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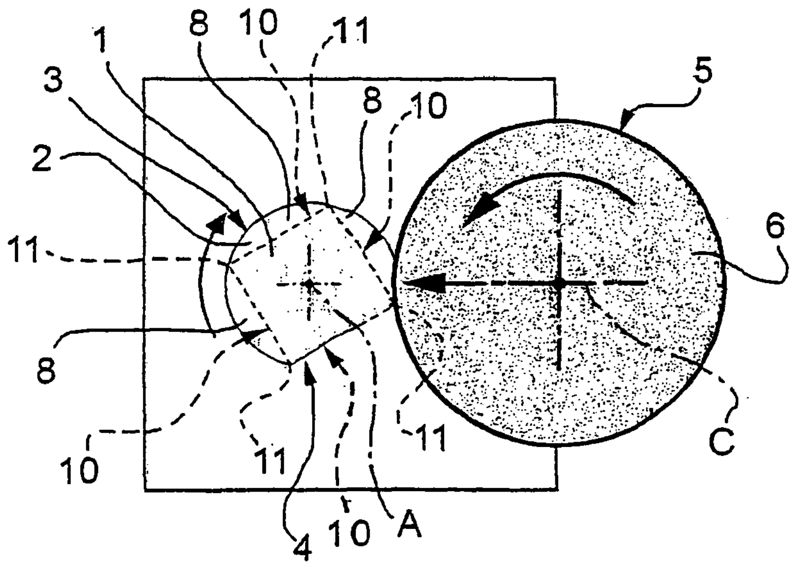
(54) **Method for forming a shaped element via removal of material from a starting element**

(57) Described herein is a method for forming a shaped element (1) via removal of material from a starting element (3); the shaped element (1) has a profile (4) that can be inscribed in a reference surface of rotation (2) having a first axis (A); the method comprises the steps of: rotating the starting element (3) about the first axis (A) and translating a tool (6) according to a path having at least one component incident with respect to the first axis (A) in such a way that the tool (6) will remove material from a peripheral edge (2) of the starting element (3); the method moreover comprises the step of forming, in a complete way, a single portion (10) of the profile (4) before passing on to forming subsequent portions (10); the portion (10) formed in each step of forming is obtained via translation of the tool (6) exclusively in a single direction.

FIG. 8



EP 2 030 731 A1

Description

[0001] The present invention relates to a method for forming a shaped element, for example a cam or a crankshaft for automotive use, via removal of material from a starting element.

[0002] It is known to obtain the profile of a shaped element by removing material from a peripheral edge of a starting element by means of a tool having, at one end edge thereof, a cutting edge, for example a grinding wheel.

[0003] In greater detail, the starting element is fixed to a supporting structure in such a way that it is able to turn about a first axis and is driven in rotation about the first axis itself.

[0004] The tool rotates about a second axis parallel to the first axis and co-operates, via the cutting edge, with the peripheral edge of the starting element so as to remove material therefrom and generate the profile of the shaped element.

[0005] The tool is moreover moved radially with respect to the first axis in such a way that the cutting edge will remain always in contact with the peripheral edge being machined of the starting element so as to be able to remove new material therefrom.

[0006] The profile of the shaped element is formed by means of a plurality of consecutive passes of the cutting edge of the tool. In particular, the cutting edge of the tool describes, in each pass, the entire peripheral edge being machined of the starting element, thus removing the material therefrom.

[0007] The profile to be formed of the shaped element comprises, in general, one or more portions, for example lobes that are eccentric with respect to the first axis; i.e., they extend at variable distances from the first axis.
More precisely, the cutting edge of the tool, when it forms said eccentric portions, moves away from the first axis to form the stretches of said portions extending at increasing distances from the first axis, proceeding in the direction of rotation of the tool itself, and approaches the first axis to form the stretches of said portions extending at decreasing distances from the aforesaid first axis with respect to the aforesaid direction of rotation of the tool itself.

[0008] Said travel of approach and recession generates a cycle of fatigue and onset of vibrations exerting pressure on the supporting members of the motor that drives the tool. Said fatigue cycle and said vibrations reduce the service life of the tool, reduce the precision thereof, and limit the maximum cutting speed thereof.

[0009] In the case where the eccentric portion is particularly steep, i.e., it presents a considerable radial extension as compared to a small circumferential extension with respect to the first axis, the tool is, moreover, subjected in a short time to considerable accelerations and decelerations.

[0010] In this case, marked inertial stresses are generated, which exert pressure on the supporting members and/or motors of the tool, further limiting the useful service life, the precision, and the maximum cutting speed thereof.

[0011] The aim of the present invention is to provide a method for forming a shaped element via removal of material from a starting element that will enable at least one of the drawbacks linked to the methods of a known type and specified above to be overcome in a simple and inexpensive way.

[0012] The aforesaid aim is achieved by the present invention in so far as it regards a method for forming a shaped element via removal of material from a starting element as defined in Claim 1.

[0013] For a better understanding of the present invention a preferred embodiment is described in what follows, purely by way of non-limiting example and with reference to the attached figures, wherein:

- Figure 1 is a perspective view of a step of the method for forming a shaped element according to the present invention; and
- Figures 2 to 8 are schematic illustrations of subsequent steps of the method for forming a shaped element according to the invention.

[0014] With particular reference to the attached figures, designated by 1 is a shaped element formed by removal of material from a starting element 2 (visible in Figures 2 to 8).

[0015] The element 1 comprises a peripheral profile 4 formed via removal of material from a peripheral surface 3 (visible in Figures 2 to 8) of the element 2.

[0016] In particular, the material is removed from the surface 3 via a tool 6 (only schematically illustrated in Figures 2 to 8), for example a grinding wheel, provided with a cutting edge 5, which is designed to interact with the surface 3 of the element 2 for forming the profile 4 of the element 1.

[0017] The element 1 is rotatably mounted about an axis A on a self-centring platform (Figure 1), and the tool 6 is rotatably mounted about an axis B parallel to the axis A.

[0018] Alternatively, the element 1 could be mounted on a headstock and a tailstock.

[0019] The profile 4 and the surface 3 delimit the elements 1, 2 on the side opposite to the axis A, whilst the cutting edge 5 delimits the tool 6 on the side opposite to the axis B.

[0020] The tool 6 is mobile, moreover, in a direction C radial with respect to the axes A, B.

[0021] The tool 6 is driven in rotation about the axis B and is made to advance in the direction C by a motor member (not illustrated). The motor member is supported by supporting means (not illustrated either).

[0022] The profile 4 of the element 1 can be of any type and can be inscribed in a surface of rotation of axis A, i.e., obtained by rotating a generatrix about the axis A.

[0023] According to the shape of the profile 4, the surface of rotation can be the lateral surface of a cylinder or of a cone.

[0024] In the case where the profile 4 were inscribed in the lateral surface of a cone, the axis B would be coplanar and incident with respect to the axis A.

[0025] In particular, the element 1 could be a solid without faces and delimited only by curved surfaces.

[0026] In an extreme case, the element 1 could be a cylinder having an axis eccentric with respect to the axis A.

[0027] In the case illustrated in Figure 1, the element 1 is a hexagonal prism constrained to a crankshaft, whereas in the case illustrated in Figures 2 to 8, the element 1 is a parallelepiped.

[0028] In the sequel of the present description, reference will be made, for reasons of simplicity and without this implying any loss of generality, to the method for forming the element 1 of a parallelepipedal shape illustrated in Figures 2 to 8.

[0029] The profile 4 of the element 1 comprises four faces 10, lying on four planes set at a distance from the axis A, orthogonal two by two to one another.

[0030] Each face 10 is delimited by a pair of elongated sharp edges 11 parallel to the axis A.

[0031] The profile 4 is inscribed within the lateral surface of a reference cylinder coinciding, in the case illustrated, with the cylindrical surface 3 of the starting element 2.

[0032] Each face 10 has a plane passing through the points of the face 10 itself set at the minimum distance from the axis A.

[0033] Since the face 10 is inscribed in the lateral surface of a cylinder of axis A, the aforesaid plane coincides with the median plane of the face 10 itself.

[0034] The face 10 moreover comprises a region 12 extending from a first sharp edge 11 delimiting the face 10 up to the plane passing through the points set at the minimum distance of the face 10 itself, and a region 13 extending from a second sharp edge 11 delimiting, on the side opposite to the first sharp edge 11, the same face 10 up to the aforesaid plane.

[0035] Thanks to the fact that the element 1 is a parallelepiped, the regions 12, 13 of each face 10 are separate from the median plane of the face 10 itself.

[0036] Proceeding in a clockwise direction with respect to the axis A, the region 12 follows the region 13 and extends at increasing distances from the axis A.

[0037] Proceeding always in a clockwise direction with respect to the axis A, the region 13 extends at decreasing distances from the axis A.

[0038] The surface 3 of the element 2 has four generatrices in common with the sharp edges 11 of the profile 4.

[0039] The method for forming the shaped element comprises the steps of rotating the element 2 about the axis A and the tool 6 about the axis B and translating the tool 6 in the direction C so as to bring the cutting edge 5 into contact with the surface 3 and remove therefrom material so as to form the profile 4 of the element 1.

[0040] Preferably, the point of contact between the cutting edge 5 and the surface 3 is distinct from the generatrices of the surface 3 coinciding with the sharp edges 11 of the element 2.

[0041] Advantageously, the method according to the present invention comprises the step of forming in a complete way a single face 10 of the profile 4 before passing on to forming the subsequent faces 10; each face 10 is formed via translation of the tool 6 exclusively in the direction of the axis A.

[0042] In greater detail, the tool 6 forms, one after the other, a plurality of stretches 14, 15, 16, 17, 18, 19 of each face 10.

[0043] Each stretch 14, 15, 16, 17, 18, 19 is formed via the respective translation of the tool 6 exclusively towards the axis A in the direction C and the simultaneous rotation of the tool 6 about the axis B.

[0044] In particular, the stretches 14, 16, 18 form part of the region 12, whilst the stretches 15, 17, 19 form part of the second region 13 of the face 10.

[0045] Each face 10 is obtained via removal of material from a corresponding portion 8 of the element 2.

[0046] In particular, each portion 8 has in a section transverse to the axis A the shape of a circular segment, and is delimited on the side opposite to the axis A by the area of the surface 3 comprised between the two generatrices that coincide with the sharp edges 11 of the corresponding face 10.

[0047] Each portion 8 comprises a first region and a second region set symmetrically on opposite sides of a median plane thereof and designed to form, once the removal of material has been completed, the regions 12, 13 of the face 10.

[0048] The face 10, which is made first, is formed in the way described in what follows.

[0049] The element 2 and the tool 6 are driven in rotation about the respective axes A, B in a counterclockwise direction (Figure 2).

[0050] Simultaneously to rotation about the axis B, the tool 6 translates in the direction C towards the axis A until the cutting edge 5 comes to bear upon the surface 3 of the element 2.

[0051] Next (Figure 3), the element 2 is driven in rotation about the axis A in a second direction, opposite to the first, and in the case illustrated clockwise.

[0052] The tool 6 advances towards the axis A in the direction C, removing material from the first region of the portion 8 corresponding to the face 10 being formed.

[0053] In this way, the stretch 14 of the region 12 of the face 10 (Figure 4) is formed completely.

[0054] Once the stretch 14 of the face 10 being machined has been formed, the tool 6 ceases to translate, whilst it continues to rotate about the axis B in a counterclockwise direction. Simultaneously, the element 2 continues to rotate in a clockwise direction (Figure 4).

[0055] In this way, the cutting edge 5 traverses the median plane of the portion 8 being machined, continuing to remove material from the portion 8 itself (Figure 5).

[0056] When the cutting edge 5 reaches the region 13 of the face 10 being machined, the clockwise rotation of the element 2 is stopped (Figure 5).

[0057] Next, the element 2 is driven in rotation in a counterclockwise direction (Figure 6).

[0058] Simultaneously, the tool 6 translates further towards the axis A so as to remove the area represented hatched in Figure 6 and form the stretch 15 of the face 10.

[0059] In particular, the stretch 15 is adjacent to and set at a distance from the second sharp edge 11 and is located on the opposite side of the stretch 14 with respect to the median plane of the face 10.

[0060] At this point, translation of the tool 6 is stopped, and the element 2 rotates in a counterclockwise direction until the cutting edge 5 traverses the median plane of the portion 8 and co-operates with the first region of the portion 8 in a position immediately adjacent to and set at a distance from the stretch 14.

[0061] The tool 6 advances further towards the axis A so as to form the stretch 16 of the face 10.

[0062] In particular, the stretch 16 is adjacent to and set at a distance from the stretch 14.

[0063] The stretch 16 is moreover set between the stretch 14 and the median plane of the corresponding face 10.

[0064] Once formation of the stretch 16 has been completed, translation of the tool 6 is stopped, and the element 2 rotates in a clockwise direction.

[0065] The cycle is repeated a number of times (Figure 7) until the stretches 17, 18, 19 of the face 10 are formed, in this way completing the face 10 itself.

[0066] More precisely, the stretches 17, 18, 19 are adjacent to and set at a distance from the stretches 15, 16 and 17.

[0067] During formation of each stretch 14, 15, 16, 17, 18, 19, the tool 6 advances towards the axis A by the same length measured in a direction radial to the axis A itself.

[0068] The tool 6 moreover describes a reciprocating motion of translation towards the axis A. More precisely, the tool 6 advances towards the axis A when it forms the stretches 14, 15, 16, 17, 18, 19 and remains fixed with respect to the axis A itself when it does not form the aforesaid stretches 14, 15, 16, 17, 18, 19.

[0069] The portions of the face 10 being machined set between the stretches 14, 16; 16, 18; 15, 17; 17, 19 are obtained from the impressions left by the tool 6 during formation of the stretches 14, 16, 18, 15, 17, 19. More precisely, the tool 6 has a radius of curvature much greater than the distance between the ends of the stretches 14, 16 adjacent to one another. In this way, when the tool 6 advances in the direction C and forms, for example, the stretches 14, 16, it leaves in the areas adjacent to the stretches 14, 16 themselves a pair of impressions substantially forming the corresponding region of the face 10 set, once again by way of example, between the stretches 14, 16.

[0070] The aforesaid corresponding region of the face 10 is completed via a subsequent finishing process.

[0071] It should be emphasized that, when the element 2 rotates in a clockwise direction with respect to the axis A, the tool 6 forms the stretches 14, 16, 18.

[0072] In particular, the cutting edge 5 of the tool 6 forms first the ends of each stretch 14, 16, 18 that are at a greater distance from the median plane and subsequently proceeds in the direction of the aforesaid median plane, sequentially forming, in this way, areas of the stretches 14, 16, 18 extending at decreasing distances from the axis A.

[0073] In addition, when the element 2 rotates in a counterclockwise direction with respect to the axis A, the tool 6 forms the stretches 15, 17, 19.

[0074] More precisely, the cutting edge 5 of the tool 6 first forms the end of each stretch 15, 17, 19 that is at a greater distance from the median plane and subsequently proceeds in the direction of the aforesaid median plane, forming sequentially, in this way, areas of the stretches 15, 17, 19 extending at decreasing distances from the axis A.

[0075] By forming sequentially areas of the stretches 14, 15, 16, 17, 18, 19 extending at decreasing distances from the axis A, the cutting edge 5 can form the face 10 moving exclusively towards the axis A itself and in the direction C.

[0076] At this point, the first face 10 is completely formed.

[0077] The tool 6 is positioned on one of the sharp edges 11 of the face 10 just formed, and the further faces 10 are formed in a way altogether similar to what has been illustrated with reference to the face 10.

[0078] In a second embodiment of the method according to the invention, the tool 6, during the first reversal of the direction of rotation of the element 2, does not translate in the direction C towards the axis A, but rotates only about the axis B. Also in this case, the tool 6, even though it does not form the stretch 14, even so removes material from the first region of the portion 8 corresponding to the face 10 being formed.

[0079] In a further embodiment of the method according to the invention, the tool 6 advances continuously without interruption in the direction C. In said embodiment, the stretches 14, 15, 16, 17, 18, 19 are reduced to respective points of the face 10.

[0080] From an examination of the characteristics of the method according to the invention, the advantages that it makes available are evident.

[0081] In particular, thanks to the fact that the faces 10 are formed, one after another and by translation of the tool 6 exclusively towards the axis A, the need for the tool 6 to describe a plurality of consecutive travels of approach and recession from the axis A is avoided.

[0082] Consequently, the fatigue stresses and the vibrations that exert pressure on the motor members and members for supporting the tool 6 are particularly low as compared to those involved in methods forming of a known type and referred to in the introductory part of the present description.

[0083] Thanks to the fact that the faces 10 are made in a complete way and one after another, the path that the cutting edge 5 must follow in order to form the element 1 is reduced as compared to the solutions of a known type and described in the introductory part of the present description.

[0084] This determines a drastic reduction in the times necessary for forming the element 1 without jeopardizing the precision of the forming operation.

[0085] Finally, the method according to the present invention does not require the presence of a preferential point of first contact of the tool 6 with the surface 3.

[0086] In this way, the method according to the present invention does not require execution of an operation of pre-positioning between the surface 3 of the element 2 and the cutting edge 5 of the tool 6.

[0087] In fact, reversal of the direction of rotation occurs when the cutting edge 5 reaches any point of the region 12.

[0088] Finally, it is clear that modifications and variations can be made to the method according to the present invention, without thereby departing from the sphere of protection of the present invention.

[0089] In particular, in the case where the element 1 were hollow, the cutting edge 5 would form each face 10 translating in the direction C exclusively on the side opposite to the axis A.

[0090] The direction of rotation of the tool 6 about the axis B could be clockwise, instead of counterclockwise.

[0091] Finally, the surface 3 of the cylinder could only surround at a distance the profile 4 to be formed without having any points of contact with the profile 4 itself.

Claims

1. A method for forming a shaped element (1) via removal of material from a starting element (2), said shaped element (1) having a profile (4) that can be inscribed in a reference surface of rotation (3) having a first axis (A); said method comprising the steps of:

   - rotating said starting element (2) about said first axis (A); and
   - translating a tool (6) according to a path (C) having at least one component incident with respect to said first axis (A) so that said tool (6) will remove material from a peripheral edge (3) of said starting element (2);

   said method being **characterized in that** it comprises the step of forming a single portion (10) of said profile (4) in a complete way before passing on to formation of a subsequent portion (10); said portion (10) of said profile (4) being formed in each of said steps of forming via translation of said tool (6) exclusively in a single direction.

2. The method according to Claim 1, **characterized in that** said step of forming said single portion (10) comprises the step of forming a stretch (14) of said portion (10) before passing on to formation of a subsequent stretch (15, 16, 17, 18, 19); each of said stretches (14, 15, 16, 17, 18, 19) being formed via a translation of said tool (6) exclusively in a single direction.

3. The method according to Claim 2, **characterized in that** said tool (6) translates, during said step of forming each of said stretches (14, 15, 16, 17, 18, 19), towards the first axis (A) of the same length measured radially with respect to said first axis (A) itself.

4. The method of forming according to Claim 2 or Claim 3, **characterized in that** said step of forming said single portion (10) comprises the steps of:

   - rotating said starting element (2) in a first direction about said first axis (A) so that a first region of said starting element (2) will face said tool (6);
   - rotating said starting element (2) in a second direction, opposite to the first direction, about said first axis (A) so as that a second region, distinct from said first region, will face said tool (6);
   - translating said tool (6) towards said first axis (A) during said step of rotating said starting element (2) in said first direction so as to remove material from said first region and form a corresponding first said stretch (14, 16, 18) of said portion (10); and
   - translating said tool (6) towards said first axis (A) during said step of rotating said starting element (2) in said second direction so as to remove material from said second region and form a corresponding second said stretch (15, 17, 19) of said portion (10).

5. The method according to Claim 4, **characterized in that** said tool (6), during each of said steps of rotating said starting element (2) in said first and second directions, first translates towards said first axis (A) so as to form, respectively, said first and second stretches (14, 16, 18; 15, 17, 19) and is subsequently arrested during the residual rotation of said starting element (2).

6. The method according to Claim 4 or Claim 5, **characterized in that** at least one of said second stretches (15; 17) is formed immediately after a said first stretch (14; 16) and immediately before a further said first stretch (16; 18).

7. The method according to any one of Claims 4 to 6, **characterized in that**, during said steps of rotating

said starting element (2) in said first and second directions, said first and second stretches (14, 16, 18; 15, 17, 19) are formed starting from ends of their own, each of which is set on the opposite side of a plane passing through the point located at the minimum distance of the portion (10) itself from said first axis (A) and proceeding towards said plane.

8. The method according to Claim 7, **characterized in that,** during said steps of rotating said starting element (2) in said first and second directions, said first and second stretches (14, 16, 18; 15, 17, 19) of said portion (10) are formed on opposite sides of said plane passing through the point located at the minimum distance of the portion (10) itself from said first axis (A).

9. The method according to any one of the preceding claims, **characterized in that** it comprises the step of rotating said tool (6) about a second axis (B) coplanar to said first axis (A).

10. The method according to any one of the preceding claims, **characterized in that** it comprises the step of using as said reference surface of rotation said peripheral edge (3) of said starting element (2).

11. The method according to any one of the preceding claims, **characterized in that** said step of translating comprises the step of setting said tool (6) in a point of said reference surface of rotation (3) distinct from a common region (11) between said reference surface of rotation (3) and said profile (4) of said shaped element (1).

12. The method according to any one of Claims 4 to 11, **characterized in that** said first stretches (14, 16, 18) are set at a distance from one another and said second stretches (15, 17, 19) are also set at a distance from one another.

13. The method according to any one of the preceding claims,
characterized in that said step of rotating said starting element (2) comprises the step of rotating a cylindrical element (2).

14. The method according to any one of Claims 1 to 12, **characterized in that** said step of rotating said starting element (2) comprises the step of rotating a conical element.

15. The method according to Claim 1, **characterized in that** it comprises the step of translating said tool (6) in an exclusively continuous way towards said first axis (A), during said step of forming said portion (10).

FIG. 1

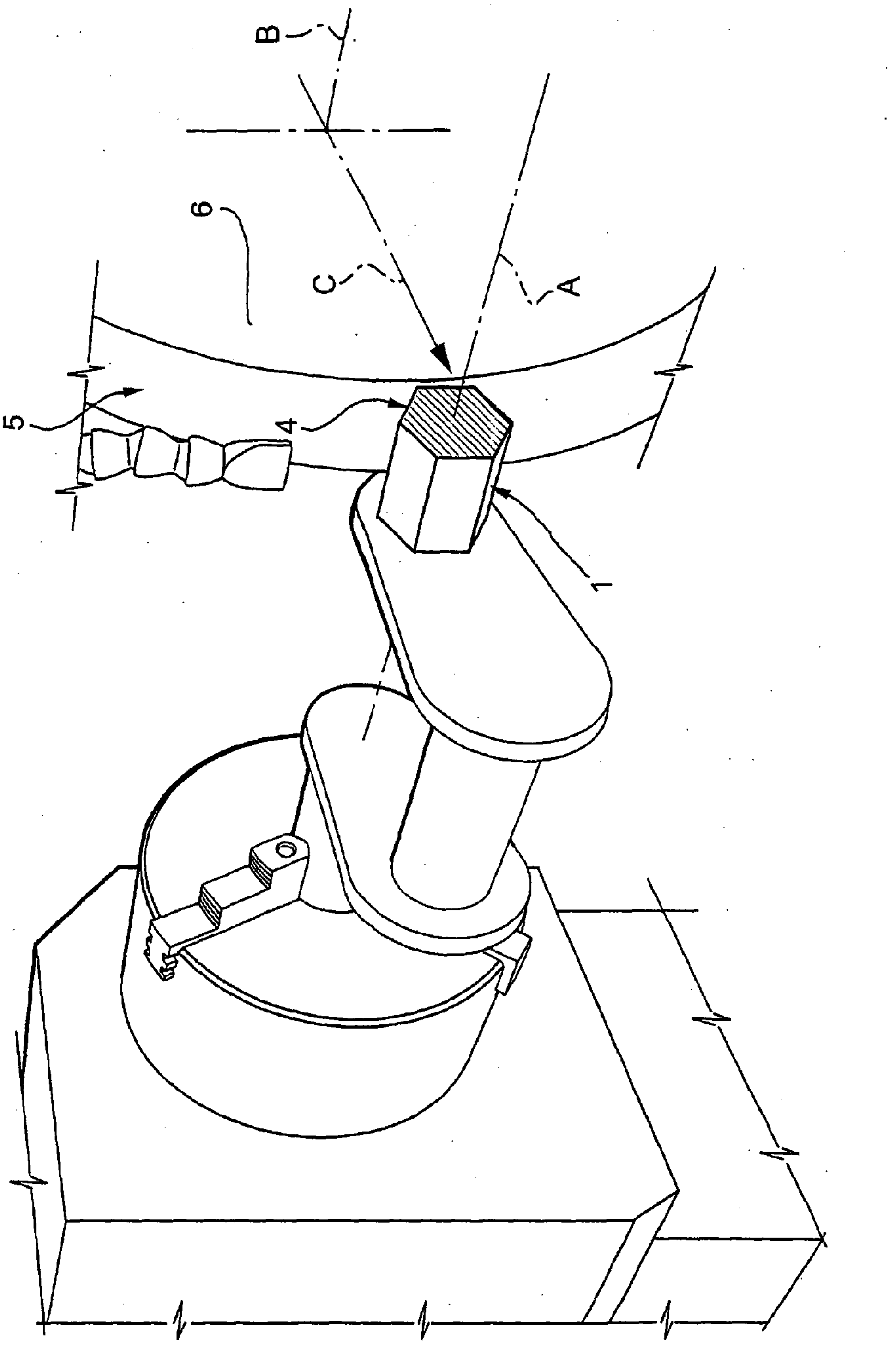


FIG. 2

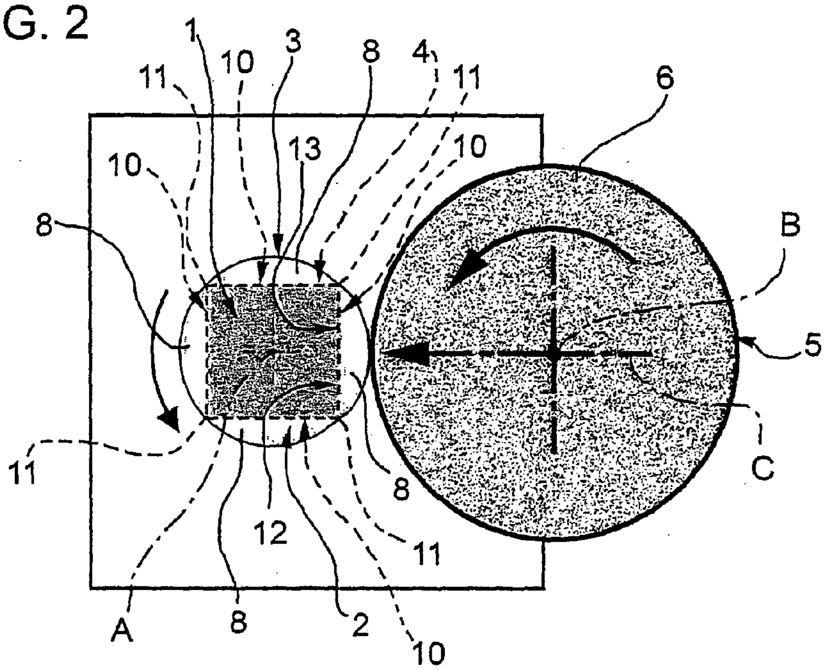

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FIG. 3

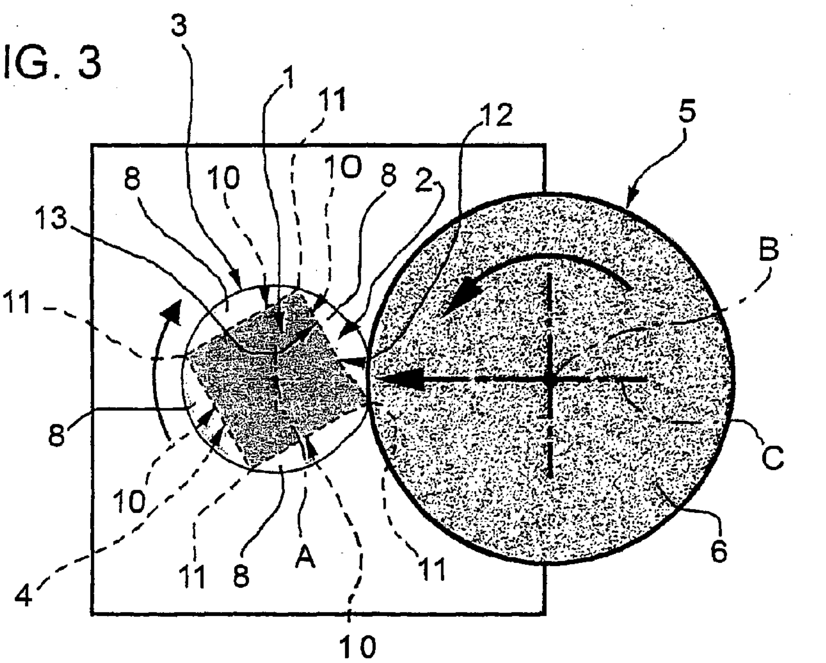
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FIG. 4

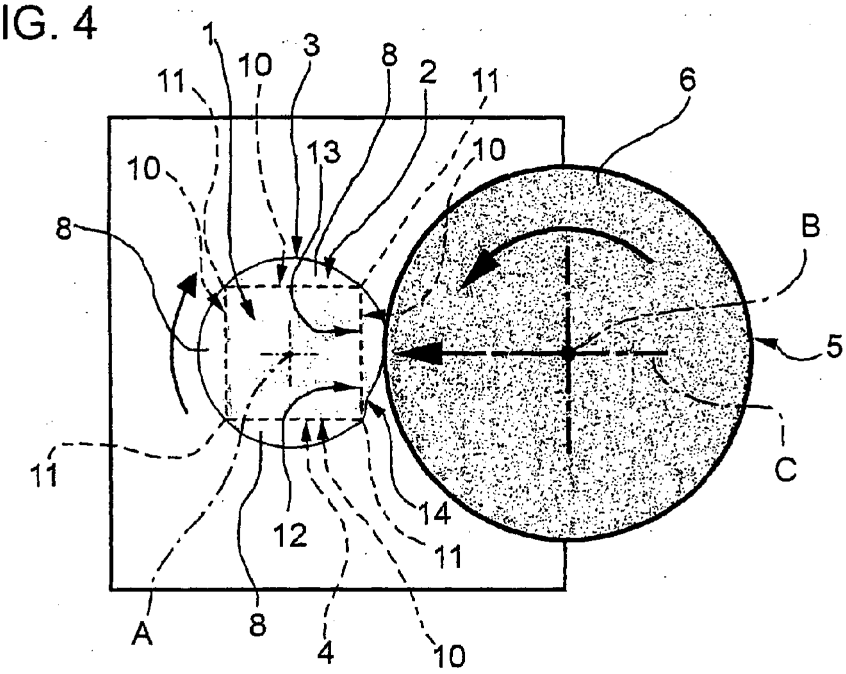
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FIG. 5

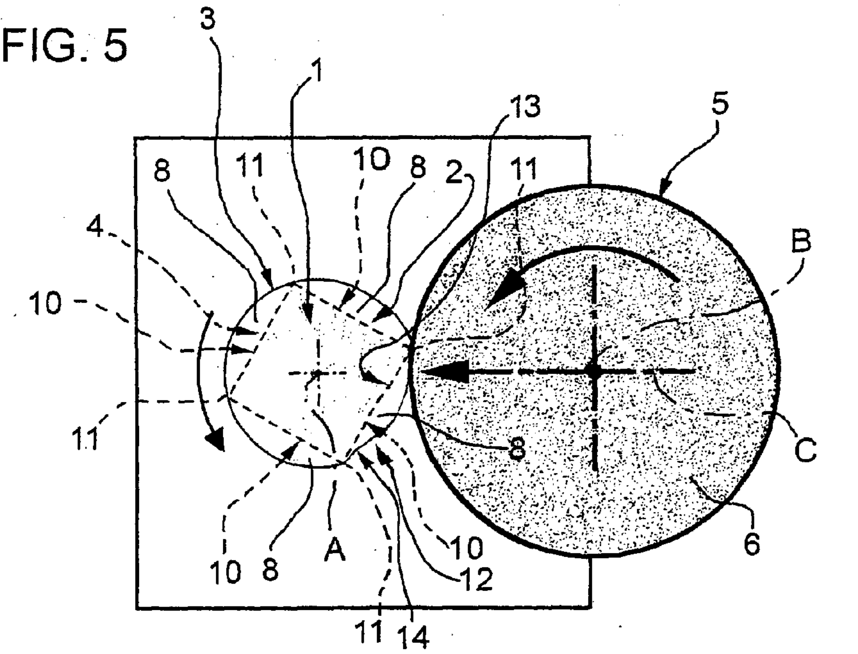
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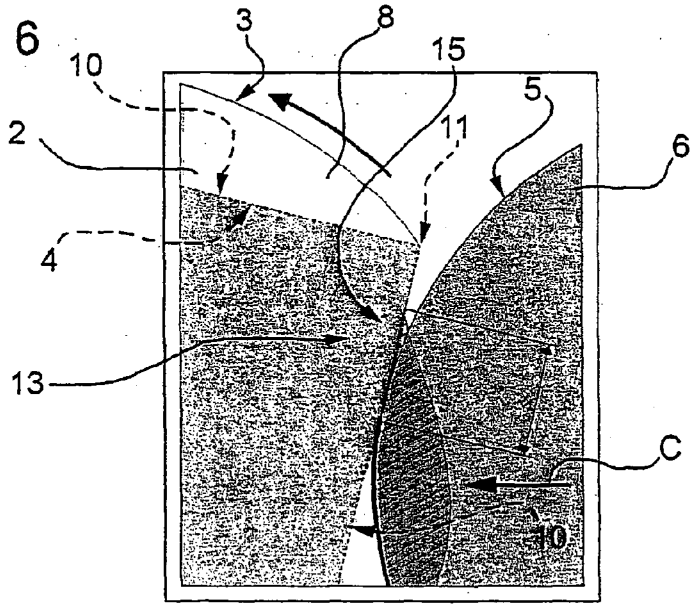
FIG. 6



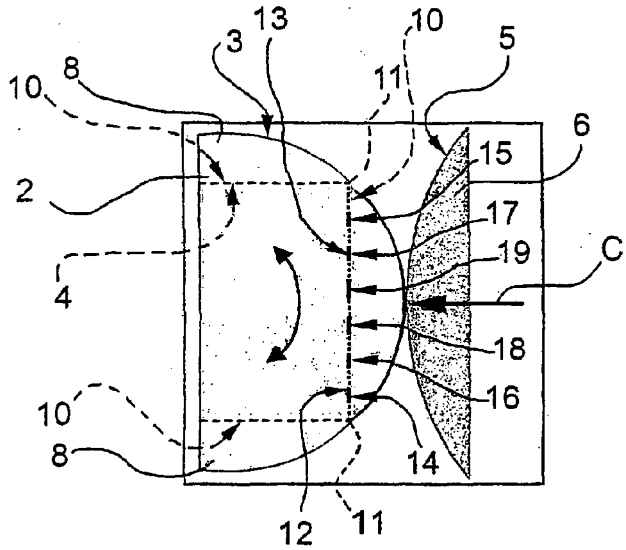
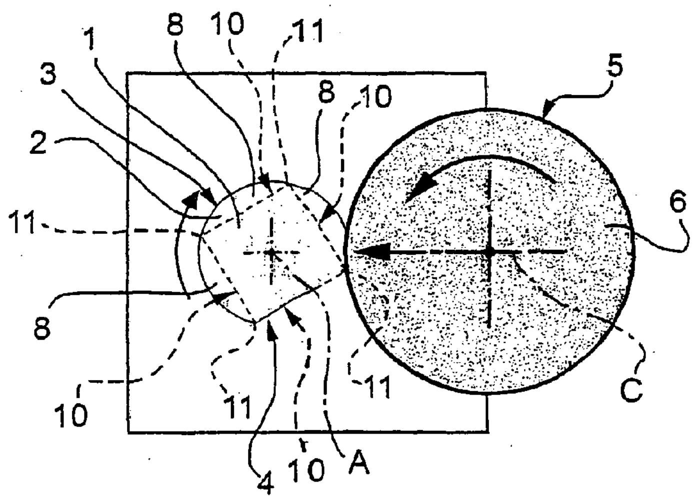


FIG. 7

FIG. 8



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EUROPEAN SEARCH REPORT

Application Number
EP 07 42 5662

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	FR 2 505 709 A (OD POLT INSTITUT [SU]) 19 November 1982 (1982-11-19) * pages 18,24; figures 6,8 * -----	1	INV. B24B19/08 B23B5/36 B23C3/10 B23C3/24 B23Q27/00
A	DE 10 2006 007055 A1 (BSH HOLICE A S [CZ]) 16 August 2007 (2007-08-16) * paragraph [0054]; figure 6 * -----	1-15	

TECHNICAL FIELDS SEARCHED (IPC)

B24B
B23B
B23C
B23Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	27 February 2008	Gelder, Klaus

1

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