SYNTHESIS AND DESIGN OF HYPERBOLOID GEAR DRIVES: METHODOLOGY AND ASPECTS

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Abstract: *The high current requirements for the characteristics determining the accuracy, reliability and efficient manufacturing of modern machines, apparatus and devices applicable in various fields of industry and transport in a big extend dictate the applied scientific methodology to the technological synthesis, design and production of gears. In the processes of synthesis and design of the different types of gear transmissions, the designer faces an extremely complex set of questions to solve, which together define the desired optimal construction. In this case, an optimal design means a gear transmission that is capable of delivering preliminary defined kinematic and / or strength requirements at minimum design, production and operation costs (including the repair costs during their exploitation).*

This work presents a review of the methodology, developed by the authors, oriented towards the synthesis and design of spatial gear mechanisms (hyperboloid gear drives), realizing rotations transformation between crossed shafts. The main principles, on which the construction of adequate software programs are based for the synthesis of treated transmissions, are presented.

Keywords: HYPERBOLOID GEAR DRIVES, SPIROID AND HELICON GEARS, SYNTHESIS, DESIGN, MATHEMATICAL MODEL, COMPUTER PROGRAMS

1. Introduction

The high current requirements to the accuracy and reliability characteristics of the machines, apparatus and devices applicable in industry and transport in a big extend dictate the applied scientific methodology to the technological synthesis, design and manufacture of gear drives. In the processes of synthesis and design of the various types of gear transmissions, the designer faces an extremely complex set of questions to solve, which together define the desired optimal construction. In this case, an optimal design means a gear transmission that is capable of delivering the preliminary defined kinematic and / or strength requirements at minimum design, production and operation costs (including the repair costs during their exploitation. By its essence, the systems of requirements for different quality characteristics of the gear drives, ensuring its optimality, are [1]:

- ***geometric ones***, which control the kinematic exactness, smoothness of the work process, the character of the contact (the placement of the contact point, an orientation of the contact lines in the contact points) in the relation of the gear drives' loading capacity and etc.;
- ***dynamics*** ones, that influences the noise and vibrations in the gear systems, the conditions for occurring the resonance phenomena and etc.;
- ***strength ones***, determining durability and reliability of gear drives, including the transfer of nominal power in the process of rotations transformation with avoidance of "scratching" (scoring) , "pitting" and etc. on the active tooth surfaces of the synthesized mechanism;
- ***economic ones,*** defining the production costs (e.g., per unit of power), energy loss in motions transformation (coefficient of efficiency) and etc.

Considering the wide variety of requirements to the quality characteristics of the gear drives, in connection with the actual existing technological, manufacturing and economical price limitations, it is obvious that the solution of a real task of creating an optimal gear design is realized with some approximation with respect to the theoretical variant. The realization of this only possible approach to creating real gear drives requires it to be complex one, which should be foreseen in the processes of synthesis and design of the gear systems.

2. Aspects of Computer Design

The wide variety of gear mechanisms used in industry and transport, as well as the permanent pursuit of researchers to create new and improved gears drives on one hand and on the other- the different and changing approaches to the mathematical modeling for synthesis and design, make it difficult to realize universal CAD systems. In connection to all said above, it specially should be noted the note the extremely dynamic development of modern technical computing tools and software programs. This often requires a reassessment not only of the way in which computer programs are organized, but also leads to informal changes of applied mathematical models [2]. In order to realize these researches into the field of theory gearing, as well as to provide an adequate scientific support for this type of production, the computer design has evolved, forming three types of software:

First type. The programs, included here, are designed to study the mutual influence between various kinematic, structural, technological and exploitation parameters of the studied gear drives. Essentially, this type of software is not subordinate to a particular strategy associated with the construction of CAD systems. The elaborated mathematical models, algorithms and computer programs are designed to determine the influence of one or other real-life existing parameters on the qualitative characteristics of the concrete gearings. However, the programs created in this case can be used as software modules, which are elements of system of criteria for the quality control of the synthesized gear drives.

Second type. This group includes computer programs organized on the basis of algorithms, contained in standardization documents [3], company methodologies [4] or handbooks (guides) [5-8]. Here, it should be included, the program products, elaborated on the basis of algorithms for geometric and strength calculation of the traditional types of gear drives: cylindrical involute with external and internal mating gears, cylindrical worm gears, bevel gears with straight teeth and so on. It should be noted, in particular, that the algorithms used in the prevailing number of cases do not ensure the optimization in the synthesis and design of gear transmissions. For example, the known algorithms for the synthesis of cylindrical involute, conic and worm gears [6] are able to provide only the technological and instrumental requirements for their manufacture, in terms of standardized determined modules (ptiches) and in terms of the occurrence of undercutting on the tooth surfaces under instrumental gearing or interference - in work gearing. Secondly, this category of software products it can also be included those, through which the strength characteristics of the already geometrically and technologically synthesized gear drives [3] are examined. As such, these computer programs can be treated as tools for analysis of the gear mechanisms.

Third type. Included in this category of computer program products are those based on mathematical models, developed on the basis of the specially oriented scientific studies. For example, for Bulgaria, these are the computer programs that covers the synthesis and design of Spiroid and Helicon gear sets (Spiroid and Helicon are registered trade mark of Illinois Tool Works, Chicago, Illinois) [1, 9, 11], and with conic and hypoid gear mechanism – type Gleason [5, 12, 13]; and others. For the contemporary gear transmissions, including even classical gear mechanisms, treated in terms of current engineering requirements, the elaboration of new mathematical approaches to their geometric, technological and strength synthesis is required. The process of optimization synthesis, in this case, is realized by applying the ***method of direct search***. This method provides an opportunity to reduce the number of calculated gear pairs, which compose the synthesized gear mechanism. It will be reminded, that the essence of this method is as follows:

- input parameters are defined, as well as those that will not be changed throughout the whole synthesis process;
- the variables parameters are determined as well the way of their variation, respectively;
- the process of variating the defined variable input parameters compared to their initially given value continues, until the preliminary defined optimization criteria are fulfilled;
- from the calculated pairs of conjugated gear sets, a final variant is chosen for which, there is the best fulfillment of the additional conditions (restrictions) introduced in the mathematical model.

In other words, the process of optimization synthesis and design of the third type of software is based on adequate iterative procedures, by which the desired solution is found by variation of certain parameters.

3. Computer Programs: Principles and Methodology

The computer programs designed for the synthesis and design of linear contacting hyperboloid gear mechanisms belong to the third type software. Considering, the known methodological limitations [14], the following sequence is kept when constructing this type software, for elaboration of the system for the computer design of hyperboloid gears with linear contacting tooth surfaces.

3.1. Basic Principles and Approaches of the Mathematical Modeling for Synthesis and Design

When profiling the kinematically conjugated surfaces, by means of which the rotations transformation between crossed axes is realized, the basic observed principles are the principles of T. Olivier [1]. Here, it will be summarized only that part of them, which is directly related to the construction of the concrete computer programs.

When generating the tooth surfaces Σ_1 and Σ_2, firmly connected with the bodies B_1 and B_2, through the generating (instrumental) surface Σ_J, firmly connected with the body B_J, the mentioned bodies B_1, B_2 and B_J realize rotations motion with different vectors of rotation. In this case, relative motions are characterized by velocity ratios $i_{12} = \omega_1 / \omega_2$, $i_{iJ} = \omega_i / \omega_J$ $(i = 1,\ 2)$. If the surfaces Σ_2 (or Σ_1) are respectively a one-parameter envelope of the instrumental surface Σ_J, when the conditions $\Sigma_J \equiv \Sigma_1$ ($\Sigma_J \equiv \Sigma_2$, respectively), $B_J \equiv B_1$ ($B_J \equiv \Sigma_2$, respectively) and $i_{12} = i_{J2}$ ($i_{12} = i_{1J}$, respectively) it is said that the tooth surfaces are generated in accordance with the second principle of T. Olivier. In this case, Σ_1 and Σ_2 have always a linear contact.

In [1, 14-17], are formulated two approaches (applied by the authors) to the elaboration of mathematical models for the synthesis: mathematical modeling, which defines and optimizes the geometric, technological and exploitation characteristics of the design gear drives in a small vicinity of the *pitch contact point* and a mathematical modeling related to the ensuring of the quality characteristics in the whole *region of mesh*.

In connection with all said, it is obvious that the methodological difference between the two approaches for the synthesis of spatial gear drives requires to define in advance the adaptability of the future designed hyperboloid gear drive to one of the two mentioned approaches. The determination of the adaptability of the planned procedure for creating of an adequate mechano-mathematical model is a complex creative process, requiring the knowledge of both the theoretical content of the approaches to the synthesis and the specific technological and exploitation requirements characterizing the created transmissions.

3.2. Principles of Organizing g the Design Process

The following principles are obvious and have been commented by various authors [1, 2, 9, 12-15]. Here, the focus will be put on those which are determining for the construction of the computer programs for synthesis of gears type Spiroid and Helicon.

Determination of the groups of independent and variable input parameters. To the group of independent input parameters a set of standardization modules should be included, that determines the technological capabilities of the hobbing machines; coefficients that define the tooth geometry as a function of the modules; coefficients of frictions between the different pairs of materials applicable for producing of the toothing of the conjugated gear pairs; coefficients, linear and angular values associated with the design of the instrumental equipment and etc.

To the input data parameters, among which the variable ones are chosen, as a rule are included those which define the overall geometry of the calculated gear system. Here belongs the parameters determining the dimensions of the gear structure: the offset, distances from the offset to the planes in which the pitch circles lie; the angles defining the orientation of the above said planes relative to the pitch normal and etc. The variable input data include also those, from which the geometry of the conjugated active tooth surfaces depends: the independent coordinates of the tooth surfaces; their helical parameters; parameters which determine face width of the teeth, etc.

Introducing the main analytical relations, which are based on the chosen approach to the mechano-mathematical modelling.

Here are included solutions of the fundamental tasks of the synthesis upon a pitch contact point and upon a mesh region with the application of the adequate geometric interpretations of the basic equation of meshing, namely [1, 14-17]: the task for the synthesis of pitch circles; the task for the defining the geometry of the active tooth surfaces by their linear and angular characteristics in the pitch contact point; the task for defining the singularity in the pitch contact point (without describing the analytical type of the tooth surfaces); the task for analytically defining of the entire mesh region; formulations of relations, which are used to determine the optimal dimensions and placement of the region of mesh on the active surface and etc.

This principle of organizing the computer design includes also the introduction of geometric and kinematic relations, intended for the reduction of the input parameter sets.

Constructing the complex process for synthesis and design of hyperboloid gear drives. This is realized by defining the separate sub-stages of the synthesis and design in their sequence and interconnection. This principle, applied in the design of each computer program, is directly dependent on the type of functioning, in the elaborated algorithm, complex of criteria. Those criteria determine the preliminary defined quality characteristics of the gear mechanism in dependence of the accepted approach to the mathematical modelling. A distinctive characteristic of the accepted principle for construction of the complex process for synthesis and design is the chosen approach for the estimation of the calculated option of gear drive.

4. Programs for Synthesis of Spiroid and Helicon Gear Drives

The shown considerations for designing of software programs, applicable to the synthesis of hyperboloid mechanisms are also realized in connection with constructing three types' software products for the design of Spiroid gears, which functional relations are shown in Fig. 1 [1]. Each one of the illustrated three main directions, has its own importance. It means that the user can restrict himself to use the results of only one program; to analyze and interpret these results and then after an adequate assessment, to go through the entire process shown in the figure.

Further below, each of the directions, that includes the whole process of synthesis and design of Spiroid gears, will be considered.

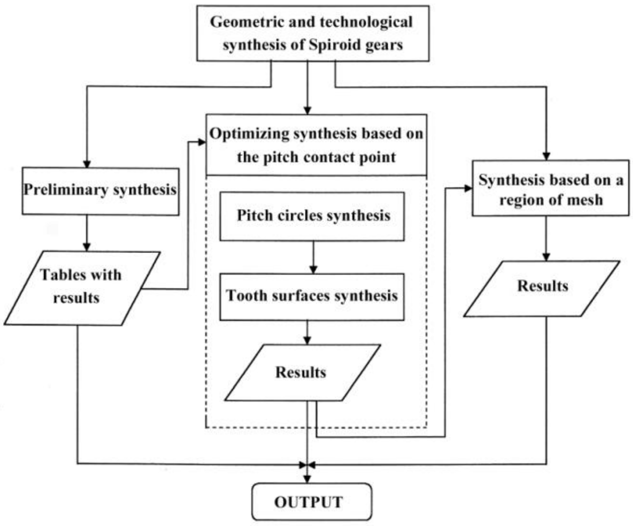

Fig. 1 *General block-scheme of the approaches for the synthesis of Spiroid gears*

4.1. A Software Program for a Preliminary Synthesis

The aim of the preliminary synthesis is to be calculated the main geometric parameters of the special case of Spiroid gear, when the angle, at which the rotations axes are crossed, is 90^o, and pinion is of cylindrical form. With other words, the preliminary synthesis of the Spiroid gears is essentially oriented to the geometric dimensioning (without an optimization) of hyperboloid drive of type Helicon [11, 18].

The mathematical model upon a pitch contact point is in the basis of the program for a preliminary synthesis. It is assumed that this point is placed on the outside cylinder of the Helicon pinion [19].

The input data of the computer program are: gear (velocity) ratio u ; offset a_w ; z_1 - number of teeth of the pinion depending on the degree of accuracy and the conjugation type of the tooth surfaces; a standard pinion tooth deflection (thinning) - Δb ; set of standard axle modules; coefficients and etc. In the commented program, the possibility of defining the following geometric-technological requirements is taken into consideration when choosing the outer diameter d_{a2} of the gear:

a) in the case of the double bearing of the pinion, when one support is located in the field of the offset (in this case the synthesized gear drive is characterized by smaller sliding velocities [18]);
b) to ensure the possibility of generating the gear sets, over a wide range of external diameter d_{a2} variations, and with the use of hobbing machines.

The program works for velocity (gear) ratios of up to 100 and offset not exceeding 250 mm. The only optimization ensured by this program is related to the selection of a standard axle module of the Helicon pinion (the calculated axle module has to belong to the set of standard input modules).

The data for u , z_1 , a_w , Δb and one of the mentioned geometric-technological conditions is input by the designer at the start of each computational procedure.

Thus, only by inputting the above mentioned input data by the designer, the program calculates and chooses the values of the standard axle module, outer and inner diameters of the pinion and the crown (gear), the width of the toothing of the gear and the length of the generated part of the pinion, the minimum mounting distance of the pinion and etc. The program enables a technological check of the values of the big profile angle of the teeth (corresponding to low-side driving) as well as for obtaining variations of the gear drive for the minimum and maximum possible values of the number of the teeth of the gear (crown).

The organization of the program for a preliminary synthesis is illustrated on Fig. 2 [1].

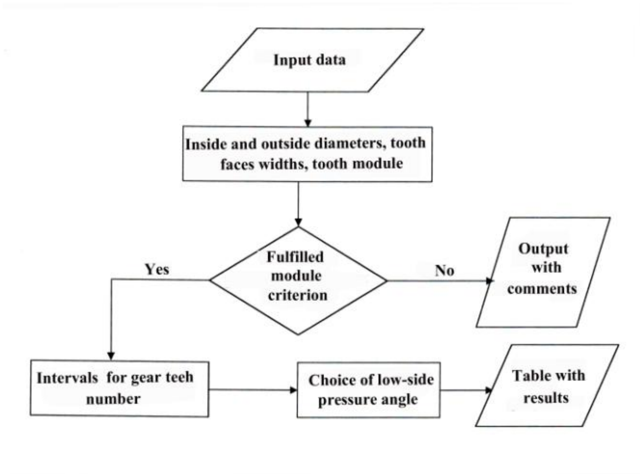

Fig. 2. Scheme of preliminary synthesis program

4.2 Program for Optimization Geometric and Technological Synthesis of Spiroid Gears upon a Pitch Contact Point

This program includes solving of the following tasks [1]:

- Synthesis of geometric pitch circles.
- Synthesis of the active tooth surfaces of the Spiroid pinion and of the cutting tool for generation of the Spiroid crown (Spiroid hob);
- Verification if that the accepted quality criteria of the gear drive are fulfilled.

From the formulation of the defined tasks, it can be seen that the algorithm of this program corresponds to the approach to mathematical modeling for synthesis upon a pitch contact point [1, 14-17]. In this sense, when designing the Spiroid gears, it is of particular importance to select the location of the pitch contact point in the fixed space. The placement of the pitch contact point (as a common point of the pitch circles and conjugated active tooth surfaces) affects on one hand on the common geometry of the designed gear system (overall dimensions of the gear pair) and on the other- on the geometry and proportions of the gears' teeth, as well as on the gears' quality (through the geometric, kinematic and strength characteristics of the conjugated gear pair).

For the purposes of this study, here will be briefly outlined some of the information contained in [1, 14-17], dealing with the geometric nature of the externally contacting geometric pitch circles.

The pair of the pitch circles $(H_1^c : H_2^c)$ from the mentioned type are circles H_i^c $(i = 1,\ 2)$, having only one contact point P. Their centers are places on the axes of rotations $i-i$ $(i = 1,\ 2)$ of the movable links, and the corresponding circles are perpendicular to those axes. Mutual placement of the crossed axes is uniquely determined by the angle $\delta = constant$ between the skewed axes and by the length of their axis –the offset (center distance) $a_w = constant$. The position of the geometric circles H_i^c $(i = 1,\ 2)$ in respect with the rotations axes $i-i$ $(i = 1,\ 2)$ and with their offset line is defined by four parameters for each circle. The condition for the two circles to have a common contact point is expressed by five independent scalar equations. Hence, the mutual position of two circles is not defined in a unique way. It is a function of 5 independent parameters. The synthesis of geometric pitch circles is preceded by the decision, which five of the eight parameters (for both circles) to be chosen for independent ones and how to choose the intervals for their variation.

For this specific case, these five independent parameters are chosen as: an angle δ between the axes of rotations $i-i$ $(i = 1,\ 2)$; the offset a_w; the angle δ_1, which is concluded between H_1^c and the pitch normal $m-m$ (half of the angle at the top of the pitch cone H_1^s of the Spiroid pinion); radius r_1 of H_1^c and the distance a_1 between the offset line of the gear drive and the plane in which H_1^c lies.

The ambiguity of the solution enables the possibility these free parameters to be discreetly changed within certain limits and among many pairs of geometric pitch circles to search for those ones, which parameters ensure that the preliminary defined requirements for the quality of the synthesized gear drives in the vicinity of the pitch contact point are satisfied. The criteria used in the program will be discussed further below.

The program allows choosing the type of conic linear helicoid, applied as active tooth surfaces of the Spiroid pinion: convolute, Archimedean or involute ones. The calculation of the necessary and sufficient geometric and technological parameters for the design of the Spiroid gear pair and cutting instruments are realized for the required type of conic helicoid.

The indicators, which serve to control the quality of the gearing, are essential for the design process. As it has already be mentioned, the dependence on the solution of the task for the synthesis of the pitch circles from concrete free parameters, should be searched among the optimal geometric, kinematic and technological quality characteristics in the vicinity of the pitch contact point. They will be briefly explained.

Basic technological criterion. This is the main criterion related to the technology of elaboration of Spiroid gears. It is related to the reduction of the nomenclature of cutting tools by ensuring the conditions for the design of Spiroid hobs with standard modules (hob parameters are functions of this module). This causes the requirement that the calculated in the pitch contact point module to coincide (with a given exactness) with any of the modules contained in the input set of standard modules.

Criterion controlling the singularity in the pitch contact point. The constructed criterion is analytically described in [1]. The ensuring of the implementation of this criterion helps to reduce the ordinary nodes from the mesh region of the synthesized gear drive. Hence, it leads to the improvement of its loading capacity, of the efficiency and of the durability. It will be reminded, that the elimination of the singularity of first order, by this criterion, is guaranteed in vicinity of the pitch contact point. The optimization, when using this criterion, is realized by the verification of the analytical dependencies introduced for each of the selected combination of the five independent variables.

Criterion for controlling the transmission angle of the normal force (pressure angle). This criterion provides optimization of gear drive in terms of the transmission of the normal forces from the pinion to the big gear (crown), when the gear mechanism is operated under the conditions of the rotations transformation at low-side driving.

Criterion for controlling the value of the Spiroid pinion spiral angle. By this criterion is carried out the control of the value of the angle in the pitch contact point. Its values have to belong to definite intervals in accordance to the purpose of the designed gear drive.

Here, it should specially be noted, as it is shown in [6], that the choice of the appropriate values for the pressure angle and the Spiroid pinion spiral angle of the longitudinal line of the active tooth surface $\Sigma_1^{(1)}$ in the pitch contact point substantially affect the efficiency of the gear drives. Therefore, by appropriately selecting of the geometric characteristics of the tooth surfaces of the Spiroid pinion, an indirect control of the gear drives' efficiency is achieved. It also should be mentioned, that from the calculated equivalent variants of the synthesized gear mechanisms, from a geometric and technological view point, the program allows to select that one which has the highest value of the coefficient of efficiency for the computational (pitch) contact point.

Criterion related to the durability of the gear drive. It controls the magnitude of the sliding speed at the computational contact point, depending on the chosen material for the toothing of the Spiroid gear - different types of bronze.

Criterion controlling the hydrodynamic conditions of meshing. This optimization aims the accomplishment of the following condtions: the synthesized gear drive has to obtain a maximum as a value of the summed circumferential velocity $|\overline{V}_\Sigma|$ in the pitch contact point and a minimum value of the angle Ω, which $\overline{V}_\Sigma$ concludes with the normal to the contact line in the pitch contact point.

Technological criteria for hobbing. These criteria are related to the choice of the minimum value of the axial (normal) profile angle of the Spiroid hob, in order to provide optimal conditions for hobbing, both in terms of cutting the metal and in relation to the strength characteristics of the cutting elements of the hob and etc.

In number of design cases, some of the initially defined independent parameters could be fixed due to the specific requirements (or example because of requirements for the maximum sizes of the gear drives and the mutual position of the shafts of the gears), which results in reduction of the number of independent variables without limitation to search and find an optimal geometry of the tooth surfaces.

Input parameters of the software program: number of the Spiroid pinion' threads and number of Spiroid gears' spiral teeth; offset; standard pressure angle; type of the conical helicoids (type of the tooth surfaces of the Spiroid pinion); type of the bearing of the gear shafts (on two bearing supports or on a console); frequency of revolution and etc. Keys parameters will take values of 1 or 0 depending on whether a given criterion will be taken in consideration for the synthesis or not. For each of the free parameters, the minimum and maximum values as well as the pitches of variation, are chosen. The independent variation cycles in the computer program are equal to the number of the free parameters.

On Fig. 3 the main block-scheme of the commented above program can be seen. The table of the results consists of: the basic geometric parameters of the Spiroid pinion and of the Spiroid gear, the design parameters of the Spiroid hob, geometric and constructive parameters of the three-link spatial gear mechanism, parameters related to the quality of meshing at the pitch contact point, such as coefficient of the efficiency of the gear drive, forces acting in the pitch contact point (pole of meshing); loading of the bearing supports, etc.

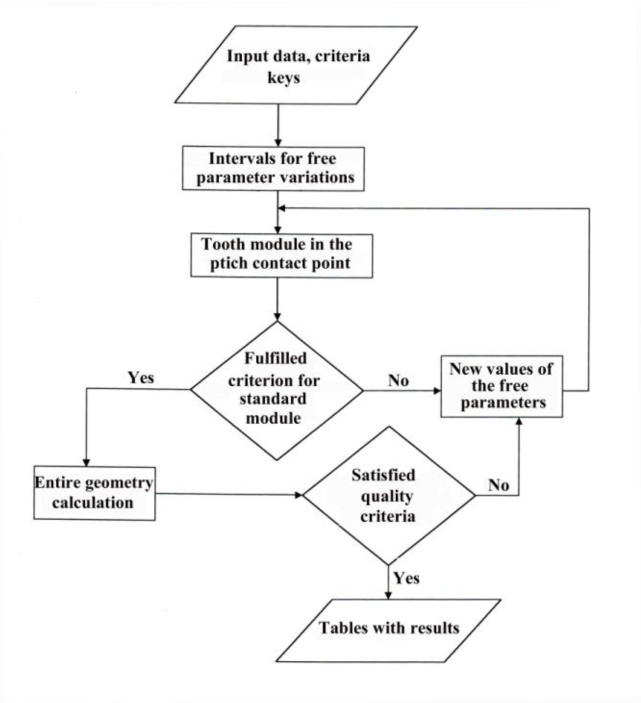

Fig. 3 *Program scheme for an optimization synthesis of a Spiroid gear pair*

It should be mentioned that, when the bearing supports are calculated, the distances between them and the pitch circles in real dimensions *mm* or dimensionless - as the ratio of the distances to the diameter of the pitch circle of the Spiroid gear are given. In the program, all forces, that act in the pitch contact point and at the bearing supports are dimensionless in relation to the peripheral force, acting on the Spiroid gear. If in the input of the program, the torque on the gear shaft or a torque on the pinion shaft is given, then this peripheral force has a concrete value and all forces and loads are calculated in [*N*]. Analogically, the sliding velocity is calculated as the ratio with the magnitude of the Spiroid pinion' angular velocity. If in the input, the numbers of pinion' revolutions per minute are given, then the sliding velocity is obtained in [m/s].

4.3. A Computer Program for Synthesis upon a Mesh Region

This program for synthesis of Spiroid gear, based on the commented in [1] mathematical model, represents a logical final stage of the organized complex process of the synthesis for this class high-reduction spatial gear mechanisms. This approach is applied in the following two cases:

When synthesizing a gear drive for which elaboration it has to be used the existing instrumental equipment (in particular an existing Spiroid (Helicon) hob).

In this case, in the designing of the gear drive, it is not possible to define an optimally positioned pitch contact point. In a number of cases, the existing instrumental equipment is suitable for generating the gear mechanism, for which it is not possible to define a pitch contact point in the mesh region. In this case, the constructively defined region of mesh is tested for the singularity of first and second order. In case, when the constructively defined gear drive contains an unacceptable amount of undercutting points and ordinary nodes, a change of the location of the mesh region in the fixed space is used.

When types of Spiroid (Helicon) reductor are synthesized. The type reductors represents a family of products, which are elaborated on the basis of the same: corpus details; gear blanks; purchased groups of assembled details and parts. A rational and applied approach by the authors of this research is as follows:

At the beginning a basic model is designed, the synthesis of which is realized by using the computer program for synthesis upon a pitch contact point. The rest of the elements of the family of the created type are designed, by using adequate analytical dependencies [1], that ensure design of gear drives, so the ordinary nodes (contact points) are completely eliminated from their mesh region. Thus, the selected types of gear set, together with the base gear drives, are tested for the presence of singularity of second order in the whole region of mesh.

Through the created software program for the synthesis upon a mesh region, the entire region of mesh is checked in order to determine the type and amount of singularity. For the discrete variation of the meshing parameter φ_1 (an angle of rotation of the Spiroid pinion), the contact lines on the active tooth surfaces $\Sigma_1^{(j)}$ of the pinion are are defined as a function of one of their curvilinear coordinates $u^{(j)}$, $\vartheta^{(j)}$. The parameter φ_1 varies in the interval $k\pi$, as the real number k depends on the geometric-kinematic characteristics of the synthesized gear drive, as well as form the foals of the study. The curvilinear coordinate $\vartheta^{(j)}$ varies in an interval, which depends on the length of the generated part of the pinion - L_1 and its axial module m, i.e. $\vartheta^{(j)} \in \left[-L_1/m, +L_1/m\right]$. The interval is divided by the number of points chosen by the designer. For each of these values, it is firstly checked whether the curvilinear coordinates belong to the mesh region, and then checking if that these curvilinear coordinates satisfy the analytical dependencies that indicate the presence of ordinary nodes and undercutting points. The finding is noted with the relevant text in the software program.

The input date in the program are [1]: number of teeth of the Spiroid pinion z_1, number of teeth of the Spiroid crown z_2, offset a_w, a distance from the offset line to the origin of the coordinate system $S_p(O_p, x_p, y_p, z_p)$, in which the equations of conic linear helicoids, profile angle, the length of the generated part of the Spiroid pinion, the module of the tooth surfaces are written. These data can be obtained from the synthesis of the base model upon a pitch contact point. In this case after the check with the program for synthesis upon a mesh region, the base gear drive is synthesized upon the so-called ***combined approach.*** The input of the program can be set from the constructive considerations, depending on the available instrumental and technological equipment. In this case, the synthesis upon mesh region is transformed into evaluating of the constructively chosen parameters.

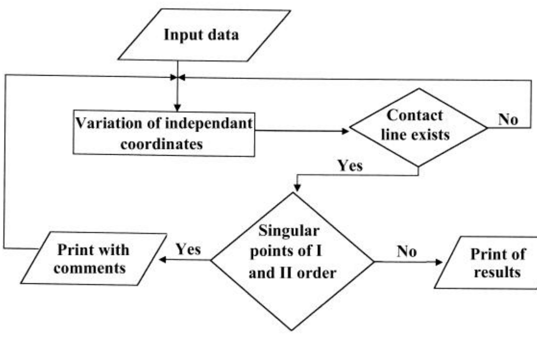

Fig. 4. Computer program for synthesis upon mesh region

The computer program is organized upon following Fig. 4 [1]. In the appendices to the publication [14], exemplary calculation results are presented from the execution of the computer programs for synthesis of Spiroid gear sets.

5. Conclusion

The current work presents an adequate review of the created methodology and the approaches to the synthesis and design of hyperboloid gear mechanisms with face mated gears. It is an actualized and added presentation of the illustrated in [20] strategy for synthesis of gear drives with crossed axes.

The main features of its content are as follows:

- A classification of the types of specialized software applicable in the analysis, synthesis and calculation of gear drives is realized.
- The principles, applied by the authors, for organization of the process of the synthesis and design of hyperboloid gear mechanisms, are briefly defined (described).
- The essence of the elaborated computer programs for preliminary synthesis, optimization synthesis upon a pitch contact point and upon a region of mesh, applicable in the design of Spiroid and Helicon gears, are summarized.

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