EXPERT SYSTEMS USED THROUGHOUT THE TRAINING OF MASTER ENGINEERS IN THE FIELD OF INDUSTRIAL ENGINEERING

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Abstract: *The article offers an approach for training of students from qualification degree 'Master' in the specialty of 'Industrial engineering'. It represents analyses of suitable expert systems which are used throughout the process of computer-based designing and diagnostics of mechanical products. We have created a scheme of an expert system for gear transmission designing as well as algorithms based on rules of production for the purpose of investigation of stress concentrators and change of the geometry of segments from a gear or a shaft. We have also rationalized the usage of appropriate methods for engineering analysis and the usage of software products for simulation modeling and investigation of designed objects' behavior through the use of a Frequency Analysis. The latter also includes searching for collisions that take place during the generation of the designed objects' assembled unit. The results are useful for the purpose of acquisition of skills and knowledge in the field of expert systems application; they would help in the process of searching for creative solutions within the stages of computer-based designing of technical objects, and in the process of diagnostics of their exploitation.*

Keywords: EXPERT SYSTEMS, PRODUCTION SYSTEM, TEACHING, MASTER DEGREE, INDUSTRIAL ENGINEERING

1. Introduction

The expert systems for monitoring and diagnostics have had widest application in industry but lately they have been also used in engineering, computer-based designing of technical objects [1.12]. The basic conditions about the expert systems are shown in [5]. The expert systems are based on artificial intellect and that's the reason why they have been widely studied through the training of engineers [8,9].

The Artificial Intellect, according to Bar and Feigenbaum, is a part of Informatics related to design of intellectual computer systems, as intelligence in human behavior and etc. The Artificial Intellect is *a* new field of human activity from traditional computer sciences. They represent a module from integrated systems for computer-based designing of technical objects as well as details, assembled mechanical units, etc.

In order to establish a base of knowledge and symbolic presentation, one has to use a specialized programming language which is based on rules of production of the 'condition-action' type or of the 'situation-action' type. According to Newel's and Simon's hypothesis [5], each of the physical, symbolic systems has ample, required means for universal, intelligent actions like Heuristic search for solutions. The Heuristic searching is related to specific knowledge and is used as a basis of a graph model.

The presentation which has been made gives us a ground point to consider that the reviewed issue is relevant within the process of training of the forthcoming master engineers who are to use computer-based designing, methods for diagnostics of constructive solutions, and methodology of the bone tissue diagnostic images processing [11].

The main tasks which are to be assigned are the following ones:

- a brief analysis of the training program and a rationale of specific application tasks for the purpose of training in a particular subject and acquisition of knowledge and practical skills within the field of engineering activity;

- application of expert systems for diagnostics of machines and facilities as well as an engineering analysis for searching of creative, constructional solutions.

2. Analysis of the program and rationalization of application tasks throughout the training in the field of expert systems

Expert systems is an optional subject for students from educational degree 'Master' from specialty 'Industrial Engineering'. The students must acquire knowledge and skills in the usage of expert systems within the process of engineering designing in a CAD environment as well as knowledge and skills in the process of searching for optimal versions of technical solutions throughout the development of constructional documentation. The training course of the subject reviews issues in relation to engineering informatics, structure of expert systems which are based on Artificial Intellect and algorithms created for the purpose of knowledge acquisition in the field of process management. The exercises in a laboratory environment are related to development of algorithms for the purpose of creation of expert systems structures, adaptive control models and management of objects and processes. They also develop knowledge and skills in work with applicable software products whose purpose is to search for creative, technical solutions throughout the designing of mechanical products and methods for diagnostics and improvement. In relation to everything mentioned above, we have reviewed the following issues:

- diagnostics and control of machines and facilities through the use of a vibration analysis;

- development of an expert system and rules of production;

- a frequency analysis of geometrical models through the use of resonance frequencies and their geometrical shape.

2.1 Reducer diagnostics according to a criterion of vibration

Mechanical drives are most frequently encountered in practice as they are represented of gearboxes, reducers, variable-ratio transformers, etc. as they contain bearing knots, couplings, gear transmissions and other units [4]. Fig.1 shows the main machines of a mechanically driven system and the spots in which the vibration in the bearing knots is measured since they are representative extract in the present research [1,7]. According to normative documents VDI 2056 and ISO 10816, the maximum of admissible vibration frequencies in the bearing knots must vary from 10 Hz to 1000 Hz.

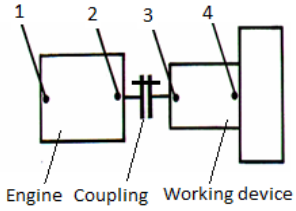

Fig. 1 *Measurement of the vibrations in the bearing knot*

Fig.2 shows the distribution of vibration frequency of a mechanically driving system which includes an electric motor and a reducer according to the type of breakdowns given by R. Jigulic's 'Theory of oscillation' inherent in this type of a mechanically driving system. It is possible that the following types of stresses could occur throughout the process of exploitation: pulsing stress and altering stress with asymmetrical and symmetrical cycles.

In order to perform diagnostics of elements of a reducer in accordance with a criterion of vibration presence, it is necessary to use a software product for treatment of experimental data as well as a reference record of the normal state of the reducer which corresponds to the condition of performance. An assessment is to be done regarding the vibrations, i.e. strong ones and weak ones [3].

On Fig.3 are shown some reference records which concern the spectrum of vibrations of a reducer.

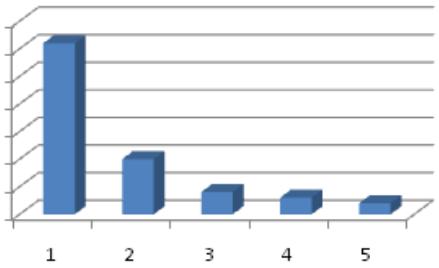

Fig.2 *Distribution of the frequency of vibrations*

1- Breakdowns in bearings, 2- Imbalance, 3- Axial incompatibility; 4- High temperature,5- Breakdowns in gears

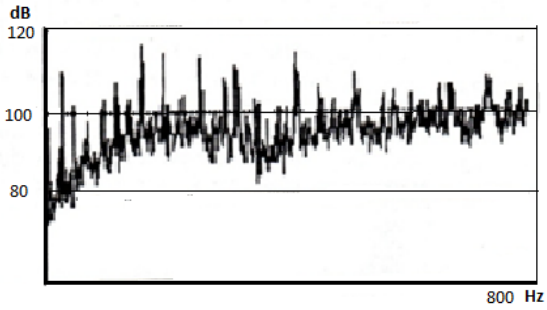

Fig.3 *Spectrum of vibrations of a reducer*

This methodology can be used for the purpose of establishment of decisions throughout the process of replacement of some machine elements. This is to be performed by preparation of a conclusion made by experts as the most rational way of achieving that is to obtain the conclusion from the system for data treatment. As a result, one can form a recommendation based on the obtained motives as one can have a basis for the decision. The application of this approach can be illustrated by an example of a bearing replacement which is shown on Table 1.

Table 1: *Results from diagnostics of bearing vibration test*

Conclusion
RECOMMENDATION: To change the bearing. **Reason:** Accumulation of amplitudes in specter of vibration. The diagnostic symptoms in specter of vibration. 73,06 Hz [59%]; 147.12 Hz [11%]; 218.48 Hz [36%]; 292.3 Hz [11%]; 367.2 Hz [18%].
Remark: >High level in harmonic component of specter; >Strongly harmonic component in region of filter.

Another example of decision establishment during replacement of a bearing can be performed according to a criterion of performance.

2.2 Establishment of a decision for bearing replacement according to the 'performance' criterion

After the completion of all necessary observations and analyses, we have established the following most frequent defects which cause bearing performance loss. These malfunctions can be assessed according to the following indexes: heating, noise, vibrations and durability, and the possible defects are shown on the Table 2.

Table 2: *Criteria for diagnostics and defects in bearing elements*

Index	***Possible defects***	***Degree***
Heating	Break surface, Lubrication	Badly, Strongly
Noise	Break separator, Break ring	Faint noise, Strong noise
Vibration	Deflection in bearings	Badly deflection, Strong deflection
Durability	Catalogue limit live in hours (L_h)	< or >

The complex assessment is to be prepared by the use of two phases of influence: weak and strong or low and high, i.e. in accordance with the durability of the bearing measured in hours time.

The same example can be observed throughout the process of bearing assembly designing in accordance with complex indexes: Durability - by choosing a proper bearing; Heating- by choosing a proper assembly and suitable lubricant; Noise and vibrations- by choosing a camping scheme and determination of the admissible deformations.

3. Application of Production systems.

Production rules are a formalism used in design of program languages before it was used in psychological modeling and in Expert systems. Some of most popular model from “production rules” include: Rules from kind “IF” and “THEN”; Different kinds of network; Logistic equations for coding of facts and principles [2].

In literature concerning expert systems sometimes they are called “condition-action” type of rules or “situation-action” type of rules. This is due to the fact that they are used in order to code empiric relations between models of data presented to the system and actions as the system must execute them as a consequence.

3.1 Solving of conflicts

The strategy of conflict solving is of particular importance for the work of production system and for this purpose must be chosen precisely. The mechanisms for conflicts solving varied but three of them are very popular and often are used in combination thus forming a global direction regime.

Unity. One rule cannot be used more than once for one and the same data.

Actuality. The elements in operational memory in OPS5 contain a field for time, thus it is known on the period of which cycle they are added to operational memory.

Specificity. The concrete elements, drawn from more specific rules, for example rules with greater number of condition, are more difficult to be satisfied and therefore are prefer before more general rules with smaller number of conditions.

Fig.4 shows a sketch of a composed expert system for computer-based designing of a gear transmission with the participation of a constructor and an expert in a dialogue mode. The

constructor has an opportunity to look for technical solutions for improvement of the construction. In most cases, these solutions concern concentrators of stresses. In such a case, the constructor has to make a decision about what to change by composing an algorithm for another geometrical shape or brand of the used material.

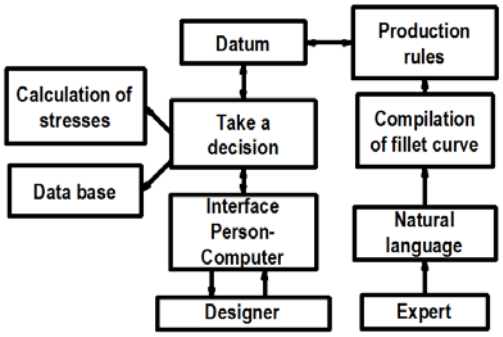

Fig.4 *Scheme of expert system for design*

This is illustrated by the following algorithm:

If: 1. The filet radius of curve is 0,5 mm;
2. The stress σ > 0,260E9.MPa
Then: To change the filet radius of 1,5 mm.
If: The stress σ > 0,200E9.MPa
Then: To chose Steel grade 41Cr4
If: The stress < 0,200E9.MPa.
Checking of stress is to be performed regularly by the use of the Method of the finite elements ANSYS. Fig.5 shows its corresponding example.

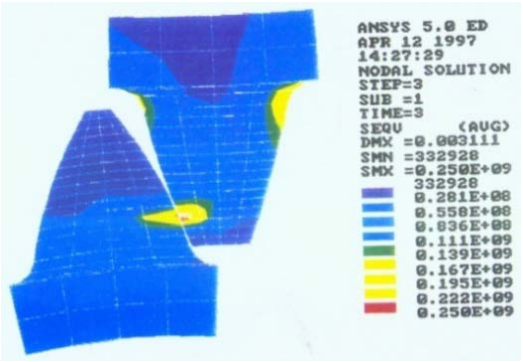

Fig.5 *Distribution of stresses in pinion and gear*

For investigation of stresses in fillet curves of shaft with Finite Element Methods by ANSYS the designer used 3D geometrical model of shaft and determined theoretical distribution of stresses in character points and surfaces concentrators. Next pictures shown graphical presentation of finally results (Fig.6 and Fig.7).

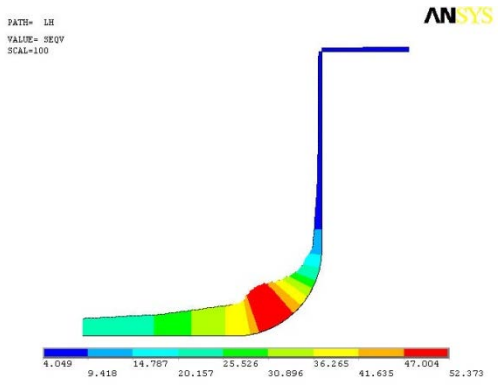

Fig.6 *Distribution of stresses in left fillet curve of shaft*

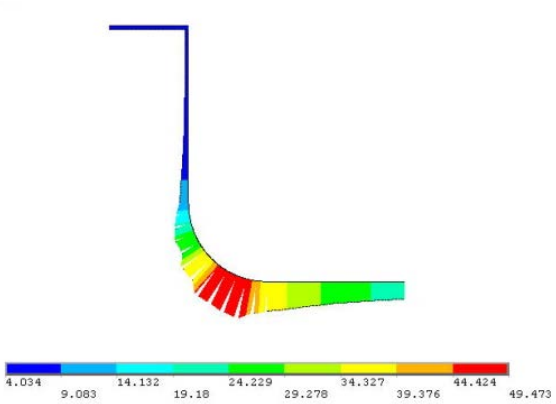

Fig.7 *Distribution of stresses on right fillet curve of shaft*

The results shown that maximum value for stresses are in left and right zone of fillet curve. This value are from *49 MPa to 53 MPa* in the both sides of shaft. The designer can to used the same algorithm.

3.2 Application of simulated modeling for the purpose of engineering analysis

Virtual analysis becomes more and more widely used throughout the process of computer-based designing of mechanical products and their manufacturing. The virtual initiative and development of products include their respective production, manufacture and marketing after their designing is completed. Hence it is advisable to utilize the capabilities of engineering analysis and simulated modeling of technical objects throughout the training in the field of Expert systems. This yields an opportunity for acquisition of better skills and knowledge in the search of creative solutions throughout the engineers' designing thesis works [10].

To this end, one has to use the following methods:

- an engineering analysis through the use of the finite elements method (FEM) which allows researching of the created 3D geometrical models for concentration of stresses [4]. Frequency analysis for the purpose of resonance frequencies verification as well as checking of their respective shape [6] :

- an engineering analysis in order to verify the turbulent streams through the designing of objects that work with fluids and consistent materials through the usage of the COSMOFLOW software product;

- usage of the Failure Mode and Effects Analysis (FMEA) in order to provide quality of products as means for decreasing of the number of errors during a system analysis. These methods also can reveal the causes for these errors;

- creation of geometric models for kinematic and simulation analysis for the purpose of assembling of the compound parts of assembled units which are planned for the purpose of searching of collisions performed by SolidWorks.

Fig.8 depicts the results from the simulated modeling and from the Frequency Analysis of computer-based investigation of the critical frequency of rotation of a shaft with a symmetrically placed disc, and investigation of the resilience deviation of the shaft. These results could be analyzed and compared to the results which are obtained from exercises performed through the use of a test machine which are frequently conducted through the training in the 'Basics of construction' subject.

The constructor has an opportunity to acquire skills working with Simulation Manager by Solid Works in order to perform frequency analyses of assembled units. The following results are obtained throughout the process of working:

- visual representation of given limitations, division of finite elements of geometrical models (fig.7), and a list of resonance frequencies;

- visual representation of the results obtained from the process of deformation at various resonance frequencies which is done via the use of a fundamental geometric shape (Fig.8).

Fig.9 represents a developed 3D geometrical model of a safety overflow valve which is composed during seminar exercises of the subject 'Basics of construction'. Two basic tasks can be resolved through the use of a simulation model: a mechanical task and a hydraulic task. The mechanical task is related to the axial shifting of the piston whereas the hydraulic task concerns the alteration of pressure and viscosity of the fluid. The distribution of pressures in the inner geometrical shape within the body of the safety overflow valve can be investigated by the use of computer-made simulations.

The useful applicability of the presented models appropriates important motivation to the students when they utilize relevant methods in order to find creative solutions throughout the process of computer-based designing of technical products. The students would be able to use informative materials that are necessary for practical task execution, forming of decisions which concern diagnostics and control of the exploitation reliability of industrial machines and facilities.

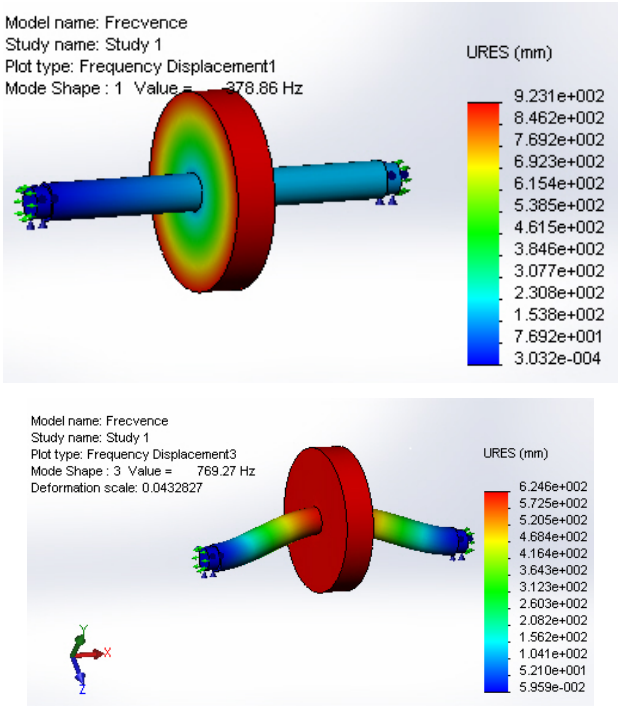

Fig.8 *3D simulation model of a rotating shaft*

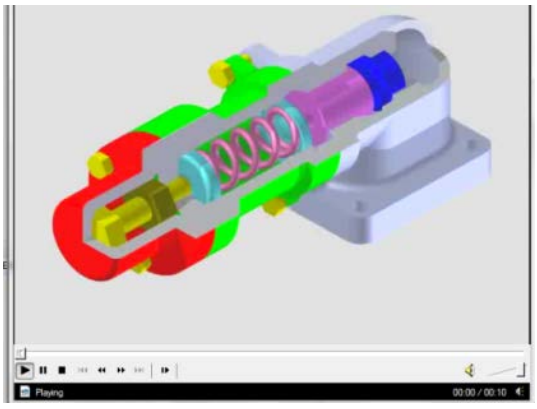

Fig.9 *3D simulation model of safety overflow valve*

4.Conclusion

Contextual issues related to the training of students studying in the field of qualification degree of 'Master engineer' have been structured in accordance with the already developed curriculum. Specific practice tasks have been assigned as they concern vibration analysis in bearing knots which refer directly to malfunctions and diagnostics of reducers according to criteria of vibration. The excessive clearance in a rolling bearing can cause generation of discrete harmonics frequences.The typical failures are the following ones: defects on the inner and outer rings, defects of the balls, and, finally, defects in the separator.

A sketch of an expert system has been made as it could be used for the purpose of designing of a gear transmission and algorithms that are based on rules of production which concern investigation of concentrators of stresses and changes of the geometry of elements in a gear or in a shaft.

We have also rationalized the usage of methods for engineering analysis; software products for simulated modeling; investigation of the behavior of designed objects via the Frequency Analysis as well as the process of searching for collisions during the generation of an assembled unit.

The results are useful for the purpose of acquisition of skills and knowledge throughout the application of expert systems as well as for the purpose of development of creative solutions through the stages of computer-based designing of technical objects and the diagnostics of their exploitation.

5.References

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