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Glimpel et al.(10) **Pub. No.: US 2007/0293329 A1**(43) **Pub. Date: Dec. 20, 2007**(54) **METHOD AND TOOL SET FOR PRODUCING
A THREAD IN AT LEAST TWO WORKING
STEPS**(30) **Foreign Application Priority Data**

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Hechtle**, Pegnitz (DE)**Publication Classification**(51) **Int. Cl.**
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1000 EAGLE GATE TOWER
SALT LAKE CITY, UT 84111 (US)(57) **ABSTRACT**

In order to produce a thread in a workpiece, a preliminary thread can be produced in the workpiece in at least one first working step by removing material from the workpiece. The preliminary thread profile of the workpiece (from which material was removed) has two preliminary thread flanks and a preliminary thread root connecting the two preliminary thread flanks. In addition, a preliminary thread profile that has a final thread having a final thread profile is produced in at least one second working step by plastic pressing-in of the material of the workpiece at least in a section of at least one of the two preliminary thread flanks by a predetermined or predeterminable pressing-in volume.

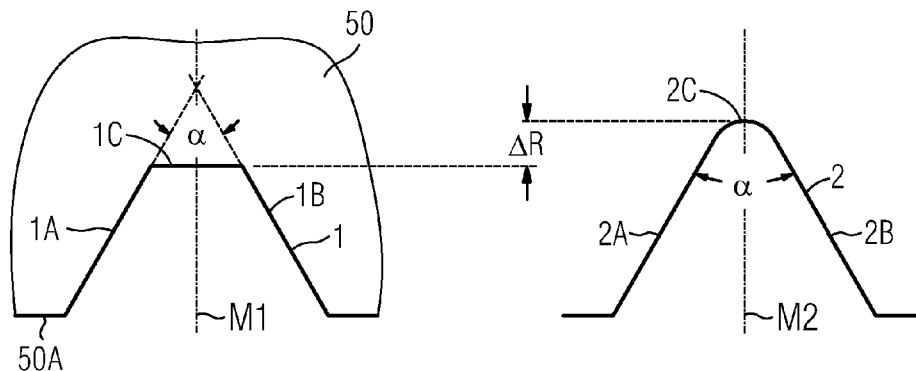
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GmbH & Co. KG Fabrik fur Prazision-
swerkzeuge**, Lauf (DE)(21) Appl. No.: **11/759,037**(22) Filed: **Jun. 6, 2007**

FIG 1

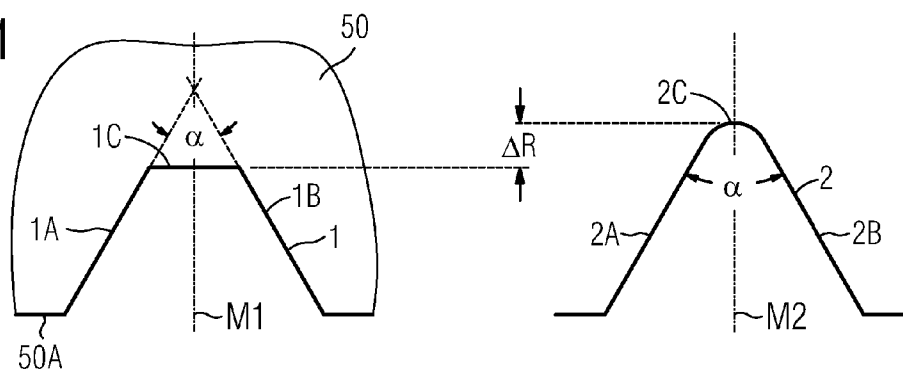


FIG 2

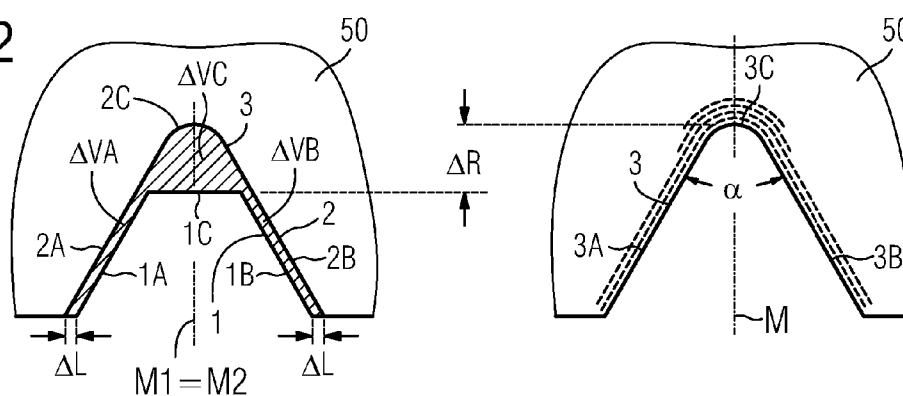


FIG 3

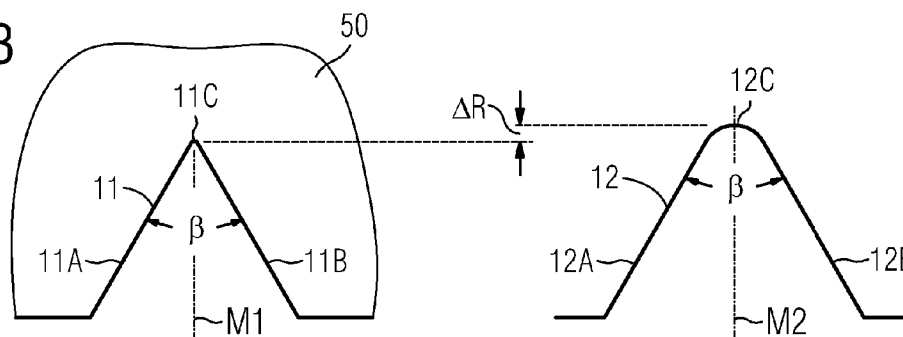


FIG 4

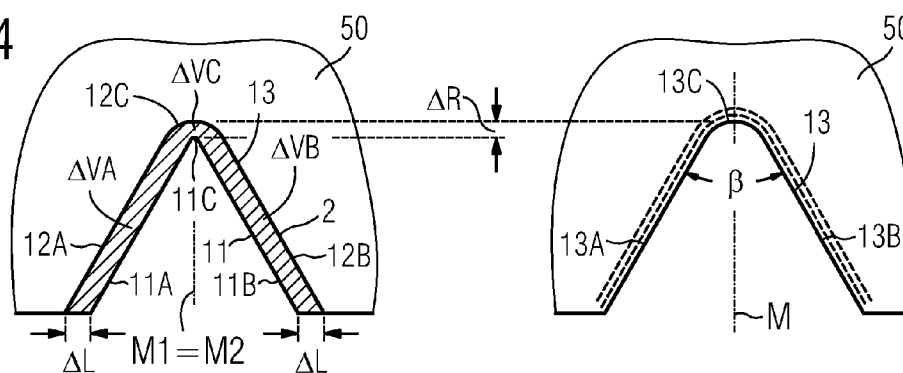


FIG 5

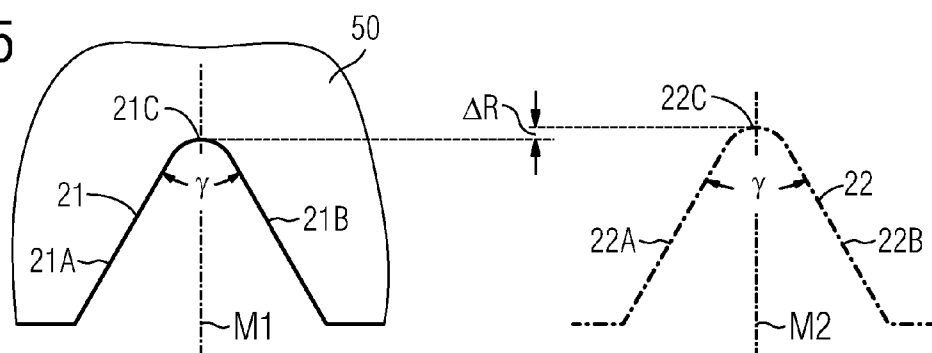


FIG 6

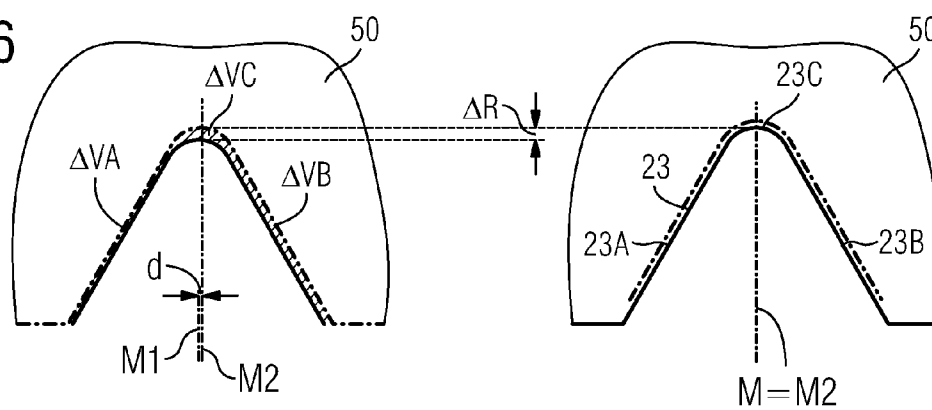


FIG 7

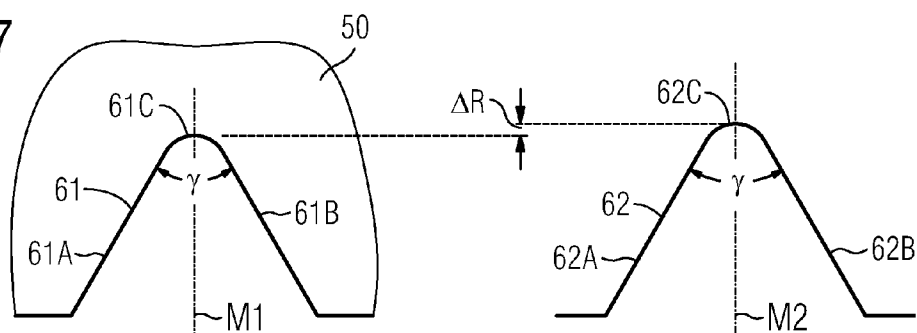


FIG 8

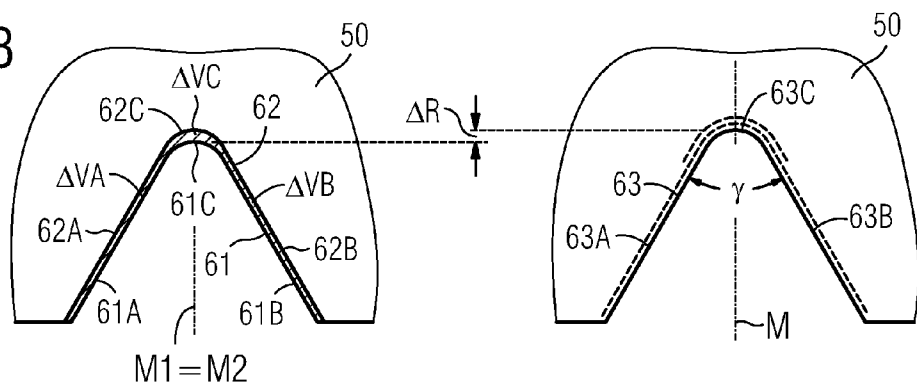


FIG 9

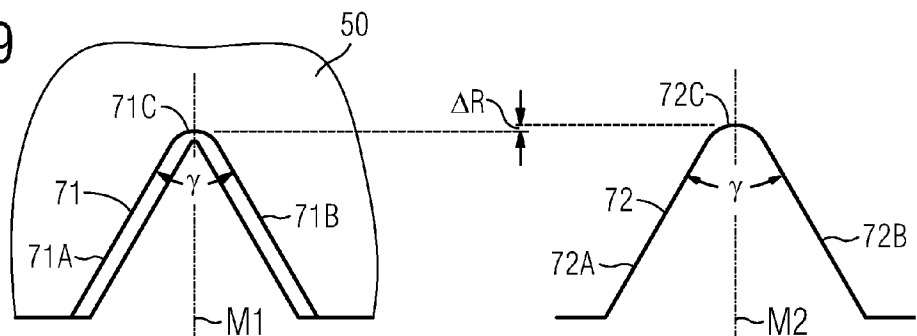


FIG 10

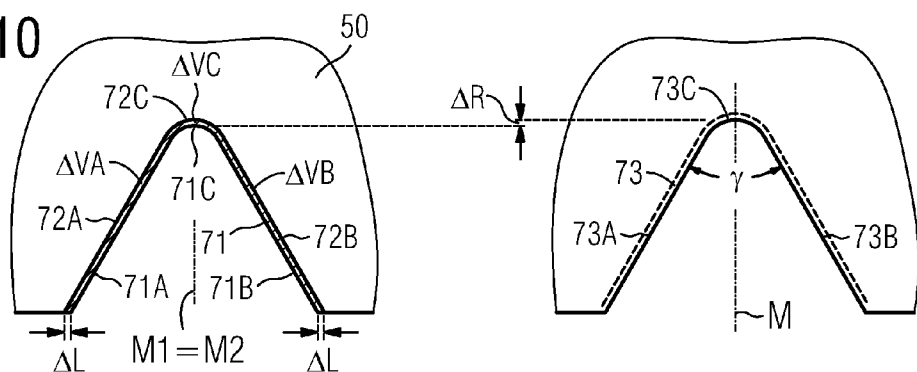


FIG 11

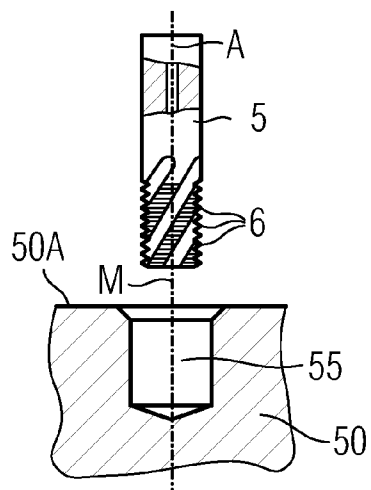


FIG 12

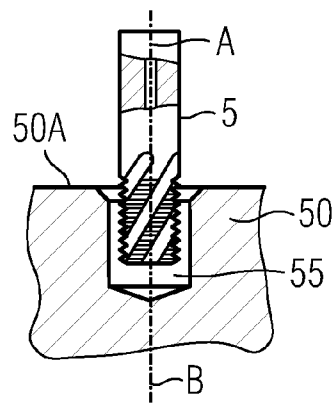


FIG 13

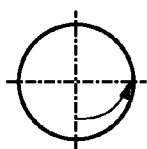


FIG 14

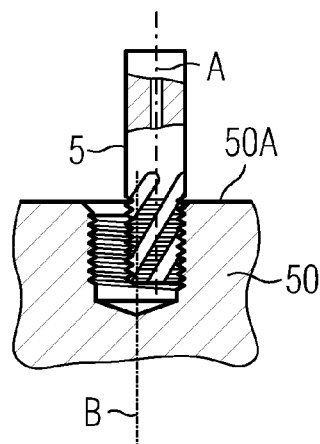
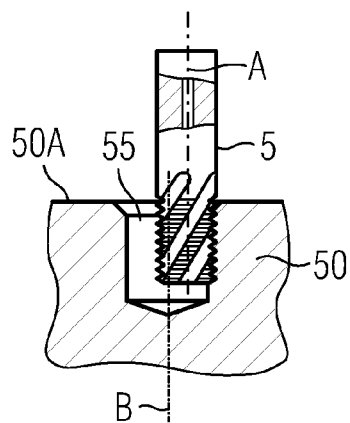
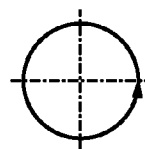


FIG 15

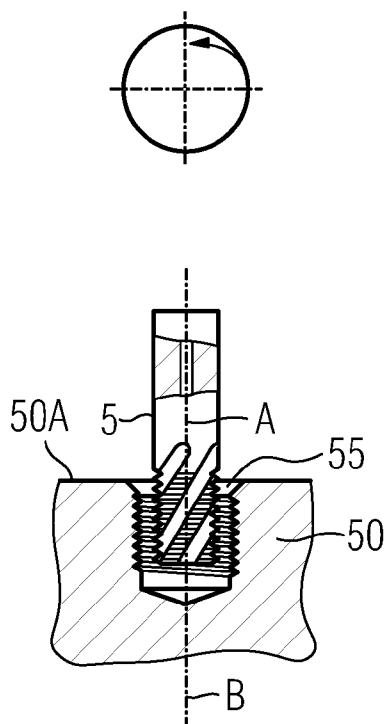
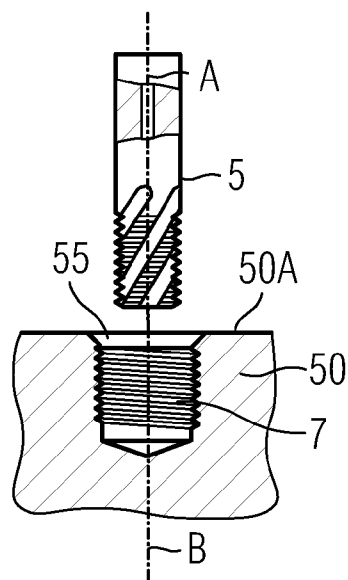


FIG 16



METHOD AND TOOL SET FOR PRODUCING A THREAD IN AT LEAST TWO WORKING STEPS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present invention claims the benefit of priority under 35 U.S.C. § 119 to German Patent Application No. 10 2006 026 992.6-14, filed on Jun. 8, 2006, having a translated title of “Method and Tool Set for Producing a Thread in at Least Two Working Steps,” the entire contents of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0002] 1. The Field of the Invention

[0003] The invention relates to a method and a tool set in each case for producing a thread in at least two working steps.

[0004] 2. Background and Relevant Art

[0005] For thread production or thread rework, exclusively cutting, exclusively chipless and both cutting and chipless methods and threading tools are known. Cutting thread production is based on the removal of the material of the workpiece in the region of the thread turn (or, thread profile). Chipless thread production is based on production of the thread turn in the workpiece by pressure and the forming or plastic deformation, effected as a result, of the workpiece. An advantage of the chipless thread production compared with the cutting thread production is that, due to the consolidation or compaction at the surface, the hardness of the material in the region of the thread profile increases and thus a more wear-resistant thread can be produced.

[0006] Coming within the scope of cutting thread production are taps (cf. Handbuch der Gewindetechnik und Frästechnik [Manual of threading practice and milling practice], publisher: EMUGE-FRANKEN, publishing firm: Publicis Corporate Publishing, year of publication: 2004 (ISBN 3-89578-232-7), designated below only as “EMUGE manual,” chapter 8, pages 181 to 298) and thread milling cutters (cf. EMUGE manual, chapter 10, pages 325 to 372).

[0007] A tap is a thread-cutting tool which works axially relative to its tool axis and whose cutting edges are arranged along an external thread having the thread pitch of the thread to be produced. During the production of a thread, the tap is moved with an axial feed and while rotating about its tool axis into a hole of the workpiece at a rotary speed dependent on the feed rate, its cutting edges being permanently in engagement (continuous cut) with the workpiece at the wall of the hole.

[0008] In the thread milling cutter, a plurality of milling teeth having milling cutting edges are arranged offset along the tool circumference and/or axially relative to the tool axis. To produce the thread, the thread milling cutter is rotated about its own tool axis and is moved with its tool axis in a linear feed movement on the one hand and additionally in a circular movement about a center axis of the thread to be produced or of the pilot hole in the workpiece on the other hand, as a result of which a helical movement of the tool is obtained, the pitch of which corresponds to the thread pitch of the thread to be produced. The milling cutting edges of the

thread milling cutter engage intermittently one after the other in the workpiece (interrupted cut).

[0009] Coming within the scope of chipless thread production tools are “thread formers” (cf. EMUGE manual, chapter 9, pages 299 to 324) and “circular thread formers.”

[0010] On a tool shank, thread formers have an outer profile which encircles the tool axis spirally or helically with the pitch of the thread to be produced and has an approximately polygonal cross section. The generally rounded-off polygon corner regions form pressing lobes or forming teeth or forming wedges which press the thread into the material by plastic deformation and flow of the workpiece material into the spaces between the outer profile one the one hand and compaction of the workpiece material on the other hand. To produce an internal thread in an already existing hole, the thread former is inserted into the hole with a linear feed movement axially relative to the tool axis and with the tool rotating about this tool axis. Known exemplary embodiments of such (axial) thread formers are also found in DE 101 36 293 A1, DE 199 58 827 A1 or also in DE 39 34 621 C2.

[0011] WO 02/094491 A1 discloses a circular thread former and a circular forming method for chipless thread production. This known circular thread former is elongated and comprises a working region with one or more annular circumferential profiles separated from one another by annular grooves and having a least three respective pressing lobes like a polygon. This tool is inserted into a hole having a larger diameter than the tool and performs, in addition to a rotation about its own tool axis, a helical movement along the hole wall for the chipless production of the thread in the hole. A further circular former and a further circular forming method are known from DE 103 18 203 A1.

[0012] Finally, combined methods having at least two working steps for producing internal threads are known, in which, in a first working step, a preliminary thread is produced and, in a further working step, the internal thread is completed by forming from the preliminary thread. Due to this two- or multi-stage method, the entire volume of the thread profile does not have to be produced by a single forming tool by plastic deformation of the material, and the loading and the wear are reduced.

[0013] For such a combined method having a plurality of working steps, a separate tool can be used in a first variant in each working step. DE 10 2004 033 772 A1 discloses such a method, in which, in a first working step, a preliminary thread is initially produced in the workpiece with a cutting or chipless action by means of a tap, thread milling cutter, by turning, grinding or winding or also by means of a thread former and, in a second working step, the finish production of the preliminary thread is effected with a chipless action using a thread former or circular former, the forming wedges of which press into the thread root of the preliminary thread.

[0014] The forming wedges are in this case centered by widened portions of their flanks in the initially produced thread. The thread flanks of the preliminary thread produced in the first working step remain unchanged in the second working step, since the widened portions of the forming wedge flanks bear only against the preliminary thread flanks for centering, but do not deform the latter. In the second working step, the workpiece material is deformed further

only in the region of the thread root, connecting the two thread flanks, of the preliminary thread.

[0015] As a result, in the second working step, the entire thread root and also those regions of the thread flanks of the final thread which directly adjoin the thread root and lie in extension of the thread flanks of the preliminary thread are completed by forming and are thus additionally compacted and consolidated, whereas the predominant region of the thread flanks of the final thread have already been completely produced in the first working step and have not been worked further in the second working step.

[0016] In a second known variant of a combined method having a plurality of working steps, a combination tool having a cutting tapping part and a chipless thread-forming part, offset axially to the tool axis relative to the tapping part, on a tool shank is used, the tapping part, with rotation about the tool axis and with axial feed, cutting a preliminary thread in the workpiece in a first working step, and the following thread-forming part forming the preliminary thread in a predetermined manner in a second working step in order to produce the final thread. The tap therefore initially cuts the thread and the thread former subsequently partly forms the initially cut thread. Such an axial combination tool and method are known from DE 70 17 590 U and DE 196 49 190 C2.

[0017] According to DE 196 49 190 C2 the thread is first of all produced with a precise profile and accurately to size in the thread flanks by a cutting action by means of the tap of the combination tool and then only the thread root of this initially cut thread is compacted with a chipless action to a predetermined final diameter by the directly following thread former. As a result, in particular the first thread turns, following an initial thread cut, can be produced in such a way that they are more resistant to vibrations and are less susceptible to fracture. In the second working step, the two thread flanks cut by the tap in the first working step remain completely unchanged.

[0018] DE 70 17 590 U1 discloses a combination tool for producing internal threads, having a tapping drill, designed as a taper or second tap, as a front tool part for the initial cutting of the thread and a thread former, adjoining in the working direction, as a rear tool part for the finishing of the thread.

BRIEF SUMMARY OF THE INVENTION

[0019] Implementations of the present invention relate to methods and devices for producing a thread in at least two working steps. For example, at least one method of producing a thread in a workpiece can involve producing a preliminary thread, having a preliminary thread profile with two preliminary thread flanks and a preliminary thread root connecting the two preliminary thread flanks, in the workpiece by removing material from the workpiece (or, by machining) in at least one first working step (or, process step); and producing a final thread by plastic pressing-in (or, chipless forming) of the material of the workpiece at least in a section of the preliminary thread flanks by a predetermined or predeterminable pressing-in volume in at least one second working step.

[0020] In addition, a device in accordance with an implementation of the present invention can include at least one

preliminary thread production region for the cutting production of a preliminary thread, the preliminary thread profile of which has two preliminary thread flanks and a preliminary thread root connecting the two preliminary thread flanks; and at least one thread-forming region for re-forming the preliminary thread by plastic pressing-in of the material of the workpiece at least in a section of the preliminary thread flanks by a predetermined or predeterminable pressing-in volume.

[0021] First of all, a preliminary thread can be produced in the workpiece with a cutting action or by material removal in at least two working steps, and then the preliminary thread is reworked without material removal, but rather only by plastic pressing-in of a thread-forming region or tool and by the permanent deformation, effected as a result, of the workpiece material and is formed further into the final thread.

[0022] In other words, during the plastic pressing-in for producing the final thread in the second working step, such a high pressure is exerted on the workpiece surface that, beyond purely elastic deformation, specific plastic forming of the workpiece material in the thread region is obtained, this plastic forming in turn leading to an increase in volume in the final thread profile relative to the preliminary thread profile. The plastic pressing-in or forming consolidates the structure in the workpiece material at the relevant thread profile regions and as a rule also effects a flow of the workpiece material if the pressure exerted is above the yield point of the workpiece material. Both the consolidation processes and the flow processes lead on their own or in combination to the desired reduction in volume of the workpiece material and to the complementary increase in volume of the thread profile.

[0023] Implementations of the present invention then, are based at least in part on the notion that, during the re-forming of the preliminary thread, for the material of the workpiece located at the thread flanks of the preliminary thread to be plastically or permanently pressed in (or, formed) by a predetermined or predeterminable pressing-in volume only at or also at said thread flanks.

[0024] Due to this combination of cutting or forming production steps, in particular, threads can also be produced by forming in materials that flow poorly or are difficult to form, such as gray cast iron for example (partly or in final processing); the process forces can be reduced; threads having large thread pitches, in particular 6 mm, and/or large processing cross sections (in the final processing) can be produced by forming; a "claw formation," despite the forming final processing, can be avoided or reduced and thus the nut core or the core diameter can be kept within close tolerances; consolidation and increase in the fatigue strength and dynamic strength of the thread, at least of its finally formed thread flank regions, can be achieved; and smoothing of thread surfaces, at least at the formed flank regions, can be achieved.

[0025] The pressing-in volume at the preliminary thread flanks is in this case preferably established by adapting a thread-forming profile or an effective profile of the thread-forming region to the preliminary thread profile produced beforehand and results in particular as a differential volume of the respective dimensions of preliminary thread profile and thread-forming profile at the preliminary thread flanks

less a possible and as a rule relatively small restoring volume on account of elastic restoring of the workpiece material.

[0026] The final thread also has as a rule a final thread profile with two final thread flanks and a final thread root connecting the two final thread flanks. The final thread flanks of the final thread profile extend at least in sections further into the workpiece material than the preliminary thread flanks beforehand, or the final thread profile is larger, at least in a section of the thread flanks, than the preliminary thread profile by the volume displaced during the pressing-in.

[0027] A thread profile, whether the preliminary thread profile, the thread-forming profile or the final thread profile, is in this case defined in a conventional manner as a contour of a cross section of the thread turn in a sectional plane containing the thread center axis or tool (rotation) axis or in a longitudinal section through the thread turn.

[0028] In one embodiment, the preliminary thread can be reformed only in at least one flank section, in particular flank sections lying further on the inside, of the preliminary thread flank(s), or the final thread profile can be formed only in a flank section or flank sections of the final thread flank(s), in particular in an inner flank section, and can be exclusively cut or machined in the remaining flank section(s).

[0029] In another embodiment, the preliminary thread flanks are pressed in completely or are pressed in further over their entire profile length and the final thread flanks are accordingly reformed completely.

[0030] The pressing-in volumes at the flanks and the thread root, with respect to the same profile length, may be selected to be different, for example larger or smaller at the thread root than at the flanks. In addition, the pressing-in volume may also be selected to be different at different flanks or different flank regions, for example by displacing the preliminary thread profile and the thread-forming profile relative to one another, in particular in the direction of or axially relative to the thread center axis.

[0031] The preliminary thread profile and the thread-forming profile can be produced or represented by a single profile or also by superimposition of a plurality of profiles as a resulting effective profile.

[0032] Furthermore, the production of the preliminary thread profile and the further forming of the preliminary thread profile into the final thread profile in the two working steps may be effected with different tools or also with a joint combination tool.

[0033] The tool or tools or the tool region or tool regions for producing the preliminary thread profile in the first working step may in particular comprise a tapping region and/or a thread milling region, and the tool or tools or the tool region or tool regions for finish forming the final thread in the second working step may comprise a thread-forming region and/or a circular thread-forming region.

[0034] Alternatively, both working steps may also be carried out with a combination tool which has a preliminary thread production region and a thread-forming region which engage one after the other in the workpiece.

[0035] To insert the following thread-forming region into position, said thread-forming region may have an insertion

region or an insertion thread having a profile adapted to the preliminary thread profile, and/or smooth compensation for compression or minus programming with compensation for tension may be provided in the tool clamping means.

[0036] Furthermore, a defined thread start of the preliminary thread in the workpiece or exact insertion of the following thread-forming region at this thread start can be produced by determining the rotary position of the tool(s).

[0037] With the method and the tool(s) according to the invention, all common thread types, including metric threads (e.g. according to DIN or ISO), pipe threads, US UNIFIED threads, MJ threads, US UNJ threads, tapered threads, cylindrical threads, trapezoidal threads, round threads, buttress threads, WHITWORTH threads and also special threads such as re-circulating ball screw threads or self-locking threads, can be produced in two or more stages.

[0038] Additional features and advantages of exemplary implementations of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by the practice of such exemplary implementations. The features and advantages of such implementations may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features will become more fully apparent from the following description and appended claims, or may be learned by the practice of such exemplary implementations as set forth hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] In order to describe the manner in which the above-recited and other advantages and features of the invention can be obtained, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. Understanding that these drawings depict only typical embodiments of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0040] FIG. 1 shows a first embodiment of a cut preliminary thread profile and of a thread-reforming profile in a longitudinal section;

[0041] FIG. 2 shows the superimposition of the two thread profiles according to FIG. 1 and the final thread profile resulting therefrom;

[0042] FIG. 3 shows a second embodiment of a cut preliminary thread profile and of a thread-reforming profile in a longitudinal section;

[0043] FIG. 4 shows the superimposition of the two profiles according to FIG. 3 and the final thread profile resulting therefrom;

[0044] FIG. 5 shows a third embodiment of a cut preliminary thread profile and of a thread-reforming profile in a longitudinal section;

[0045] FIG. 6 shows the superimposition of the two profiles according to FIG. 5 and the final thread profile resulting therefrom;

[0046] FIG. 7 shows a fourth embodiment of a cut preliminary thread profile and of a thread-reforming profile in a longitudinal section;

[0047] FIG. 8 shows the superimposition of the two profiles according to FIG. 7 and the final thread profile resulting therefrom;

[0048] FIG. 9 shows a fifth embodiment of a cut preliminary thread profile and of a thread-reforming profile in a longitudinal section;

[0049] FIG. 10 shows the superimposition of the two profiles according to FIG. 9 and the final thread profile resulting therefrom; and

[0050] FIGS. 11 to 16 are various instantaneous depictions of a working process for producing a preliminary thread using a circular thread milling cutter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0051] FIGS. 1 to 10 show various method steps according to the invention in which the workpiece 50 is formed or pressed in further at the flanks of a preliminary thread for producing a final thread.

[0052] In FIG. 1, on the left-hand side, a preliminary thread profile 1 cut in a workpiece 50 is shown as an internal thread which has a trapezoidal cross section having two flanks 1A and 1B, inclined relative to one another at an opening angle (or, apex angle, intermediate angle) α , and a straight thread root 1C which connects the two flanks 1A and 1B and preferably runs parallel to the surface 50A of the workpiece 50, said surface 50A in particular being the inner surface of the core hole. A center axis of the preliminary thread profile 1, said center axis running perpendicularly to the thread center axis (or, thread longitudinal direction) (not shown), is designated by M1 and at the same time forms, in the exemplary embodiment according to FIGS. 1 and 2, an axis of symmetry of the preliminary thread profile 1. The preliminary thread profile 1 is preferably produced by a tap or a thread milling cutter or also by a combination of both tools, such as a circular drill thread milling cutter and is generally obtained as an effective profile from superimposition of all the individual profiles of the cutting edges of the tool engaging one behind the other.

[0053] Shown on the right-hand side of FIG. 1 is a thread-forming profile 2 which is obtained as an effective profile or superimposed profile of a thread-forming process or of a thread-forming tool. In a thread-forming tool having a plurality of pressing lobes or forming teeth, the effective profile or thread-forming profile 2 shown corresponds to the superimposition of all the individual profiles of the individual pressing lobes or forming teeth. The thread-forming profile 2 has two straight or linear flanks 2A and 2B, which, inward into the workpiece 50, enclose the same opening angle α relative to one another as the preliminary thread flanks 1A and 1B (for example about 60°), and a thread root region 2C which connects the two flanks 2A and 2B and is rounded or convexly curved, in particular in the shape of an arc of a circle or with a constant radius of curvature.

[0054] A center axis, running perpendicularly to the thread center axis (not shown), of the thread-forming profile 2 is designated by M2 and at the same time forms, in the

exemplary embodiment according to FIGS. 1 and 2, an axis of symmetry of the thread-forming profile 2. In the tool, the thread-forming region 2C is the outer region lying radially furthest on the outside or the superimposition of the tooth tips of the forming teeth; and in the complementary profile formed in the workpiece, said thread root region 2C is the thread root or the deepest region in the workpiece. The thread root region 2C of the thread-forming profile 2 is now arranged further outward by a radial difference or a radial distance ΔR or has a corresponding larger radial infeed into the workpiece than the preliminary thread profile 1.

[0055] Shown in FIG. 2 on the left-hand side is the superimposition of the preliminary thread profile 1 and the thread-forming profile 2. The two center axes M1 and M2 are made to coincide or are brought into line. As a result, also on account of the same opening angle α , the flanks 1A and 2A and respectively 1B and 2B run parallel to one another and each of the flanks 2A and 2B of the thread-forming profile 2 lies further on the outside than the associated flank 1A and 1B of the cut preliminary thread profile 1 in each case by the same difference in length (or, length difference) ΔL measured in the thread longitudinal direction.

[0056] Due to the thread-forming process, following the pre-cutting process during which the preliminary thread profile 1 is produced, by means of the thread-forming profile 2, the material of the workpiece 50 at the preliminary thread profile 1 is therefore displaced further in all directions according to FIGS. 1 and 2. In the process, at the two respective flanks, due to cold working and flow of the material and due to compaction, a volumetric difference ΔVA is incorporated further into the workpiece 50 between the original flank 1A of the preliminary thread profile 1 (preliminary thread flank) and the flank 2A of the thread-forming profile 2 (thread-forming flank) and a volumetric difference ΔVB is incorporated further into the workpiece 50 between the preliminary thread flank 1B and the thread-forming flank 2B.

[0057] The two pressing-in volumes ΔVA and ΔVB are determined by the length difference ΔL of the two flanks 1A and 2A and respectively 1B and 2B. According to FIGS. 1 and 2, on account of the relatively large radial difference ΔR , a comparatively large pressing-in volume ΔVC is incorporated further into the workpiece 50 at the thread root in a forming manner by means of the thread-forming profile 2 and its thread root 2C. The pressing-in volume ΔVC lies between the thread root 1C of the preliminary thread 1 and the thread root region 2C of the thread-forming profile 2.

[0058] The finished final thread 3 produced by these two working steps is shown in the right-hand half of FIG. 2. On account of the special configuration of the preliminary thread 1 and of the thread-forming profile 2 in FIG. 1, both flanks 3A and 3B and the thread root 3C of the final thread profile 3 have the form of the thread-forming profile 2; that is to say that the thread-forming profile 2 is reproduced completely in the workpiece 50, the center axis M of the final thread profile 3 corresponds to the center axis M2 of the thread-forming profile 2, and the entire final thread profile 3 is produced over its entire surface by forming and by the volume displacement, effected as a result, of workpiece material.

[0059] As a result, compaction or consolidation of the workpiece material is also achieved along the entire final

thread profile 3, this compaction or consolidation being indicated by broken lines. A plurality of such lines mean that the compaction is greater and extends deeper, which is the case in the present exemplary embodiment in the region of the thread root 3C and of an adjoining section, corresponding to the radial difference ΔR , of the flanks 3A and 3B.

[0060] Shown in the second exemplary embodiment according to FIGS. 3 and 4 is a triangular preliminary thread profile 11 having two thread flanks 11A and 11B, arranged inward at an opening angle β , and a thread root 11C lying at the intersection of the two thread flanks 11A and 11B and forming essentially a line. Shown on the right-hand side is a thread-forming profile 12 having flanks 12a and 12B directed at the same opening angle β relative to one another and a rounded thread root region 12C. The thread root 11C of the preliminary thread profile 11 projects further into the workpiece 50 than in the case of the preliminary thread profile 1 according to FIG. 1, such that the radial distance ΔR between the thread root region 12C of the thread-forming profile 12 and the thread root 11C of the preliminary thread profile 11 in FIG. 3 is markedly smaller than in FIG. 1.

[0061] As shown in FIG. 4 on the left-hand side, upon superimposition of the two thread profiles 11 and 12, with coinciding center axes M1 of the preliminary thread profile 11 and M2 of the thread-forming profile 12, this results in a markedly reduced pressing-in volume ΔVC , compared with FIG. 2, in the thread root region between the thread root 11C of the preliminary thread profile 11 and 12C of the thread-forming profile 12. At the flanks, however, on account of the narrower preliminary thread profile 11 in FIG. 3 compared with the preliminary thread profile 1 in FIG. 1 and on account of the larger length distance ΔL , effected as a result, between the flanks 11A and 12A and respectively 11B and 12B, a larger pressing-in volume ΔVA and ΔVB is obtained at both respective flank regions during the re-forming of the preliminary thread profile 11 by means of the thread-forming profile 12.

[0062] The pressing-in volumes ΔVA , ΔVB and ΔVC approximately produce a region of constant thickness around the preliminary thread profile 11, such that approximately uniform compaction over the entire final thread profile 13 is achieved, as shown on the right-hand side of FIG. 4. The thread-forming profile 12 is also reproduced completely on the final thread profile 13 in the embodiment according to FIGS. 3 and 4, and therefore both thread flanks 13A and 13B and also the thread root region 13C of the final thread profile 13 have been completely produced or reworked during the re-forming with the thread-forming profile 12.

[0063] In the exemplary embodiment according to FIGS. 5 and 6, the thread flanks 21A and 21B of the preliminary thread profile 21 and also the flanks 22A and 22B of the thread-forming profile 22 are directed toward one another at the same respective opening angle γ or enclose this angle γ . The thread root 21C of the preliminary thread profile 21 and the thread root region 22C of the thread-forming profile 22 are both designed to be convexly curved and rounded off, in particular in a circular manner. The center axes M1 and M2 both again form respective axes of symmetry of the associated profiles 21 and 22, respectively.

[0064] The superimposition of the preliminary thread profile 21 and the thread-forming profile 22, subsequently

engaging in a forming manner, is shown on the left-hand side of FIG. 6, and the resulting final thread profile 23 is shown on the right-hand side of FIG. 6. In contrast to FIGS. 1 to 4, the two center axes M1 and M2 are not made to coincide, but rather are arranged parallel to one another at a distance d. This lateral translation of the profiles 21 and 22 or of their center axes M1 and M2 relative to one another now results in an asymmetrical pressing-in volume, despite the symmetrical profiles 21 and 22. The pressing-in volume ΔVA between the preliminary thread flank 21A and the flank 22A of the thread-forming profile 22 is smaller than the pressing-in volume ΔVB between the preliminary thread flank 21B and the flank 22B of the thread-forming profile 22 by an amount resulting from the distance d between the center axes M1 and M2.

[0065] The radial distance ΔR between the thread root region 22C of the thread-forming profile 22 and the thread root 21C of the preliminary thread profile 21 is selected in such a way that the pressing-in volume ΔVC pressed in at the thread root 21C of the preliminary thread 21 is greater, with respect to the engagement length of the profile, than the pressing-in volumes ΔVA and ΔVB .

[0066] According to FIG. 6, too, the thread-forming profile 22 is reproduced completely in the workpiece 50 and the entire final thread profile 3 is produced by forming and by the volume displacement, effected as a result, of workpiece material.

[0067] In the exemplary embodiment according to FIGS. 7 and 8, both the preliminary thread profile 61 and the thread-forming profile 62 each have two linear or straight flanks 61A and 61B and respectively 62A and 62B which are inclined at the same angle γ relative to one another and are each connected to one another via a thread root 61C and 62C. The thread-forming profile 62 is now designed to be larger than the preliminary thread profile 61 on all sides and runs essentially in parallel at the length distance ΔL , measured in longitudinal section, between the flanks 62A and 61A and 62B and 61B and at the radial distance ΔR , selected to be slightly larger. Here, the center axes M1 and M2 of the profiles 61 and 62 coincide again.

[0068] As a result, a pressing-in volume ΔVA and ΔVB which is uniform over the preliminary thread flanks 61A and 61B and is of the same width is produced in FIG. 8 on the left, and a slightly greater pressing-in volume ΔVC and thus higher compaction is produced at the thread root 63C of the final thread profile 63. The final thread profile 63 according to FIG. 8 on the right is reproduced completely from the thread-forming profile 62; in particular its center axis M is therefore identical to the center axis M2 of the thread-forming profile 62.

[0069] In the exemplary embodiment according to FIG. 9 and FIG. 10, in contrast to the exemplary embodiment according to FIG. 7 and FIG. 8, only the radial distance ΔR is selected to be smaller and corresponds to the length distance ΔL , such that the thread-forming profile 73 runs essentially at a constant distance around the preliminary thread profile 61 and therefore the pressing-in volumes ΔVA , ΔVB and ΔVC and thus the compaction are essentially uniform over the entire thread profile.

[0070] The curved thread root regions preferably curved convexly, in particular in a circular shape, or elliptically or

parabolically in all the embodiments with respect to the interior space or the thread turn.

[0071] A working movement with a tool **5** designed as a thread milling cutter and having a number of thread milling teeth **6** for producing a preliminary thread according to the invention is shown in FIGS. **11** to **16**. First of all the tool **5** is positioned with its tool axis A coaxially to a center axis B of a hole **55** in the workpiece **50** (FIG. **11**). From this initial position, the tool **5** is now plunged with a linear feed movement axially to the tool axis A and center axis B into the hole **55** in the workpiece **50**, in particular down to the thread depth (FIG. **12**). With an approach radius or an approach loop, the tool **5** is now fed in radially to the inner wall of the hole **55** according to FIG. **13**. According to FIG. **14**, the tool **5**, with a number of revolutions of its tool axis A which result from the number of thread milling teeth **6** and the number of desired thread turns, is now moved with a circular movement about the center axis B with at the same time a feed movement parallel to the tool axis A.

[0072] As a result, the tool **5** produces in the inner wall of the hole **55** an internal thread as preliminary thread **7** having a pitch which results from the feed rate and the spacing of the individual thread milling teeth **6** of the tool **5**. After this helical working movement according to FIG. **14**, the tool **5** is now adjusted radially again relative to the center according to FIG. **15**, such that the tool axis A and the center axis B are coaxial to one another again. For this retraction movement, a withdrawal radius is again provided. According to FIG. **16**, with an axial return movement, the tool **5** is moved out of the hole **55** axially relative to the center axis B back into its initial position. The center axis B of the produced preliminary thread **7** in the hole **55** coincides with the center axis of the circular movement of the tool **20** during the working movement in FIG. **14**.

[0073] Following this cutting production of the preliminary thread **7**, the preliminary thread **7** is now shaped further in a second working step for producing the final thread. The two working steps of preliminary thread production and final thread production by re-forming the preliminary thread can be carried out with various tools for each working step or also with combined tools for two or more working steps. The cutting preliminary thread region(s) of the tool(s) may be designed as a tapping region, thread milling region, drill thread milling region or grinding, turning or winding region. The final thread production region(s) of the tool(s) comprises the thread-forming profile as effective profile and preferably has at least one thread-forming region or at least one circular thread-forming region.

[0074] The invention is not restricted to the embodiments shown and described, but rather can also be realized in a multiplicity of other embodiments. For example, the flanks of the thread profiles need not be designed to be linear or straight, but may also run in a curved manner. The thread profiles need not be symmetrical to a center axis, but may also be designed to be asymmetrical to the center axis. The re-forming of the preliminary thread profile during the final thread production may also be carried out only on the preliminary thread flanks and not on the preliminary thread root too and/or only in sections of the preliminary thread flanks and/or only on one of the two preliminary thread flanks.

[0075] The present invention may be embodied in other specific forms without departing from its spirit or essential

characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes that come within the meaning and range of equivalency of the claims are to be embraced within their scope.

List of Designations

1	Preliminary thread profile
1A, 1B	Preliminary thread flank
2	Thread-forming profile
2A, 2B	Flank
3	Final thread profile
3A, 3B	Flank
5	Tool
6	Thread-milling teeth
7	Preliminary thread
11	Preliminary thread profile
11A, 11B	Preliminary thread flank
12	Thread-forming profile
12A, 12B	Flank
13	Final thread profile
13A, 13B	Flank
21	Preliminary thread profile
21A, 21B	Preliminary thread flank
22	Thread-forming profile
22A, 22B	Flank
23	Final thread profile
23A, 23B	Flank
50	Workpiece
50A	Surface
55	Hole
A, B	Axis
M1, M2, M	Center axis
α, β, γ	Angle
$\Delta VA, \Delta VB, \Delta VC$	Pressing-in volume
$\Delta R, d, \Delta L$	

We claim:

1. A method of producing a thread in a workpiece, comprising the steps:

a) producing a preliminary thread in the workpiece in at least one first working step by removing material from the workpiece, wherein a preliminary thread profile of the preliminary thread has two preliminary thread flanks and a preliminary thread root connecting the two preliminary thread flanks;

b) producing a final thread in at least one second working step by plastic pressing-in of the material of the workpiece at least in a section of at least one of the two preliminary thread flanks by a predetermined pressing-in volume.

2. The method as claimed in claim 1, wherein, in the second working step, the material of the workpiece is essentially pressed in over the entire preliminary thread flank(s) by the predetermined pressing-in volume.

3. The method as claimed in claim 1, wherein, in the second working step, the material of the workpiece is in each case pressed in in at least one first flank section of the preliminary thread flank(s) and remains essentially unchanged in at least one second flank section which adjoins the first flank section of the preliminary thread flank(s).

4. The method as claimed in claim 1, wherein the final thread has a final thread profile with two final thread flanks and a final thread root connecting the two final thread flanks.

5. The method as claimed in claim 4, wherein at least one final thread flank is formed completely by plastic pressing-in in the second working step.

6. The method as claimed in claim 4, further comprising the steps:

forming at least one final thread flank in at least one first flank section by plastic pressing-in in the second working step; and

producing the at least one final thread flank in a second flank section adjoining the first flank section solely by the material removal in the first working step.

7. The method as claimed in claim 1, further comprising the steps:

using a thread-forming profile in the second working step for the plastic pressing-in of the material of the workpiece;

wherein the thread-forming profile has two flanks and a root region connecting the two flanks.

8. The method as claimed in claim 1, further comprising producing, in the first working step, a preliminary thread in which at least one of its preliminary flanks has an outer flank section and an inner flank section extending between the outer flank section and the preliminary thread root.

9. The method as claimed in claim 8, further comprising producing, in the second working step, a final thread having a final thread profile, wherein one or both of:

a) at least one of the final thread's final flanks comprises an outer flank section of the preliminary thread profile and an inner flank section of the thread-forming profile; or

b) at least one of the final thread's final thread flanks comprises an outer flank section of the thread-forming profile and an inner flank section of the preliminary thread profile.

10. The method as claimed in claim 8, further comprising:

a) using, in the second working step for the plastic pressing-in of the material of the workpiece, a thread-forming profile which has two flanks and a root region connecting the two flanks, at least one of these flanks of the thread-forming profile being subdivided into an outer flank section and an inner flank section; and

b) producing, in the second working step, a final thread having a final thread profile, wherein one or both of:

1) at least one of the final thread's final flanks comprises an outer flank section of the preliminary thread profile and an inner flank section of the thread-forming profile; or

2) at least one of the final thread's final thread flanks comprises an outer flank section of the thread-forming profile and an inner flank section of the preliminary thread profile.

11. The method as claimed in claim 1, wherein the pressing-in volume, with respect to an identical profile length of the preliminary thread profile, is larger at the preliminary thread root than at the preliminary thread flank(s).

12. The method as claimed in claim 1, wherein the pressing-in volume, with respect to an identical profile length of the preliminary thread profile, is smaller at the preliminary thread root than at the preliminary thread flank(s).

13. The method as claimed in claim 1, wherein the preliminary thread flanks of the preliminary thread profile and the flanks of the thread-forming profile enclose the same opening angle relative to one another.

14. A device for producing threads in workpieces, comprising:

a) at least one preliminary thread production region for the cutting production of a preliminary thread, the preliminary thread profile of which has two preliminary thread flanks and a preliminary thread root connecting the two preliminary thread flanks; and

b) at least one thread-forming region for re-forming the preliminary thread by plastic pressing-in of the material of the workpiece at least in a section of the preliminary thread flanks by a predetermined pressing-in volume.

15. The device as claimed in claim 14, wherein the at least one preliminary thread production region and the at least one thread-forming region are each formed on an associated tool.

16. The device as claimed in claim 14, wherein the at least one preliminary thread production region and the at least one thread-forming region are formed on a common combined tool.

17. The device as claimed in claim 14, wherein:

a thread-forming profile of the thread-forming region has two flanks and a thread root region connecting the two flanks; and

at least sections of the flanks of the thread-forming profile have larger dimensions, or are at a larger distance apart, than one of:

the preliminary thread flanks; or

the flanks of a thread-cutting profile of the preliminary thread production region.

18. The device as claimed in claim 14, the device being configured for carrying out a method as claimed in one of 1, wherein the final thread resulting from the preliminary thread is re-formed by the thread-forming region.

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