open problem. In this paper we provide a closed form for positioning a single jammer in two dimensional wireless networks such the secrecy region is completely determined. With our model we confirm that the jamming near the legitimate receiver results with small secrecy regions. Our next challenge is to characterize the secrecy region in two and higher dimensional wireless network by obtaining a closed form for determining the positions of multiple cooperating jammers.

References:


GRUND CONTACT IN SIMMECHANICS FOR HUMANOID ROBOT

Prof. Asoc. Dr. Likaj R. 1, Prof. Ass. Dr. Bajrami X. 2, Prof. Asoc. Dr. Shala A*. 1
Faculty of Mechanical Engineering – University of Prishtina “Hasan Prishtina”, Kosovo 1
University of Prizren “Ukshin Hoti”, Kosovo 2
ahmet.shala@uni-pr.edu (*corresponding author).

Abstract: this paper deals with the comparison of analysis of two legged humanoid robots during walking. This research area is characterized by the fact that there are a lot of publications, most of which are based on the classic Zero-Moment-Point (ZMP) method. First, a brief overview is provided on humanoid robots, and also models for the dynamic behavior are discussed. As base for these models two methods Denavit Hartenberg and the Newton-Euler are used. Main aim of this work is to investigate the stability of humanoid robot developed. There is currently the low base of robot - consisting of feet, legs, hips and upper part of robots body. First, the existing low base of humanoid robot was simulated using Matlab / SimMechanics, where the derived by Newton-Euler model was used.

Keywords: KINEMATIC, DYNAMIC, HUMANOID, ROBOT, SIMULINK.

1. Introduction

SimMechanics is a 3D simulation environment that allows to create links, joints and constrains. In this context, it is used to create a 3D model of the humanoid robot for a kinematic simulation. A link is defined by its coordinates, mass and inertia moment matrix. A 3D model can be imported to Simmechanics defining the mechanical properties of the link through the imported file from CAD. Links are connected together through joints. Several joints can be chosen from the library of Simmechanics depending on the degrees of freedom required.

A 3D model of the humanoid robot is required to run a kinematic simulation. Data for joint actuators is imported to simulate the walking. Scopes are used to obtain angle-time plots on each joint, to obtain the ground contact forces and its influence on the trajectory. A rigid multi body system consists of a set of rigid objects, called links, joined together by joints such as introduced in humanoid robots and has been studied in biped locomotion articles (Ibarra, J et al., 2009).

Biped locomotion has been a topic of great attention in a various researches performed on legged robots and is probably the most suitable method for robots to execute assigned maneuvers in a real environment with various obstacle conditions and geometry.

Widespread studies have been conducted on biped walking, and now biped robots are capable of walking with a certain amount of stability. Trajectory control, motion planning and locomotion modeling is completely related to the kinematics analysis as it is fundamental in the study of linkage systems” (McGee, G and Spong, W., 2001).

Forward and inverse kinematics are commonly implemented to determine main parameters affecting humanoid robot behavior and specify the reliable method to control motion and preserve stability (Azevedo, C et al., 2004).

The most frequently practiced parameters to be defined are joint parameters, including required drive torques, angles, and related twists (Murray, R et al., 1994).

The humanoid robot locomotion requires sensible solutions of the inverse kinematics and localization problems with optimized computations. Since the end effecter and it is exact

SimMechanics has a number of blocks of physical components, such as body, joint, constraint, coordinate System, actuator, sensor and so on (Li Zheng-wen., 2011). SimMechanics provides a variety of simulation and analysis modes for mechanical systems: Forward Dynamic Analysis-Solve the response to given excitation of the mechanical system; Reverse Dynamic Analysis-Solve the required force and torque according to the results of given movement of the mechanical system; Kinematic Analysis-Solve the system’s displacement, velocity and acceleration under constraint conditions, and check the consistency; Linear Analysis-Obtain the linear model of the system in the designation of small perturbation or initial state to analyze the system’s response performance; Equilibrium point locations are related to the above mentioned joint parameters with nonlinear characteristics, inverse kinematics problem are usually complicated. For linkages, such joint parameters are a natural default since the correspond directly to the actuation of the joints and are well suited for forward kinematics computations (Christensen, J. et al., 2007)

2. Structure of humanoid robot

A very general schema of the phases of simulation/SimMechanics approach is presented below.

![General schema for simulation approach](image)

This paper deals with modeling of the biped robot’s by usage of SimMechanics, and according to simulation experiments to analysis the mechanical structure and sports performance of each part (needs to be reformulated). In order to use the SimMechanics advantages, first we must define the coordinate system of the biped robot.

SimMechanics sets its fixed coordinates in the geometric center of the robot's main body and regards it as the reference coordinate system. Some institutions use indirect coordinate method, that is, according to the coordinates of reference point to describe the location of other joints indirectly. The leg and foot’s structure of the
robot is composed of six components: leg bottom, thigh shot, calf of the ends of the lower leg and one of the ends of foot rod are welded together. The following part mainly takes the modeling of leg as an example to describe the modeling process.

First, take the hip joint which is linked with the main body as the primary coverage, and define the direction of rotation of the hip joint. The one end of hip joint is connected with the main body of the robot with a rotating joint, the other one is connected with the leg bottom. In this paper, we set X-axis as the axis of rotation of hip joint to make the leg swing front and rear. The structure of the leg link must take the defined hip joint as a reference. Set X-axis as the axis of rotation of the leg to make it swing up and down.

The model in 3D was build using the already designed model for double foot. For that matter it was necessary to allow motion and calculate the forces in the third dimension. Further, the Archie had to be composed by combining 2 legs, add the physics of the main body, and implement the hip abduction joints between the main body and the legs. The block subsystem (see Fig.2 gray color) contains the whole model of the Archie. On a first level the connection between the main body and the environment an the connection between main body an the legs was modeled (see Fig.2).

Fig.2 Model Scheme solution for Archie with simMechanic in 3D

The angular trajectory error caused by the real robot in case of the movement of the hip joint with different traversing velocities is shown in Fig. 5 and Fig.6. The hip positions (XY direction) are shown in Fig. 3 and Fig.4.

Fig.5 Hip position in direction x

Fig.6 Hip position in direction y

3. LOWER DADY IN SIMMECHANICS

Foot-Component: In this subsystem it is designed a model for humanoid robot (left_right-legs, left_right-shins, left_right-foots).

Fig.7 The Subsystem for feet with ground

The angle movement of the leg left join with PID controller is shown in Fig. 8.
4. Linear Inverted Pendulum Model

The Linear Inverted Pendulum Model was first introduced by Kajita and Tani in 1991 (S. T. Kajita 1991). The main idea of this approach is to extract a dominant feature of biped dynamics, which is high-order and non-linear, and to use this dominant factor to explain the governing dynamics of the system. In this model the robots mass is assumed to be lumped at the center of mass of the robot and the legs of the robot are assumed to be mass (Okan, K., 2006). Further, for simplicity, the height of the pendulum is assumed to be constant in this model. This lets the dynamics of the model to be linear. Such an inverted pendulum with a mass rod can be seen in Fig. 10.

![Fig. 10 Inverted pendulum](image)

where \( C = [c_x, c_y, c_z] \)

The ZMP equations for \( x - y \) plane are as follows.

\[
x_{ZMP} = \frac{\sum_{i=1}^{n} m_i (\ddot{z}_i - g_i) \cdot x_i - \sum_{i=1}^{n} m_i (\ddot{z}_i - g_i) \cdot z_i}{\sum_{i=1}^{n} m_i (\ddot{z}_i - g_i)}
\]

\[
y_{ZMP} = \frac{\sum_{i=1}^{n} m_i (\ddot{z}_i - g_i) \cdot y_i - \sum_{i=1}^{n} m_i (\ddot{y}_i - g_i) \cdot z_i}{\sum_{i=1}^{n} m_i (\ddot{z}_i - g_i) - \frac{g_z}{g}}
\]

Where, \( p_{ZMP} = [x_{ZMP}, y_{ZMP}, z_{ZMP}]^T \) shows the ZMP vector of any kinematic chain, the gravity vector is \( g = [g_x, g_y, g_z]^T \) and \( g_z = -g \cdot [x, y, z]^T \) and \( m_i \) is the position vector and the mass of each link, respectively.

Now, let the ZMP of coordinates of this pendulum to be \( P = [x_p, y_p, z_p]^T \), the mass of the pendulum (CoM) to be \( m \). Using the ZMP equation (1) and (2) the dynamics equations of the inverted pendulum can derived as follows.

\[
P_x = \frac{m \cdot (\ddot{c}_z + g) \cdot c_x - m \cdot \ddot{c}_x \cdot c_z}{m \cdot (\ddot{c}_z + g)}
\]

\[
P_y = \frac{m \cdot (\ddot{c}_z + g) \cdot c_y - m \cdot \ddot{c}_y \cdot c_z}{m \cdot (\ddot{c}_z + g)}
\]

However equations (3) and (4) are non-linear. To attain equations assume the \( z \)-coordinates of the inverted pendulum is assumed to be constant, let \( c_z = z_c \).

The equations (3) and (4) can be linearized

\[
P_x = c_x \frac{\ddot{c}_x}{\omega^2_n}
\]

\[
P_y = c_y \frac{\ddot{c}_y}{\omega^2_n}
\]

Where \( \omega^2_n = \frac{g}{z_c} \)

Henceforth, (5) is going to be referred as ZMP equations. Note that given the Center of Mass (CoM) coordinates of the pendulum \( C = [c_x, c_y, c_z] \) at any time it is straightforward to calculate the ZMP coordinates of the pendulum by (3) and (4) (Okan, K., 2006).

The walking trajectory generation is the inverse problem: Given a walking trajectory a corresponding CoM trajectory should be found. Thus, this trajectory of CoM could be used as a reference for the ZMP trajectory. The walking trajectory generation is the inverse problem: Given a corresponding CoM trajectory should be found. Thus, this trajectory of CoM could be used as a reference for the ZMP trajectory. The walking trajectory generation is the inverse problem: Given a corresponding CoM trajectory should be found. Thus, this trajectory of CoM could be used as a reference for the ZMP trajectory.
As depicted in the Fig. 11, assume the cart to be at the position showed by dashed lines. If the cart is not moving then, since the foot of the table is not long enough to equalize the torque generated by the cart, the table would fall eventually. However, if the cart has a proper acceleration, the table can remain upright for a while. At the moment, ZMP lies inside the table foot. Since the moment around the ZMP must be zero the following condition holds.

\[ \tau_{ZMP} = mg \cdot (x - p_x) - m \cdot \ddot{x} \cdot z_c \]

### 5. Solution of Humanoid Linear Pendulum Model for Fixed ZMP

In this section the exact solution of the Linear Pendulum Model (LPM) equations with given fixed ZMP trajectories, (Choi June 2004), is given. Accord to the ZMP equations (5)

\[ y_n \cdot y = x_n \cdot x + \omega_n^2 \]

Rearranging these equations,

\[ x_n \cdot x - y_n \cdot y = \omega_n^2 \]

(6)

\[ y_n \cdot y - x_n \cdot x = \omega_n^2 \]

(7)

Laplace transform of (6) and (7)

\[ C_x(s) = \frac{1}{1 - \frac{s^2}{\omega_n^2}} \left[ p_x(s) - \frac{1}{\omega_n^2} C_x(0)s - \frac{1}{\omega_n^2} \dot{C}_x(0) \right] \]

(8)

\[ C_y(s) = \frac{1}{1 - \frac{s^2}{\omega_n^2}} \left[ p_y(s) - \frac{1}{\omega_n^2} C_y(0)s - \frac{1}{\omega_n^2} \dot{C}_y(0) \right] \]

(9)

In equation (6) and (7) the following fixed ZMP trajectories are going to be used for the exact solution calculation. In Fig.12, the x-axis (for sagittal plane) reference for ZMP trajectory. In Fig. 12, the y-axis (for frontal plane) reference for ZMP trajectory, and in Fig. 13, the resulting ZMP trajectory in the x-y plane is shown (Okan, K., 2006).

\[ \sum_{k=1}^{\infty} l(t - kT_0) \]

(10)

\[ p_x = B \sum_{k=1}^{\infty} l(t - kT_0) \]

(11)

\[ p_y = A(t) + 2A \sum_{k=1}^{\infty} (-1)^k l(t - kT_0) \]

(12)

Finally, the exact reference trajectories of the CoM can be obtained by the inverse Laplace transformation of equations (12 and 13).

\[ C_x(s) = \frac{1}{s} \left[ 2e^{-T_0 s} + 2e^{-2T_0 s} + \ldots \right] \]

(13)

\[ C_y(s) = B(1 - \cosh \omega_n (t - T_0))(1 - e^{2T_0}) + \ldots \]

(14)

Although equation (13 and 14) are the exact solutions for the ordinary differential equation (5) and (6), in practices they are difficult to be used robustly for a real biped walking robot “Archie”, they are unstable and very sensitive to the variation of \( \omega_n \). Therefore, an approximated solution composed of bounded sin(.) function is suggested to serve as a robust Center of Mass (CoM) trajectory in the following section (Okan, K., 2006). The approximate solution for Linear Pendulum Model (LPM) equations, first an odd function with period \( T_0 \) is introduced from the x-directional reference ZMP \( p_x^{ref} \) of equation (5) as follows.
\[ \ddot{p}_x(t) = p_x^{ref}(t) - \frac{B}{T_0} \left( t - \frac{T_0}{2} \right) \] and \[ \ddot{p}_x(t + T_0) = \dot{p}_x(t) \]

Assuming that the x-directional reference trajectory of Center of Mass (CoM) can be expressed by a Fourier serie,

\[ c_x^{ref}(t) = \frac{B}{T_0} \left( t - \frac{T_0}{2} \right) + \sum_{n=1}^{\infty} \left[ a_n \cos \left( \frac{n\pi t}{T_0} \right) + b_n \sin \left( \frac{n\pi t}{T_0} \right) \right] \] (15)

Applying equation (13) to the ZMP differential equation (14) yields to

\[ \dddot{p}_x(t) - \frac{B}{T_0} \left( t - \frac{T_0}{2} \right) + \sum_{n=1}^{\infty} \left[ a_n \left( 1 + \frac{n^2 \pi^2}{4T_0^2} \right) \cos \left( \frac{n\pi t}{T_0} \right) + b_n \left( 1 + \frac{n^2 \pi^2}{4T_0^2} \right) \sin \left( \frac{n\pi t}{T_0} \right) \right] \] (16)

From equation (11) the form of the odd function \( p_x(t) \) is shown in Fig.14.

\[ p_x(t) = \frac{B}{2} + \sum_{n=1}^{\infty} c_n (t - nT_0) \quad t \quad [s] \]

![Fig.14 Odd function \( p_x(t) \) (Okan, K., 2006).](image)

The coefficients \( a_n = 0 \) and \( b_n \) follows from

\[ b_n = \frac{B - T_0^2}{n\pi \left( \frac{T_0^2}{4} + n^2 \pi^2 \right)} \] (17)

The x-directional reference trajectory of Center of Mass (CoM) can be found by substituting in equation (12) equation (13).

\[ c_x^{ref}(t) = \frac{B}{T_0} \left( t - \frac{T_0}{2} \right) + \sum_{n=1}^{\infty} \left[ \frac{B \cdot T_0^2 \cdot \omega_n^2 \cdot (1 + \cos(n\pi))}{n\pi \cdot \left( \frac{T_0^2}{4} + n^2 \pi^2 \right)} \right] \] (18)

In Fig. 15 it can be observed that the new \( C_x, C_y \) are smoother than both of the previous versions. This, in fact, is an outcome of the novel approach of embedding both the varying ZMP reference and the double support phases in to Fourier approximation to LPM equations (Okan, K., 2006). Also it can be observed that the Gibbs Phenomenon effect is almost disappeared and a smoother ZMP reference approximation is achieved.

In Fig. 15 (left) it can be observed that the CoM is passing through acceleration and deceleration phases in such a way that the given ZMP reference is achieved. Similarly in Fig. 15 (right) the CoM is forming a sine-like curve to satisfy the ZMP reference.

4. Conclusions

The main goal was the derivation of a walking model for dynamic behavior of a Humanoid robot. For the two different locomotion phases a new approach was created. Both phases are now included in our model on the (very well known) Newton-Euler equations. Using Newton-Euler equations enable the computation of dynamic equations numerically without going through analytical derivation procedure which is unpractical for a complex system with 30 DOF’s and to calculate reaction forces and moments between bodies which might be beneficial for the preliminary stage of mechanical design. Based on previous conclusion, mechanical model of humanoid robot for Matlab/Simulink use is done using SimMechanics Toolbox. Complete scheme is represented in Fig. (7). It is important to clarify that using SimMechanics was possible to impart parts’ design, add of dynamical characteristics e.g. masses, moment of inertia etc., add of different types of sensors e.g. position, velocity and force sensors. Using SimMechanics is realized individual control of joint actuators-motors. Increase of boundaries of stability (ZMP), in this paper is achieved by changing the center of mass of hip (change of fixed position of batteries). For the future work, there are many problems involving the implementation of the simulator and motion planning for a biped robot. The method can use to build simulator in combination with other methods for improving the stability, fields for possible future projects can be: Intelligent control – all control techniques that use various Artificial Intelligence approaches like neural networks, fuzzy logic, machine learning, evolutionary computation and genetic algorithms can be put into the class of intelligent control. New control techniques are created continuously as new models of intelligent behavior and computational methods developed to support them. Complete Control scheme using conventional and non-conventional (Fuzzy Logics and Artificial Neural Networks) controllers, will be necessary and inevitable.
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INTELLECTUAL DEVELOPMENT OF OPERATIONAL MANAGEMENT SYSTEM OF TRANSSHIPPING PROCESSES AT THE SEAPORT

РАЗРАБОТКА ИНТЕЛЕКТУАЛЬНОЙ СИСТЕМЫ ОПЕРАТИВНОГО УПРАВЛЕНИЯ ПЕРЕЗАГРУЗОЧНЫМИ ПРОЦЕССАМИ В МОРСКОМ ПОРТУ

Doctoral student  I. Dolidze, Prof. Dr. P. Gogiashvili, Prof. Dr. G. Lekveishvili
AkakiTsereteli State University, Kutaisi, Georgia
E-mail: i.dolidze@bsma.edu.ge, E-mail: pridongo@gmail.com, E-mail: g.lekveishvili@gmail.com

Abstract: The paper describes the methods for the design of systems for implementing intelligent control of transshipping processes at the seaport. Movement of cargo flows requires a constant solution of singular case transportation problems of operational planning and management. The paper shows how the obtained mathematical models of management of cargo flow movement processes, allow for solving optimization problems of the divergent options of bulk cargo movement within the seaport, as well as their communication with suppliers and consumers of loads within the transshipping complex. Modeling of different options bulk cargo movement is needed for providing the given intensity of ship loading taking into account various factors, including weather. The designed model allows for solving the scheduling problems the execution of works on cargo handling in the seaport terminals.

KEYWORDS: INFORMATION-MANAGEMENT SYSTEMS, INTELLECTUAL SYSTEMS, SIMULATION MODELING, TRANSSHIPPING.

1. Introduction

The analysis of the current state of management practice in technical systems shows the need to create automation tools allowing for providing optimal management of technological processes (TP) in real time. The implementation of such an approach is possible only in the presence of the integrated information-management systems (IMS) ensuring the solution of a wide range of problems in the automated control systems (ACS) of TP. In the existing control systems, there are no components ensuring the solution of analytical (not to mention intellectual ones) problems. This is due to the fact that the implementation, for example, of the functions of decision-making support by operational personnel of ACS TP, requires designers of these system to have knowledge not only in their own subject domain, but also the knowledge of specifics of technological processes and their management, that is the knowledge relating to other subject domain. For IMS designers, it is easier to confine themselves to the creation of the standardized information system of SCADA type (Supervisory Control and Data Acquisition System). When assessing the situations and decision-making, operational personnel, using information provided to it, will work the old-fashioned way, that is without intellectual support from such systems [1,2].

Creation of the new-generation intellectual systems (IS) for management the complex TP in different conditions of interaction with an external environment, is one of the urgent tasks of practical applications of methods of artificial intelligence and cognitive simulation in general [3]. The functional capabilities and the IC interface significantly depend on the possibilities of the formalized description and a completeness of the use of all diversity of mathematical methods of data processing. In this regard, of particular relevance is the problem developing special formal technique providing uniform representation of the models synthesized by means of different methods and means for the purpose of unification of operations of their processing in a computing environment[1,3].

2. Preconditions and means for resolving the problem

Complexity of management of cargo handling technological processing in terminals at the seaport is defined by a variety of works by their nature and labor intensity, the stochastic nature of the intensity of transshipping processes and the wait time spent of the delivery systems and cargo handling at the port, a continuity of transshipping works, and on the dependence of the activity of the cargo port on the cargo fleet movement. Competition between transhipment facilities for taking over cargo requires them to improve the quality of cargo handling, increase the intensity of performing cargo, warehouse and other works. Peculiarity of technological processes at the port consists in their continuous development conditioned by changing the needs for cargo handling, and by the constantly changing situation at the port and in the regions it serves. The specified factors result in impossibility to describe analytically and design the formal models that considerably reduces the efficiency of management of similar low-formalized technological processes, and often even makes it impossible. As the tool for the analysis of the activity of the port, there has been chosen the simulation modeling. During the simulation modeling, the algorithm realizing the model reproduces the process of the functioning of the considered system in time, and there are simulated the elementary phenomena composing the process with the preservation of their logical structure and the sequence of the course of technological processes in time enabling, by initial data, to obtain information about conditions of the process at the certain points in time and allowing for assessing the system characteristics. The modelled system represents the service process of the requests flow for the execution of cargo-handling operations on ships and in wagons with goods.

At the same time, it is characterized by it is occasional emergence of the requests for services, and also by the completion of cargo-handling processes by cranes and loaders in irregular intervals. The considered process is of a continuous-stochastic and accidental nature. The block diagram of cargo handling
Cargo to the warehouse

Vessels for loading

Collection of service requests

Application analysis block

Accepted for execution

Rejected applications

Diesel locomotives

Cargo to the warehouse

Cargo from warehouse to ship

Fig. 1. The block diagram of cargo handling technological processes at the port

Meanwhile, baseline information has been used for correlation analysis carried out for the purpose of the solution of two tasks: definition of stochastic communication between parameters and assessment of strength of relationship of factors and the resulting indicator.

The task of optimizing management of transshipping processes is as follows: in the transport hub, there is some number of loading and unloading points, the number of identical vehicles and the number of the flows of cargo passing through the transport hub. It is necessary to arrange a route of movement of each flow of cargo and of vehicle within the transport hub to provide a minimum of costs of transportation of goods and reduction of time for processing of vehicles.

For imitation of the obtained model it is offered to use a Matlab software Simulink package. Simulink is an interactive environment for modeling and the analysis of a wide class of dynamic systems by means of the block-diagrams, which may be combined in the component blocks that allows for using hierarchical representation of the structure of model, thereby providing the simplified view of components and subsystems [3].

Technological processes at the port is given in Fig. 1.

The addtion blocks summarize expenses on transshipping processes taking into account transit factor.

Fig. 2. A graph-model of transshipping processes

3. Conclusion

Thus, using the model developed in a Simulink package, it is possible to estimate costs of transshipping processes by various vehicles and methods. From this point of view, it is possible to optimize process of cargo transshipping by economic criterion, such as a total complex expense of movement of cargo flow.

4. References


1. Introduction

Medicinal and aromatic plants have been used for centuries in phytotherapy or like spices, but their current use is far wider. The relatively large number of sunny days, favourable climate, unpolluted air and soil in Bosnia and Herzegovina are particularly suitable for the cultivation and growth these plants of high quality. This fact requires the development of appropriate processing procedures and equipment. The most widespread level of processing is drying, but far more useful and profitable products were obtained by the distillation of aromatic plants. For our region, on which it is usually processed fresh plants like abies, lavender, chamomile, immortelle, mint, basil, oregano,... the most appropriate method is the steam distillation. Producers and processors of medicinal and aromatic plants is necessary to be educated in terms of distillation technology. Also, the good quality of equipment for obtain a better quality and larger quantities of essential oils are provided them.

Many years of experience in the distillation of essential oils, in terms of technical and technological improvement of equipment for distillation, resulting in a new solution for the flow of useful substances from the plants. Certain critical points, identified as potential causes of reduction of the quantity and quality of the final product were removed by using new solution.

2. Reconstruction of the substance flow system

During distillation produced steam passes through the plant material, softens it and extracts useful components of essential oils. The resulting vapor mixture is condensed and cooled, and as a result is obtained a aromatic liquid mixture with essential oil on the surface. Working for many years in the design and production of equipment for steam distillation and comparing parameters of the distillation process on different technical solutions, it was concluded that the basic mistakes that are repeated, following:
- low quality of produced essential oils, with unnatural colors or bad composition,
- traces of rust or other impurities in oil,
- low efficiency of the process.

Disrupted oil quality could be primarily due to retention of residual products from the distillation in the narrow parts and pockets in system for distillation and condensation occurring due to poor geometry of circulation system.

Key critical phases in the process are:
- the introduction of produced vapor in the fresh plants and condensation of aromatic mixtures.

Technical-technological solution of these phases implementation directly influences to the quality and quantity of produced essential oils, consumption energy for steam production, as well as a great consumption of cooling water, which is very important from the standpoint of process efficiency. Reconstruction of existing systems for distillation was carried out taking into account these factors and in order to improve the output parameters. Changes were made to the inlet of water vapor in the biomass, as well as the construction of condenser.

In a typical distiller for the steam distillation, the plant material is heated from the bottom by injection of heat, release of steam through the nozzles in the zone below the plant material (Figure 1). Wherein the water vapor is flowed in the direction from the bottom upwards. It is obvious that here is a problem due to the opposite direction of the water vapor and the condensate which is partially from the plant mass.

The vapor, in the new solution of the distiller, was introduced from the upper side, and the flow of steam through the biomass has a direction from top to bottom (Figures 2 and 3), opposite to the current technical solution. This provides a more uniform dispersal of the vapor phase in the plant material and approximately the same temperature. In this way is achieved a more spontaneous thermal treatment process of the plant material, less retention of the condensate in the plant mass and supplying "fresher" dry-saturated water vapor, which speeds up the process of distillation. It avoids also the possibility of poor quality oil production due to prolonged or inadequate heating the plant material in the distiller. This solution also avoids closing nozzles for steam supply with the plant material, which increases the energy consumption and eliminate the delays in the process.
After distillation, another very important phase is condensation of mixture of essential oil with water vapor, which occurs in the condenser. It is necessary to ensure the efficient and optimal operation of the condenser that the condensation process completed by the end completely and without excessive retention of vapor phase and the condensate. Too long retention of the mixture in the condenser results in the accumulation of essential oils on the condenser walls, which affects the purity and the amount of produced oil. Some of the technical solutions of the condenser can retain the condensate formed in the prolonged contact between the material of condenser and active substance, which results in poor quality. On the other hand, too fast process with incomplete condensation causes quantitative loss of essential oils. All impurities resulting from the process directly affect to the quality and visual acceptability of essential oil.

The previous technical solutions of condenser were mainly composed of disc-shaped surfaces (Figure 4), or in the form of a spiral pipe (Figure 4). Both solutions have their disadvantages, mainly due to the existence of a small diameters or flat surfaces that retains the essential oil, changing its natural properties and losing quality.

The new solution of the condenser (Figure 5) is designed as a vertical tube heat exchanger with a flat tubes which have a relatively small diameter in relation to the length. Its advantage is that it is not possible to retain condensate in the pipes that simply flows down the vertical pipe cooled by the cooling water. These tubes do not have bottlenecks, coils or horizontal sections, with possibility to retain condensate. In this way is achieved a more efficient process, the complete condensation in the minimum period of time and with minimal contact of steam and liquid phase with the wall of condenser. Condensing and cooling of condensate in this condenser requires significantly less water, which in the financial balance of essential oil production is an important item.

The application of these technical solutions has been reduced the duration of the distillation for 10-15%, and the resultant is a larger quantity of essential oil 2-3%, depending on the type of plant mass. The resulting oil is crystal pure color and exceptional quality from the standpoint of scents and organoleptical properties. By monitoring the consumption of energy has been observed a decrease of 5%, while the quantity of cold water necessary for the condensation of the vapor phase is reduced by as much as 20%, resulting in significant economic savings, as well as advantageous from the preservation of natural resources, environmental protection and sustainable development.

3. Analysis produced essential oil

Essential oils are a mixture of different chemical compounds. Most they include compounds of carbon, hydrogen and oxygen, to a lesser extent compounds containing nitrogen and sulfur. Characteristic properties of essential oils, as well as their quality and price, to a large extent depend on their chemical composition.

Table 1 shows the results of analysis the chemical composition of immortelle (*Helichrysum italicum*) essential oil, produced in standard distiller and in a new technical solution of distiller. Analyses, carried out on a gas chromatograph (Institute of Medicinal Plants "Josif Pančić" Belgrade), shows that the key components, responsible for the quality of the essential oil, are more represent in the sample produced in a new technical solution of the distiller. Based on the organoleptic and physico-chemical properties, this essential oil can be classified into high quality oils, with pleasant smell and authentic natural geographic features. The results are encouraging us for further development of equipment and processes, seriously organize domestic production and marketing of essential oils on the world market.

<table>
<thead>
<tr>
<th>Table 1: The chemical composition of the immortelle essential oil</th>
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<tr>
<td>Composition</td>
</tr>
<tr>
<td>α-pinene</td>
</tr>
<tr>
<td>camphene</td>
</tr>
<tr>
<td>β-pinene</td>
</tr>
<tr>
<td>β-myrcene</td>
</tr>
<tr>
<td>α-phellandrene</td>
</tr>
<tr>
<td>α-terpinene</td>
</tr>
<tr>
<td>p-cymene</td>
</tr>
<tr>
<td>limonene</td>
</tr>
</tbody>
</table>
4. Conclusion

Production of medicinal and aromatic plants and essential oils from them on the territory of Bosnia and Herzegovina reaches a commercial level. Research in the field of training equipment for the production of essential oils are therefore justified. Reconstruction of the standard distiller has resulted in shorter duration of distillation and higher amount of essential oil. Due to a shorter treatment time and more balanced allocation of the vapor phase in the distiller, oil has crystal pure color and exceptional quality from the standpoint of scents and organoleptical properties. The consumption of energy are decreased, but also the amount of water necessary for the condensation vapor phase, due to the optimization of technical and technological characteristics of the condenser. Reconstruction has made a positive impact, in terms of essential oil quality, energy savings, but also in terms of preserving natural resources and protecting the environment.

By analyzing the chemical composition of the immortelle (*Helichrysum italicum*) essential oil, produced in standard distiller and in a new technical solution of distiller and condenser can be concluded that the key components responsible for the quality of essential oil more represent in the sample produced in a new technical solution of the distiller.

5. References