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(54) **Eljárás fogasgyűrű készülék belső és külső gyűrűjén lévő fogak alakjainak létrehozására, valamint az így létrehozott fogasgyűrű**

Az európai szabadalom ellen, megadásának az Európai Szabadalmi Közlönyben való meghirdetésétől számított kilenc hónapon belül, felszólalást lehet benyújtani az Európai Szabadalmi Hivatalnál. (Európai Szabadalmi Egyezmény 99. cikk(1))

A fordítást a szabadalmas az 1995. évi XXXIII. törvény 84/H. §-a szerint nyújtotta be. A fordítás tartalmi helyességét a Szellemi Tulajdon Nemzeti Hivatala nem vizsgálta.

DESCRIPTION

[0001] The present invention concerns a method for the generation of the tooth shapes of both the inner ring and also the outer ring of an annular gear machine (also designated as a gerotor), in particular of an annular gear pump. The invention moreover concerns an annular gear of an annular gear machine, which has such toothing.

[0002] Annular gear machines (gerotor machines) possess an inner ring and an outer ring, each of which is provided with teeth and spaces between teeth regularly distributed around the periphery. The rotation axes of the inner ring and the outer ring are eccentrically displaced relative to one another. The inner ring usually possesses exactly one tooth less than the spaces between teeth provided on the internal toothing of the outer ring. Today annular gear machines are often used as annular gear pumps, for example in vehicles, as the main pump for the internal combustion engine. The displacement volume formed by the spaces between teeth and housing walls alters with the rotation of the gears, thereby effecting the delivery of the hydraulic fluid. Here the volume delivered per revolution is constant. The teeth of the externally toothed inner ring are thereby usually formed in accordance with various formation rules for the rolling behaviour of the outer ring. Such a formation rule of known art is, for example, the movement of the generating contour in accordance with the laws of cycloidal rolling curves on an established pitch circle.

[0003] The geometries selected have a significant influence on the delivery characteristics, efficiency, smooth running, and wear of an annular gear machine. In the design process the tooth shapes, the eccentricity of the rotation axes of the two annular gears, and the clearance remaining between individual tooth sections can, in particular, be configured without any direct dependence on the external conditions that are prescribed by the connected drive unit.

[0004] From US 3,709,055 tooth profiles for gears are of known art that have circular tip profiles and circular root profiles, which are connected with one another via straight flanks. From this patent specification a method is also of known art for the generation of such tooth profiles, which can, for example, be used in annular gear machines. Using the method that is recommended there, however, it is not possible to achieve a significant objective of an annular gear machine, or at best in a very limited manner, namely that of forming a geometrically closed delivery cell at all times in the movement pattern between the two annular gears. The latter is of particular importance for the efficiency of the annular gear pump and the pressures that can be achieved.

[0005] Likewise annular gear machines and options for determination of the tooth geometry are described in US 2,960,884. The tooth generation method specified is primarily suitable for achieving a movement pattern similar to that of an involute between functionally coupled tooth geometries. The above-cited main objective of an annular gear machine, namely maintenance of the sealed nature of the delivery cell over the whole angle of rotation, can only be achieved to a limited extent using this method.

[0006] In JP 10-205458 A a method is specified for the determination of the tooth geometry of an annular gear pump. For this purpose the tooth of an outer ring is described in terms of coupled circular arcs, as a result of which the inner ring toothing can be generated. The definition of particular geometries of the toothings with undercuts or, for example, for purposes of reducing the Hertzian pressure, is not possible, as a result of the limitation to the description of the tooth shape in terms of a defined number of circular arcs, or is only possible to a very limited extent.

[0007] From EP 1 340 913 B1 and DE 102 08 408 A1 an annular gear machine is of known art that finds application as an annular gear pump. Here the primary objective is that of optimising the geometry of the gears so as to reduce the noise when the pump is in operation. To this end the tooth tips and tooth roots that are used possess geometries that are described in terms of curves of a second or higher order, wherein the tooth roots or the flanks of the tooth roots are formed from circular arcs. For the determination of the profile contours of the toothings it is proposed that the internal toothing of the outer rotor is specified as the master toothing. The tooth root profile contour of the inner rotor is kinematically derived from the tooth tip profile contour of the internal toothing in accordance with the toothing law, while the tooth tip profile contour is obtained from the envelope sections of the tooth root profile contour of the internal toothing. The grid points of the polygonal lines representing the tooth roots of the external toothing are determined using the toothing law, while the grid points of the spline functions representing the tooth tips of the external toothing are determined using an envelope section method. Studies have, however, shown that the tooth shapes that can be generated in this manner lead to limitations with regard to efficiency and flow conditions in the annular gear machine. Likewise the inflexible definition of the root fillet has a disadvantageous consequence, which acts, for example, so as to limit the formation of a dirt accommodation chamber.

[0008] US 5,030,072 shows a method for the development of the tooth shape of an annular gear machine, in which a radial lobe spacing is firstly established, in order to then modify a lobe radius iteratively until a single point spacing and a double point spacing are equal to the established lobe spacing.

[0009] DE 30 26 222 A1 shows an annular gear pump in which the theoretical tooth shape of the pinion is determined by rolling the pinion pitch circle along the ring gear pitch circle. Here the starting point for purposes of developing the tooth shape of the pinion is a particular shape of the toothing. The method is only applicable for this particular tooth shape.

[0010] US 2,666,336 shows a method for the development of toothings of rotoids, which in contrast to gerotors (annular gear machines) have other toothing ratios. The starting point is an outer circle with the diameter A and a pinion circle with the diameter B, from which ensues the eccentricity E.

[0011] In the article "Design of deviation-function based gerotors", Shih-Hsi Tong et. al., Mechanism and Machine Theory 44 (2009) 1595-1606, a new type of method is described for the generation of gerotor profiles. This method is based on the use of deviation functions, but requires complex calculations and design steps and can lead to dimensioning problems, particularly in the case of undercuts.

[0012] EP 1 462 653 A1 shows an internal gear pump with an inner rotor and an outer rotor. The inner rotor has a tooth profile with a root section formed in terms of a hypocycloid. The inner rotor and the outer rotor have an eccentricity e relative to one another, wherein the intermediate rotor spacing assumes the maximum value t. The outer rotor has a tooth profile that is determined using the tooth profile of the inner rotor as a starting point. To this end the inner rotor is rotated about the centre point of the outer rotor. Here the inner rotor rotates about its axis 1/n-times (n = number of teeth), while the centre point of the outer rotor executes one revolution of its orbit. With this movement an envelope curve is described by the tooth profile of the inner rotor, which is used as the tooth profile of the outer rotor.

[0013] An object of the present invention consists, starting from the prior art, in specifying a method for the generation of the tooth shapes of the inner and outer rings of an annular gear machine, in particular an annular gear pump, which is easy to execute, does not assume any deeper knowledge concerning mathematical relationships and provides the designer with a large degree of dimensioning freedom, so as to be able to fulfil a very wide variety of requirements on the annular gear machine that is to be generated. Here the aim is to be able to avoid what has been for a long time the usual description of the tooth contours in terms of cycloids, ellipses, involutes, circular arcs, or similar curve segments that are mathematically easy to describe, since these limit the possible geometries of the tooth shapes. At the same time it should be possible to describe with sufficient accuracy the tooth shapes to be generated with technical aids that are currently available, such as CAD and CAM systems, so as to enable an automated production of corresponding inner and outer rings with existing machine tools.

[0014] The above-cited object is achieved by means of a method in accordance with the accompanying Claim 1.

[0015] The invention is based on the fundamental knowledge that the tooth shapes of the inner and outer rings can be generated in terms of the description, or execution, of a relative movement between the two rings, if a few simple to define parameters, or starting conditions, are maintained. For the generation of the tooth shape a relative movement is therefore executed, i.e. mathematically modelled, between the inner and outer rings, with the aid of the angular relationship of this relative movement and a predetermined eccentricity between the rotation axes of the rings and a provisionally defined draft pitch circle on the outer ring.

[0016] The method can fundamentally be executed starting from the starting geometry of the outer ring. Insofar as nothing is otherwise specified in what follows, the descriptions relate to an example in which the outer ring is considered to be a first annular gear, whose starting geometry is selected. The number of teeth of the outer ring is likewise necessarily to be defined as a component of the starting geometry. This necessary definition is influenced by the choice of the eccentricity and the build size of the pump (pitch circle). Here the number of teeth for the outer ring (the number of teeth of the inner ring + 1) can also be determined from the desired number of teeth for the inner ring. Another component of the starting geometry to be established is the pitch circle radius (of the outer ring), which is usually understood to be the average value between the radius at the tooth tip and that at the tooth root (circular pitch = spacing from tooth centre to tooth centre on the pitch circle). The execution of the movement generating the tooth shape contour is preferably undertaken on a computer using a CAD model. Here the provisional generating geometry is rotated in a stepwise manner as an envelope curve, whilst maintaining the movement condition, which is described further below, for the generation and assessment of the opposing tooth (on the second annular gear).

[0017] Furthermore it is an essential component of the present invention that by the multiple repetition of the above-cited movement pattern, with starting conditions that are modified in each case, a stepwise optimisation of the tooth shapes can be achieved. This occurs, for example, within the framework of an iterative process to fulfil one or a plurality of previously determined quality criteria by means of the tooth shape generated in each case, or to approach these quality criteria as far as possible. All conceivable requirements for the annular gear machine that is to be generated come into consideration as quality criteria, for example the efficiency, the delivery volume, the maximum pressure to be achieved, a residual minimum clearance dimension between inner ring and outer ring, or even a specified shaping in particular sections of the tooth geometry, as a result of which, for example, the noise characteristics of the annular gear machine can be significantly influenced.

[0018] To execute the inventive method, in a first step a starting geometry of the outer ring is specified, which geometry fully describes the latter. In addition to the tooth width and the number of teeth, this also includes a provisional pitch circle and pitch circle radius on the outer ring. In the case in which the method is implemented by means of software this specification is made utilising the functions that are available in the usual CAD programs. In the specification of the starting geometry the person skilled in the art can start with annular gear shapes from the known prior art, or can freely select an annular ring shape within wide limits, with which he anticipates good results for the achievement of one or a plurality of parameters (quality criteria) that are particularly aimed at for the annular gear machine that is to be dimensioned. The starting geometry must thereby simply ensure that an annular gear machine can in principle be constructed with this geometry.

[0019] Furthermore for the optimisation of the annular gear shapes that is to be executed it is necessary for at least one quality criteria of the annular gear machine to be defined, whose fulfilment represents an objective in the configuration of the annular gears, i.e. in the configuration of the tooth shapes that are to be used in the latter. A possible quality criterion, but not one that is necessary in every case, would be, for example, the general consistency of the tooth tip clearance over the angle of rotation. Primarily it is the tip clearance behaviour in the region of closest approach of the tip circle on the inner ring, and the root circle on the outer ring, that is to be taken into account.

[0020] It is to be noted that the specification of the starting geometry can be undertaken either in terms of generation of a geometry matched to the target toothing that is to be achieved, which includes both the tooth tip and tooth root regions, or preferably in terms of a mathematical description of a complete outer ring. For the specification of the starting geometry the complete description of at least a half-tooth period of the external toothing is sufficient. The toothing on the outer ring in question is repetitive along the periphery of the ring, wherein a tooth period consists in each case of a tooth and a tooth space. Both the tooth and also the tooth space are intrinsically symmetrical so that the complete annular gear geometry is described by the specification of a curve profile over a half-tooth period. By forming the mirror image of this curve profile the tooth period can be completed, and this is subsequently repeated multiple times over the periphery of the annular gear.

[0021] The starting geometry to be established also includes the data necessary for purposes of determining the radius of the annular gear, wherein the geometric relationships are sufficiently of known art to the person skilled in the art and therefore do not need to be described in detail. After the above-cited initial values are established, a movement is executed with the starting geometry of the first ring in accordance with the following basic movement condition: the first annular gear (outer ring), i.e. an envelope curve section describing the starting geometry, executes a rotational movement about its own (first) rotation axis; at the same time a revolving movement is executed about the rotation axis of the second annular gear (inner ring), not yet defined, the location of which relative to the first rotation axis is determined by the above-defined eccentricity (the distance between the two rotation axes A, B). During this double movement the following angular relationship is to be continuously maintained:

$$b = a \times Z$$

wherein

a = angle of rotation of the first annular gear (outer ring)
b = angle of rotation of the eccentricity
Z = number of teeth on the first annular gear (outer ring)

[0022] If the starting geometry of the internal toothing of the outer ring has been established, a rotational movement of the outer ring takes place through a certain angle of rotation relative to the inner ring, whose toothing geometry in the first instance is not yet known. To ease understanding it should be noted that in the simplest case a complete revolving movement of the outer ring is executed about the inner ring, while at the same time the profile executed by the starting geometry is plotted out. Here the path of the envelope curve sections of the starting geometry represents the opposing tooth shape of the external toothing of the inner ring. The envelope curve of the starting geometry thereby represents the sum of all the envelope curve sections in a prescribed minimum movement region.

[0023] However, a closer examination reveals that it is not necessary for the revolving movement to be executed over a complete revolution, since for the determination of the resulting tooth shape contour of the second annular gear (here the inner ring) it is likewise sufficient if at least a half period of the tooth-tooth space sequence is described. The revolving movement of the first annular gear must therefore at least be completed through an angle of rotation b, which corresponds to a half-tooth period of the second annular gear located opposite to the first annular gear. This angle of rotation b, whilst maintaining the formation rule as described, automatically generates the number of teeth for the inner ring, which fundamentally is one less than the number of teeth of the outer ring, so that the minimum angle of rotation to be applied can easily be determined.

[0024] After the execution of the double movement as described the starting geometry initially specified for the first annular gear exists, together with a first tooth shape contour generated, and at the same time plotted, for the second annular gear, and thus a geometry that is in principle a possible option. As a rule the quality criterion that has also been specified is not yet achieved after the first step. In accordance with the invention the starting geometry of the first annular gear is therefore modified in terms of at least one parameter in what is in the first instance a random direction. Boundary conditions can preferably be prescribed for the modification, and/or relationships can be used as a basis for logical modifications. For example, the width of the tooth of the first annular gear can be modified by 10% so as to adapt the starting geometry for the next step in the method. Alternatively or additionally, for purposes of modifying the starting geometry of the first annular gear the eccentricity between the rotation axes of the two annular gears can also be modified; this also has repercussions on the ensuing tooth shape contour. However, initially a fixed value is advantageously maintained for the eccentricity. Here the target that is being aimed at is a functionally optimised tooth shape, with at the same time a minimum circular pitch and potentially a maximum number of teeth.

[0025] In the next step of the method the double movement of the first annular gear about the second annular gear and about its own rotation axis is executed once again, using the modified starting conditions as a basis, whilst maintaining the movement condition, i.e. angle condition, as has been described previously. A second tooth shape contour is generated, which deviates from the first tooth shape contour obtained from the previous steps, so that a check can then be undertaken as to which of the two tooth shape contours determined better fulfils the defined quality criterion. Finally the above-cited steps can be repeated iteratively, in order for the tooth shape contours to approach an optimum that is being aimed at with regard to the quality criterion.

[0026] As a result of the previously described generation and optimisation of tooth shapes on the inner ring and outer ring of an annulus gear machine the tooth shape contours or geometries that have been created as a rule can only be represented in terms of higher order splines (for example 3rd order). While it is true that in the simplest cases with the tooth shape that can be generated using the described method can also approximate to that which can be achieved by means of conventional methods, in a deviation from the prior art tooth shapes can now also be generated that are easy to optimise for various applications, although they can no longer be represented using conventional methods. With the aid of the splines as cited the contours can also be mathematically described such that they can be used in available data processing programmes, in particular for purposes of further optimisation, and for the activation of machine tools.

[0027] One advantage of the inventive method thus consists in the fact that in contrast to the classical use of rolling curves (cycloids) for purposes of describing the tooth shapes, which for purposes of generating the cycloids roll along the pitch circle of the toothing, and which form one side of a toothing contour, no mandatory coupling to the pitch circle as a shape generating condition is presumed.

[0028] Since by means of the inventive method the complete tooth shape contour of the inner ring and the outer ring is generated in each pass, starting from a prescribed starting geometry for the first annular gear, the tooth shape contours or geometries that are created on the one hand, and the rolling and/or sliding characteristics of the toothing of both annular gears on the other hand can be subjected to an assessment, i.e. to a comparison with a quality criterion. With a suitable choice of the quality criteria even gerotor toothings with relatively large eccentricities can be generated in this manner. Here the maintenance of the movement pattern as described above ensures a harmonious movement pattern between the inner and external toothings, together with kinematically harmonious running with a high efficiency.

[0029] In particular, when the annular gear machine is used as an annular gear pump the inventive method enables dimensioning with large eccentricities, as a result of which it is possible to design flow-optimised delivery chambers, which effect an improvement of the delivery performance at higher rotational speeds. The method can fundamentally be deployed for a very wide variety of tooth shapes, tooth numbers, eccentricities and pitch circle radii. It is furthermore advantageous that no special measures need to be met in order to adapt the ends of individual curve sections, which are usually deployed in the description of the tooth shape, in their transitional characteristics to any mathematical presuppositions of the description that is being used. Instead the curve profiles are completely created on the basis of the sequence as described during the optimisation of the tooth shape. The mathematical description of the resulting geometry is undertaken in terms of higher order splines, wherein it is usually possible to use just 3rd order splines to achieve sufficient accuracy to meet the practical requirements.

[0030] In accordance with a preferred form of embodiment it is possible to define a plurality of quality criteria, the fulfilment of which is checked in parallel during the assessment of a plurality of generated tooth shape contours. For example, in addition to the minimum volume that is to be delivered, a specification can also be defined for the force conditions that must be maintained between the tooth flanks of the opposing teeth. In this manner the option exists of reducing the Hertzian pressure, for example by increasing the size of the local contact radii (arcs).

[0031] It is also advantageous if, as early on as in the definition of the starting geometry of the first annular gear, the description of the tooth contour is not undertaken, as in the prior art, in terms of circular arcs, ellipses, or segments of angle functions and involutes, but rather the starting geometry is determined in terms of a modifiable spline, preferably of 3rd order. With established software (e.g. Inventor, Catia, Pro-E and UG) it is possible to describe such types of splines, and to vary these in a targeted manner by means of the above-described optimisation loop. Further advantages, forms of embodiment, and details ensue from the following description of a preferred procedure for the execution of the inventive method, with reference to the figures. Here:

Fig. 1 shows a flow diagram of the essential steps in the execution of the inventive method in accordance with a first form of embodiment;

Fig. 2 shows a schematic representation of an annular gear machine, with an inner ring with external toothing, and an outer ring with internal toothing, together with identified geometric parameters;

Fig. 3 shows a detailed representation of a tooth of the inner ring, during a movement segment through a tooth space of the outer ring;

Fig. 4 shows a schematic representation of the movement pattern for purposes of generating the tooth shape contour at a first point in time at the start of the movement;

Fig. 5 shows a schematic representation of the movement pattern for purposes of generating the tooth shape contour at a second point in time at the end of the movement.

[0032] The following description of essential and preferred steps of the inventive method is undertaken with reference to Fig. 1, in which the method sequence is summarised, together with simultaneous reference to Figs. 2 and 3, in which important geometric details of the teeth of an annular gear machine are plotted out.

[0033] Fundamentally, the aim is to generate tooth shapes of an annular gear machine by means of the inventive method, wherein the annular gear machine has an inner ring 1 with external toothing, together with an outer ring 2 with internal toothing, as the main elements. In a typical application the inner ring can be fitted onto an output drive shaft of a drive unit, while the outer ring 2 is mounted such that it can rotate in a housing (not represented). In operation the inner ring 1 rotates about a first rotation axis A, while the outer ring 2 can be rotated about a second rotation axis B. The rotation axes A, B are displaced relative to, i.e. spaced apart from, one another by the amount of an eccentricity e. Moreover, in operation of the annular gear machine the outer ring 2 moves in a revolving movement about the first rotation axis A, i.e. the eccentricity e rotates about the point of rotation through which the first rotation axis A runs. In Fig. 3 the typical tooth shape contour of an individual tooth of the inner ring 1 can be discerned in an enlarged detail, as can a complementary tooth space of the outer ring 2. There the geometrical conditions that are required for the definition of the starting geometry are also plotted out. Fig. 3 records the highest elevation of the tooth at R_A+e, together with the lowest depth of the tooth space at R_A-e. Finally, both the maximum tooth tip width, together with a tooth tip width that may be waisted in the case of necked teeth, can be of importance for the definition of the starting geometry. The individual geometric features of the tooth shape contour are entered into further below.

[0034] The pitch circle of the inner ring is automatically generated by the functional relationships, which derive from the pitch circle of the outer ring in accordance with the following law:

$$R_i = R_A - 2e$$

wherein

R_A = pitch circle of the outer ring;
R_i = pitch circle of the inner ring
e = eccentricity between the rotation axes

[0035] For purposes of describing the starting geometry the following relationships are also significant:

$$Z_{tw} = 360° / Z$$

wherein

Z_{tw} = tooth pitch angle on the outer ring

$$K_{tw} = Z_{tw} \cdot g$$

wherein

K_{tw} = tooth root pitch angle on the outer ring
g = tooth pitch/root width ratio, preferably 0.08 to 0.13

$$W_{ef} = 0.5 Z_{tw}$$

wherein

W_{ef} = flank generation angle

$$E_{fv} = W_{ef}/K_{tw} = h$$

wherein

E_{fv} = flank generation angle ratio
h = tip width/root width ratio, preferably 3 to 5.5

[0036] In the example represented in Fig. 3 a lobe-shaped tooth has been generated on the inner ring. The lobe shape can be defined in terms of the lobe angle d. A flattened geometry region, as represented on the tooth of the inner ring, represents the result of a tooth geometry optimisation. The said region serves to provide a partial reduction of the Hertzian pressure in the region of contact with the toothing on the outer ring. From experience the said region is highly loaded with the introduction of torque, and in the event of Hertzian pressures that are too high can lead to possible wear.

[0037] Figs. 4 and 5 show in an exemplary manner two sections in the generation of a tooth shape. For the execution of the inventive method a starting geometry of a first annular gear is established in the first step. The outer ring can be defined as the first annular gear. The starting geometry can be fully defined by the description of a half-tooth period. In Fig. 4 a section of the outer ring 2, consisting of a half-tooth and a half-tooth space is represented as an outer ring contour 6 (full line). This section of the starting geometry is preferably defined in terms of a third order spline 4 with, for example, eight grid points. The spline 4 describing the starting geometry is enclosed by two radial angle lines (or pitch demarcation lines), which are spaced apart from one another by a half-tooth period. The angle W_{ef} enclosed between the angle lines (Fig. 2) is designated as a flank generation angle. Both ends of the spline 4 run at right angles to the angle lines. In the radial direction, the spline 4 is bounded by the relationship between the pitch circle of the outer ring R_A and the eccentricity e (Fig. 3). On the opposing inner ring an inner ring contour 7 is to be generated by virtue of the movement, the shape of which, yet to be created, is represented by a dashed line.

[0038] In addition to the starting geometry the eccentricity e between the rotation axis A of the inner ring 1 and the rotation axis B of the outer ring 2 must also be established at the start of the method, together with at least one quality criterion as a boundary condition, which the annular gear machine that is to be generated is to fulfil.

[0039] As has already been described above in general terms, in the next step of the method a rotational movement of the predefined starting geometry 6 of the outer ring 2 is executed about its own rotation axis B, at the same time together with a revolving movement about the rotation axis

A of the inner ring 1 that is to be shaped. In accordance with the invention the following general movement condition must be maintained during this double movement:

$$b = a \times Z$$

wherein, in the example here described

a = angle of rotation of the outer ring
b = angle of rotation of the eccentricity
Z = number of teeth on the outer ring

[0040] For the complete description of the tooth contour on the second annular gear it is fundamentally sufficient if the relative rotational movement is executed over at least a half-tooth period of the second annular gear, so that the starting geometry previously established, i.e. the envelope curve, which describes at least a half-tooth period on the predefined first annular gear, is moved along a path that describes the tooth contour of the opposing second annular gear.

[0041] Fig. 5 shows the situation at a later point in time after the execution of the double movement. Here, compared with the position shown in Fig. 4, the eccentricity e, and with it the outer ring contour 6, have been further turned through an angle of rotation b = 707° about the rotation axis A. At the same time the angle of rotation a has altered from 68° (with b = 476°) to 101°. With a number of teeth on the outer ring of Z = 7, the movement condition as cited has thus been maintained. In the state shown in Fig. 5 the inner ring contour 7 is almost completely described, i.e. the generation movement is almost complete.

[0042] After the tooth shape contour of the second annular gear has been generated and plotted out by the execution of the double movement, a first check can be undertaken as to whether the tooth shape contours of both annular gears that thus exist already fulfil the previously established quality criterion, or whether the tooth shapes must be further adapted. If the quality criterion is not yet fulfilled, which after the first pass will usually be the case, the starting geometry and/or the initially established eccentricity is modified by a predetermined value, preferably in a prescribed direction that allows an improvement of the geometry to be anticipated. The said modification of values can be undertaken automatically under predetermined boundary conditions, or can be manually prescribed by the user, who may be asked at this point to enter data. The user can allow his experience in dimensioning to influence the modification to the starting geometry, although this is not necessary in the automatic sequencing of the method. With the modified initial values the rotational movement is then carried out once again so as to plot out a second tooth shape contour for the second annular gear. This repetitive loop can be executed a number of times, preferably with the execution of iterative steps. As soon as the specified quality criteria are fulfilled the method can be terminated, and the final established and plotted tooth shape contours for the two annular gears thus represent the result of the generation method.

[0043] By the application of the above-cited movement condition a very simple reproduction of the movement pattern and thus a simple generation method for the tooth geometries is provided, in comparison to the movement equations used in the prior art. Here a closed envelope curve is generated in each case to describe the tooth shape on the second annular gear; this curve represents the contour of the tooth geometry for the teeth to be arranged on the latter, with mandatory maintenance of the movement condition on the outer ring. By including the pitch circle diameter R_A of the outer ring in the possible variables that can be modified during a plurality of passes through the method, and by the computerised simulation/modelling of the movement condition of the outer ring contour, it is possible in a few iteration steps to find an optimum geometry for the inner ring tooth contour, which can then be represented in terms of splines.

LIST OF REFERENCE SYMBOLS

[0044]

1 - Inner ring
2 - Outer ring
3 -
4 - Spline
5 -
6 - Outer ring contour
7 - Inner ring contour

A - Rotation axis of the inner ring
B - Rotation axis of the outer ring
e - Eccentricity
W_{ef} - Flank generation angle
a - Angle of rotation of the first annular gear (outer ring)
b - Angle of rotation of the eccentricity e
Z - number of teeth on the first annular gear (outer ring)
R_A - Pitch circle of the outer ring
R_i - Pitch circle of the inner ring
Z_{tw} - Tooth pitch angle on the outer ring
E_{fv} - Flank generation angle ratio
K_{tw} - Tooth root pitch angle on the outer ring
g - Tooth pitch/root width ratio
h - Tip width/root width ratio
d - Lobe angle

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SZABADALMI IGÉNYPONTOK

1. Eljárás fogasgyűrűs készülék első és második fogasgyűrűjén lévő fogak alakjának létrehozására, amely eljárás a következő lépéseket foglalja magában:

a) meghatározzuk az első fogasgyűrű kiindulási geometriáját, amely első fogasgyűrű a fogasgyűrűs készülék külső gyűrűje (2), a fogasgyűrűs készülék legalább egy minőségi kritériumát, valamint a kívánt excentricitást (e) a két fogasgyűrű forgástengelyei (A, B) között, amely kiindulási geometriát magasabb rendű szplájnok írnak le;

(b) mozgást hajtunk végre a meghatározott kiindulási geometriával, amely kiindulási geometria a saját forgástengely (B) körül forgómozgást és ezzel egyidejűleg a második fogasgyűrű forgástengelye (A) körül körforgó mozgást hajt végre, amely forgómozgás és körforgó mozgás egymással úgy van összecsatolva, hogy az excentricitás (e) elfordulási szöge (b) folyamatosan egyenlő az első fogasgyűrű elfordulási szögének (a) és az első fogasgyűrű fogszámának (Z) a szorzatával ($b = a \times Z$);

c) létrehozzuk a második fogasgyűrű fogalakjának körvonalát a kiindulási geometria burkológörbéje által a b) lépés szerinti mozgás végrehajtásánál leírt pálya regisztrálásával, amely regisztrált fogalak-körvonalat magasabb rendű szplájnok írnak le;

d) vizsgáljuk, hogy a kiindulási geometriával és a regisztrált fogalak-körvonallal teljesül-e a meghatározott minőségi kritérium;

e) amennyiben a minőségi kritérium még nem teljesült, módosítjuk az előzőleg alkalmazott kiindulási geometriát és/vagy a meghatározott excentricitást (e);

f) iteratív módon megismételjük a b)-e) lépéseket, és létrehozunk egy módosított fogalak-körvonalat, amíg a minőségi kritérium nem teljesül.

2. Az 1. igénypont szerinti eljárás, amelynél kiindulási geometriaként a külső fogazásnak legalább egy fél fogperiódusát határozzuk meg.

3. Az 1. vagy a 2. igénypont szerinti eljárás, amelynél a relatív forgómozgás végrehajtását a belső és külső gyűrű között számítógéppel támogatott módon, a belső és külső gyűrű matematikai modelljének alkalmazásával kivitelezzük.

4. Az 1-3. igénypontok egyike szerinti eljárás, amelynél a b)-e) lépések iteratív megismétlését a minőségi kritérium teljesülésétől függetlenül megszakítjuk, ha egy előzőleg meghatározott megszakítási kritérium teljesül.

5. Az 1-4. igénypontok egyike szerinti eljárás, amelynél a körforgó mozgás a b) lépésben az excentricitás (e) egy olyan elfordulási szöge (b) körül megy végbe, amely lefedi a második fogasgyűrűnek legalább a fél fogperiódusát.

6. Fogasgyűrűs készülék fogasgyűrűje, azzal jellemezve, hogy fogazásának fogalakja az 1-5. igénypontok egyike szerinti eljárással lett előállítva.

(A meghatalmazott)

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Fig. 1

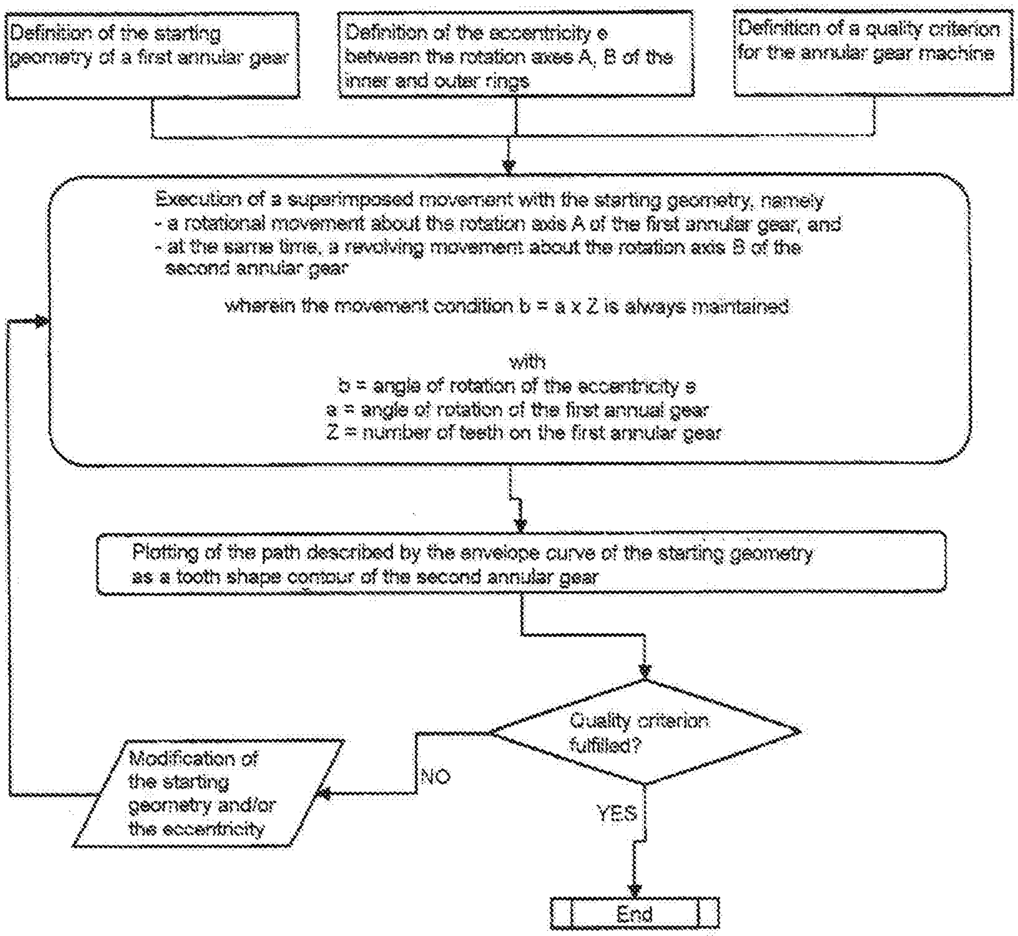
Definition of the starting geometry of a first annular gear
Definition of the eccentricity e between the rotation axes A, B of the inner and outer rings
Definition of a quality criterion for the annular gear machine
Execution of a superimposed movement with the starting geometry, namely
- a rotational movement about the rotation axis A of the first annular gear, and
- at the same time, a revolving movement about the rotation axis B of the second annular gear
wherein the movement condition b = a x Z is always maintained
with
b = angle of rotation of the eccentricity e
a = angle of rotation of the first annual gear
Z = number of teeth on the first annular gear
Plotting of the path described by the envelope curve of the starting geometry as a tooth shape contour of the second annular gear
Quality criterion fulfilled?
NO
Modification of the starting geometry and/or the eccentricity
YES
End

Fig. 2

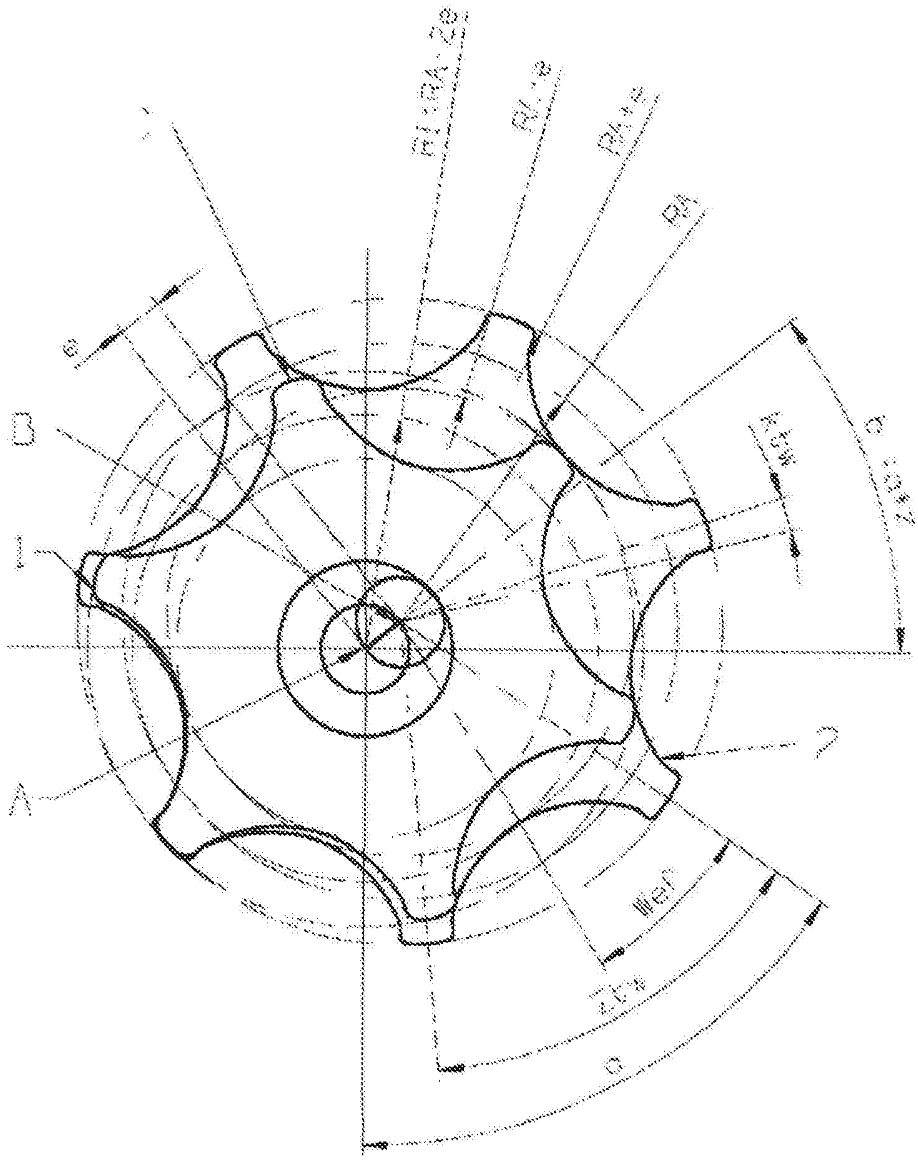

Fig. 3

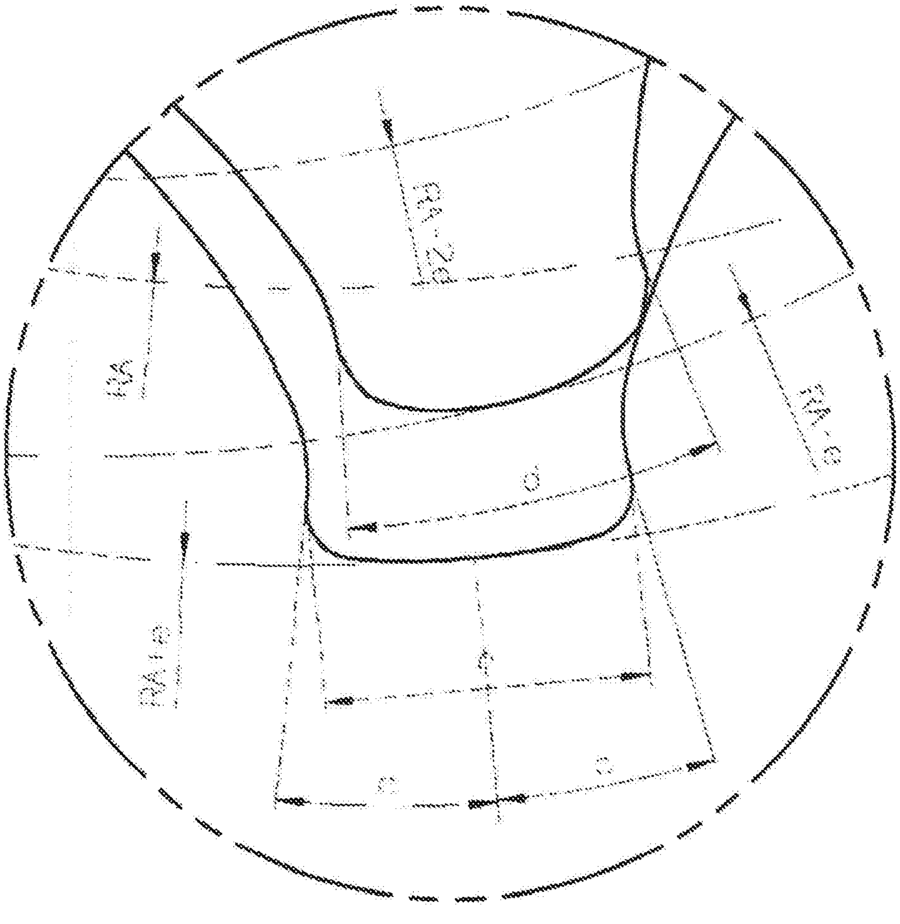

Fig. 4

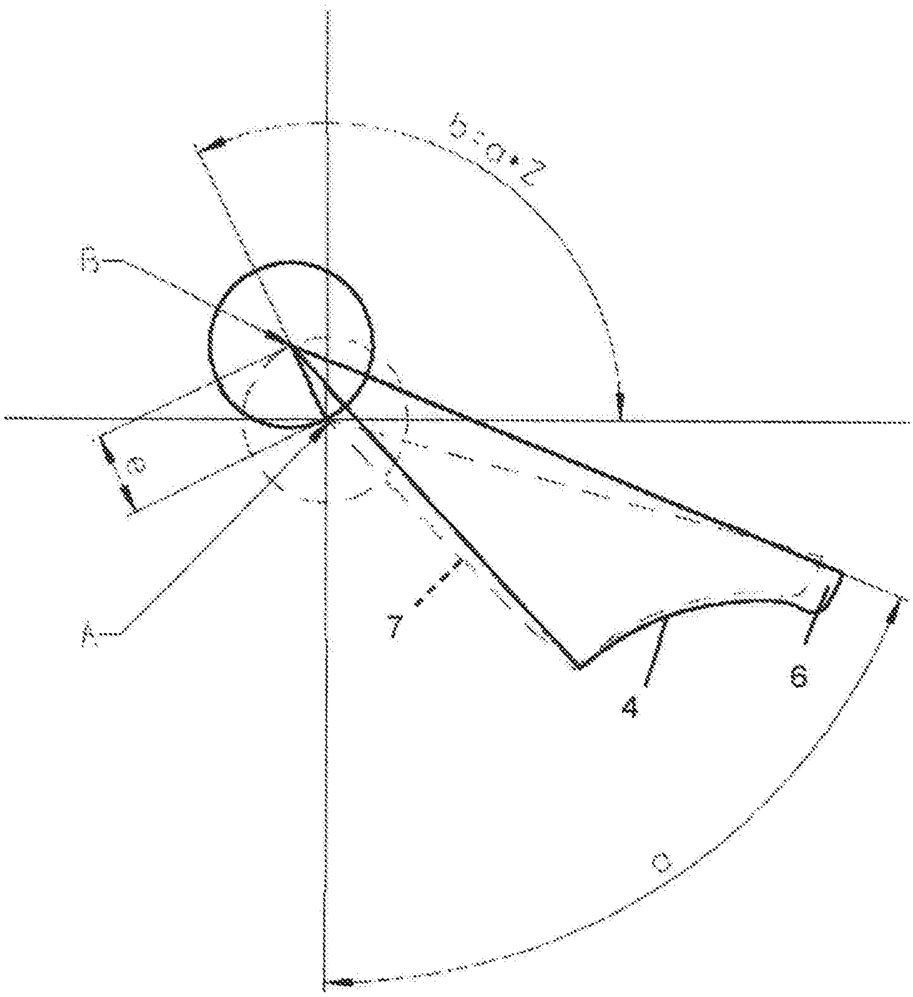

Fig. 5