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(54) METHOD AND APPARATUS FOR PRODUCING A PISTON TOP WITH A COOLING CHAMBER

(57) The invention relates to a method and apparatus for producing a piston top with a cooling chamber, wherein the establishment of a wide opening angle in the final forming step allows the wear upon the tool used for the coining step to be significantly reduced.

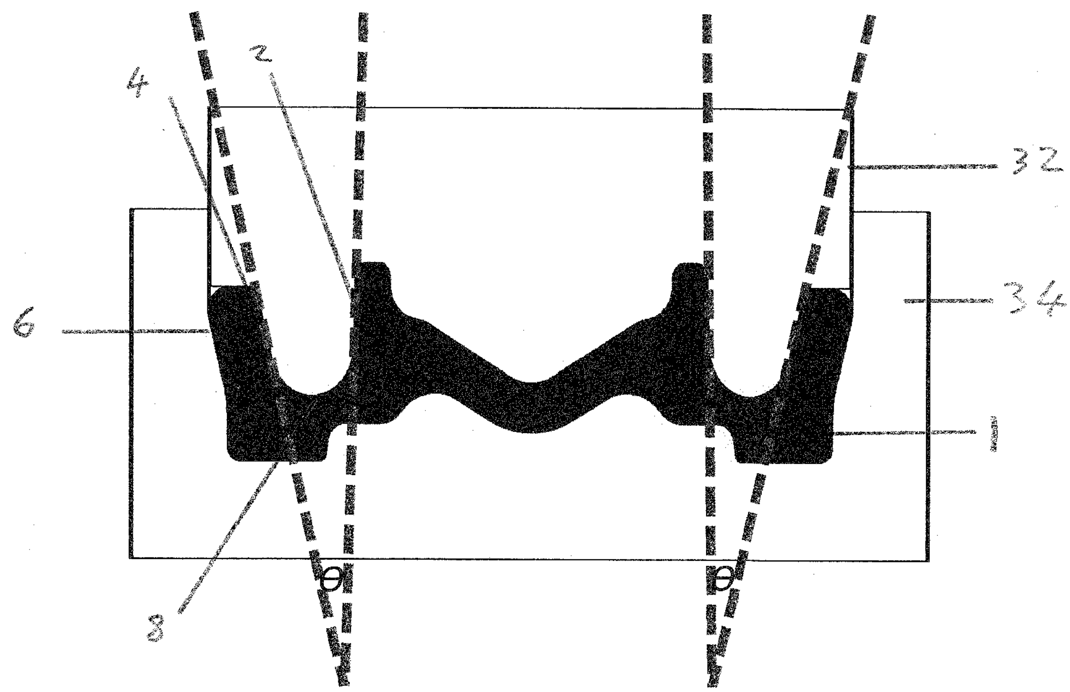

Fig. 6

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Description

Background art

[0001] Pistons are used in a variety of different mechanical systems and are an integral part of internal combustion engines. They are used to transfer a force generated from an expansion of gas within an engine cylinder to a crankshaft, wherein the crankshaft is connected to a rotating shaft. The part of the piston exposed to this expansion of gas is known as the piston top or piston crown, and forms a relatively flat shape for the expanded gas to come into contact with. As specific power output increases in modern combustion engines, the temperature of the combustion chamber in which the piston operates has increased significantly, leading to an increase in the thermal load the piston is subjected to. This increase in temperature often results in the piston top being the main constraint within a combustion system, as the piston top can be damaged when operated above a certain temperature. As such, there has become a need for developing piston tops which can operate in a high temperature environment. One such method by which these temperature limitations can be combatted is through the use of cooling chambers (also known as cooling galleries) built into the piston tops. These cooling chambers can be filled with a coolant which aids in preventing the piston top increasing in temperature significantly, thus keeping the piston top from reaching a degradation temperature when in operation. The piston top may thus be used in the higher temperature environments of many modern combustion engines and is thus not rendered the limiting factor.

There are a variety of ways of producing a piston top with a cooling channel as may be seen in US7918022B2 and US4843698A. US7918022B2 outlines a method for creating said cooling channel by producing a piston blank with a circumferential collar, radially projecting in the area of the piston top. The collar is then formed over, and the collar comes into contact with a seating area positioned between the top and the piston lower section, to form a closed cooling channel. US4843698A outlines a similar method wherein a piston top is cast, the piston top comprising an annular collar with tab-segments, wherein this annular collar is bent over to form an annular cooling space.

[0002] However, each of these methods outlined, and many others, suffer in that the formation of a cooling chamber requires multiple manufacturing steps, thus leading to a costly and complicated manufacturing method. Many methods require the forging of the piston top first, and then focus on performing steps to generate a cooling chamber afterwards as may be seen in US7918022B2 and US4843698A. Thus, it is advantageous for the main structure of a cooling chamber to be generated through a simpler method, preferably at the same time as the generation of the piston top itself, therefore when the piston top is coupled to the main piston body, the cooling chamber may be sealed (or left open) and the cooling chamber is completely formed without the need for further machining steps.

[0003] A known method for forging a piston top which comprises a cooling chamber involves the use of specific shaped dies compressing a workpiece to produce a cooling chamber which has specific dimensions. This step is known as a final forging step, and takes place after a flattening step for removing scale, an upsetting step for reducing the length and increasing the diameter of the workpiece, and a pre-forming step wherein a rough final dimension of the workpiece is generated. This final forging step uses a die which has very precise dimensions such that the cooling chamber with final dimensions may be defined. However, due to the large amount of pressure applied to the die during this final forging step, and the precise dimensions of the die, features of the die are subjected to a large amount of pressure. This large amount of pressure leads to the tool being deteriorated rather quickly due to high amounts of stress, and as such the precise dimensions of the tool are rapidly deteriorated.

[0004] This leads to the tool requiring replacement frequently, which incurs significant component costs, as well as costs for a process line downtime whilst the tool is replaced. As such it is necessary for a method to be found wherein the dies used in the forging process are exposed to less wear, and thus replacements occur less frequently.

Summary of the invention

[0005] The present invention relates to a method for producing a piston top comprising an annular recess for a cooling chamber. The method comprises an upsetting step wherein a workpiece is reduced in length and increased in diameter, a preforming step wherein the workpiece is deformed to form a shape approximate to the finished piston top shape, a final forming step wherein the workpiece is deformed to define an annular recess with an opening angle between the inner wall and the outer wall, this opening angle ensuring that pressure is evenly distributed across the tools used, and a coining step wherein the workpiece is deformed to reduce the opening angle of the annular recess, wherein the establishment of a wide opening angle in the final forming step allows the wear upon the tool used for the coining step to be significantly reduced. By using the coining step, there is no material flow above the annular recess region on the die. The coining step aims to decrease substantially the amount of die wear and, by correct volume control, it aims also to decrease the bending forces acting on the die, thereby avoiding tool deformation and mechanical fatigue.

Brief description of the drawings

[0006]

Figure 1 is a cross sectional view of the workpiece at the beginning of the upsetting step.

Figure 2 is a cross sectional view of the workpiece at the end of the upsetting step.

Figure 3 is a cross sectional view of the workpiece at the beginning of the preforming step.

Figure 4 is a cross sectional view of the workpiece at the end of the preforming step.

Figure 5 is a cross sectional view of the workpiece at the beginning of the final forming step.

Figure 6 is a cross sectional view of the workpiece at the end of the final forming step.

Figure 7 is a cross sectional view of the workpiece at the beginning of the coining step.

Figure 8 is a cross sectional view of the workpiece at the end of the coining step.

Detailed description of illustrative embodiments

[0007] The method for producing a piston top comprising an annular recess for a cooling chamber according to the present invention includes four main steps; an upsetting step, a preforming step, a final forming step and a coining step.

[0008] These steps make up a hot forging process, wherein a workpiece (1) is maintained at a temperature above the recrystallization temperature associated with the workpiece (1) material. The workpiece (1) is maintained above this temperature to prevent potential strain hardening of the piece during deformation.

[0009] The workpiece (1) may be a solid piece of metal, preferably steel or aluminium. The workpiece (1) is heated to a forging temperature. The workpiece (1) may initially have a basic shape such as a cylinder.

[0010] The workpiece (1) may be moved from one set of dies to the next as it undergoes each individual step. The dies may all be pressed at the same time using a single pressing machine, wherein at least four different workpieces, each at a different step in the process may be pressed, and subsequently moved onto the next step, wherein the workpiece (1) in the coining step may be removed once the coining step has been performed.

[0011] The pressing machine may provide a compressive force to the upper die, wherein this force is conveyed to the workpiece (1). The workpiece (1) may thus be deformed due to the high pressure exerted and the temperature at which this pressure is applied. This deformation may be plastic, thereby making a permanent alteration to the structure of the workpiece (1).

[0012] The direction in which said pressing is performed, is along the piston longitudinal axis of the finished workpiece (1). The piston longitudinal axis is defined as the axis which runs through the piston top from its upper surface to its lower surface. This may also be the direction in which the piston top is intended to move once formed as part of a piston system. The piston longitudinal axis can also be called an axis of rotational symmetry of the finish-formed piston top.

[0013] Prior to the upsetting step being performed on the workpiece (1), the workpiece (1) may go through one or more pretreatment steps. One such pretreatment step that may be performed is flattening, wherein scale removal is performed. Alternatively, scale removal may also be performed during the upsetting step. The distance between an upper and a lower surface of the workpiece (1) prior to the upsetting step may be defined as its length. The distance between one side of the external circumferential surface to the other passing through the middle of the workpiece (1) may be regarded as its diameter.

[0014] The beginning of the upsetting step may be seen in figure 1. At this stage the workpiece (1) is in a raw state in which it is of a basic shape such as a cylinder. The workpiece (1) is placed in the first lower die (14), with the lower surface of the workpiece (1) contacting the first lower die (14). The first upper die (12) then contacts the upper surface of workpiece (1) by a single stroke of a forging press. The forging press may be an automatic or manual mechanical press. The stroke applied by the forging press may use a press velocity ranging between that of a hydraulic press velocity and a hammer press velocity.

[0015] The end of the upsetting step may be seen in figure 2 wherein the workpiece may be regarded as an upset workpiece. The workpiece (1) has been deformed through the compressive force applied by the forging press.

[0016] This deformation reduces the length of the workpiece (1) and increases its diameter. This process is also known as barreling as friction between the workpiece (1) and the dies tends to prevent the workpiece (1) from widening as much at the upper and lower surfaces in comparison to the middle of the workpiece (1). This allows the workpiece (1) to be in a shape better suited for the following pre forming step.

[0017] The beginning of the preforming step may be seen in figure 3. The workpiece (1) is placed between a second upper die (22) and a second lower die (24) in preparation for the stroke of the mechanical press.

[0018] The end of the preforming step may be seen in figure 4 wherein the workpiece may be regarded as a preformed workpiece. The mechanical press deforms the workpiece (1) to form a shape approximate to the finished piston top shape. A shallow annular recess is formed in the upper surface of the workpiece (1). The annular recess represents a groove formed in the upper surface of the workpiece (1) wherein the groove may be regarded as a shallow trench. The preforming step may also deform a section of the lower surface which may later be used to form a bowl. This bowl may provide different effects on the combustion process by controlling the movement of air and fuel when the piston top is used in a combustion chamber. The lower surface of workpiece (1) in fig. 4 is the surface that will face the combustion chamber when the piston is in use in an internal combustion engine.

[0019] The beginning of the final forming step may be seen in figure 5. The workpiece (1) is placed between a third upper die (32) and third lower die (34) in preparation for the stroke of the mechanical press.

[0020] The third upper die (32) contains an annular protrusion (9) with an inner wall and outer wall angled with respect to each other such that the deformation created by the annular protrusion (9) corresponds to the opening angle of the annular recess of the piston top. The annular recess may be ring-shaped, preferably circular. The inner wall is defined as the wall of the annular protrusion (9) closest to the piston longitudinal axis, while the outer wall is defined as the wall of the annular protrusion (9) furthest from the piston longitudinal axis.

[0021] The end of the final forming step may be seen in figure 6 wherein the workpiece may be regarded as a final-formed workpiece. The annular recess has been further deformed, to define the annular recess with an opening angle.

[0022] The opening angle θ is defined as the angle between the respective inner and outer walls (2, 4) of the annular recess (the wall closest to the piston longitudinal axis and the wall furthest from the piston longitudinal axis respectively), wherein the walls are substantially straight. The opening angle may be measured by the angle between the walls at an imaginary point where the walls would meet if they were to continue straight, and were not joined by a curved recess base, but rather by a corner, as represented by the dashed lines in the cross sectional view of figure 6.

[0023] The opening angle of the workpiece (1) at the end of the final forming step is between the range of 1° and 30°. The force applied to the upper die may be distributed across the die. This distribution allows the force to be less concentrated on specific areas of the annular protrusion (9), distributing the pressure evenly. This thus allows the wear on the tool to be kept low. The annular recess produced by this step allows the subsequent coining step to only be required to make minor alterations to the shape of the recess, as the majority of the deformation has been performed in the final forming step.

The final forming step may also deform the external circumferential surface (6) of the workpiece (1). This deformation may render the workpiece (1) with a smaller diameter at the lower surface than at the upper surface. This may render the workpiece (1) somewhat conical.

[0024] The final forming step may define the base of the annular recess as substantially curved.

[0025] The beginning of the coining step may be seen in figure 7. The workpiece (1) is placed between a fourth upper die (42) and fourth lower die (44) in preparation for the stroke of the mechanical press.

[0026] The end of the coining step may be seen in figure 8. The workpiece (1) has been deformed into the final desired form, reducing the opening angle of the annular recess. The inner wall (2) and outer wall (4) of the annular recess may have been deformed such that they are relatively (substantially) parallel to each other, i.e. they are either parallel or have an opening angle of less than 5°. The inner wall (2) and outer wall (4) may also be parallel with respect to the piston longitudinal axis.

[0027] The base of the annular recess (8) may be deformed to alter its dimension from a curved shape to an angled shape. This angled shape may feature the inner wall (2) of the annular recess having a reduced depth with regard to the outer wall (4) of the annular recess, whilst the base (8) is relatively flat and connects the two walls (2, 4).

[0028] Furthermore, the coining step deforms the outer wall (4) of the annular recess to render all parts of the external circumferential surface (6) parallel to all other parts in the longitudinal direction, thereby forming a cylindrical shape. The workpiece (1) is thus rendered parallel to the piston longitudinal axis as well. This ensures the piston top is cylindrical and is thus suitable for use in a cylinder as part of a piston.

[0029] Due to the deformation seen in the final forming step, the deformation required by the coining step is relatively low. This ensures that the die used in the coining step to produce the final shape of the piston top, which requires a great level of detail, would be subject to far less wear than would be present if the die required to produce the final shape of the piston top was used upon a workpiece (1) that had not been subjected to the final forming step.

[0030] After the coining step has been performed, the workpiece (1) may be removed and taken for post-production steps. These steps may allow for the dimensions of the workpiece (1) to be further defined.

[0031] An additional advantage of the present method is that it reduces the necessity for removing of large quantities of material by machining.

[0032] A cold coining step may be performed wherein the annular recess or other features of the piston top are deformed further to meet required dimensions. This cold coining step may take place at room temperature for steel and aluminium.

[0033] The annular recess may then form a cooling chamber within the piston top, wherein said cooling chamber may be filled with a fluid that aids in reducing a temperature increase of the piston top when exposed to the high temperatures of a combustion engine environment. The cooling chamber may be closed using another feature to block the opening of the annular recess, or further machining may allow for the cooling cylinder to be sealed by further deforming the piston top.

[0034] The lower surface of the workpiece (1) may form the surface of the piston top which is exposed to the expanding gas in the cylinder. The upper surface of the workpiece (1) may be attached to further components which comprise a piston body.

[0035] The invention has the added advantage that it may make use of a single press used to compress all the stages of the dies in one single movement. This allows for easier replacement of the previously known final forming step of existing methods, with the final forming step (which defines an opening angle) and coining step of the present invention. As such, existing systems which make use of a method with a single press may be easily modified (only requiring additional dies to be added) to take advantage of these technical advantages.

List of reference numerals

[0036]

1	Workpiece
2	Inner wall of annular recess
4	Outer wall of annular recess
6	External circumferential surface
8	Base of annular recess
9	Annular protrusion
12	First upper die
14	First lower die
22	Second upper die
24	Second lower die
32	Third upper die
34	Third lower die
42	Fourth upper die
44	Fourth lower die

Claims

1. A method for producing a piston top comprising an annular recess for a cooling chamber, the method comprising:

   an upsetting step wherein a workpiece (1) is reduced in length and increased in diameter;
   a preforming step wherein the upset workpiece (1) is deformed to form a shape approximate to the finished piston top shape;
   a final forming step wherein the preformed workpiece (1) is deformed to define an annular recess with an opening angle between an inner wall and an outer wall of the annular recess;
   a coining step wherein the final-formed workpiece (1) is deformed to reduce the opening angle of the annular recess.

2. The method according to claim 1, wherein the final forming step deforms the workpiece (1) to define the opening angle of the annular recess as between 1° and 30°.

3. The method according to claim 2, wherein the lower limit of the opening angle is preferably 5°, further preferably 7°, further preferably 10°, further preferably 12°, further preferably 15°.

4. The method according to claim 2 or 3, wherein the upper limit of the opening angle is preferably 25°, further preferably 23°, further preferably 20°, further preferably 18°, further preferably 15°.

5. The method according to claim 2 wherein the opening angle is preferably between 5° and 25°.

6. The method according to claim 2 wherein the opening angle is preferably between 10° and 20°.

7. The method according to any of claims 1 to 6, wherein the coining step deforms the workpiece (1) to reduce the opening angle to less than 5° or renders the inner and outer walls of the annular recess parallel to each other.

8. The method according to any of claims 1 to 7, wherein the walls of the annular recess are rendered parallel to a piston longitudinal axis by the coining step.

9. The method according to any of claims 1 to 7, wherein the coining step deforms the outer wall of the annular recess and renders it parallel to a piston longitudinal axis.

10. The method according to any of claims 1 to 9, wherein the bottom of the annular recess is rendered as curved due to the final forming step.

11. The method according to any of claims 1 to 10, wherein the bottom of the annular recess is rendered as angled due to the coining step.

12. The method according to any of claims 1 to 11, wherein a second coining step takes place after the coining step, wherein the second coining step preferably comprises a cold coining step.

13. The method according to any of claims 1 to 12, wherein the final forming step renders the external circumferential surface of the workpiece (1) angled.

14. An apparatus for producing a piston top comprising an annular recess for a cooling chamber with an opening angle between the inner wall and the outer wall, comprising:

   - A first die and a second die for a final forming step, wherein the first die comprises an annular protrusion with an inner wall and outer wall angled such that the annular protrusion corresponds to the opening angle of the annular recess of the piston top.

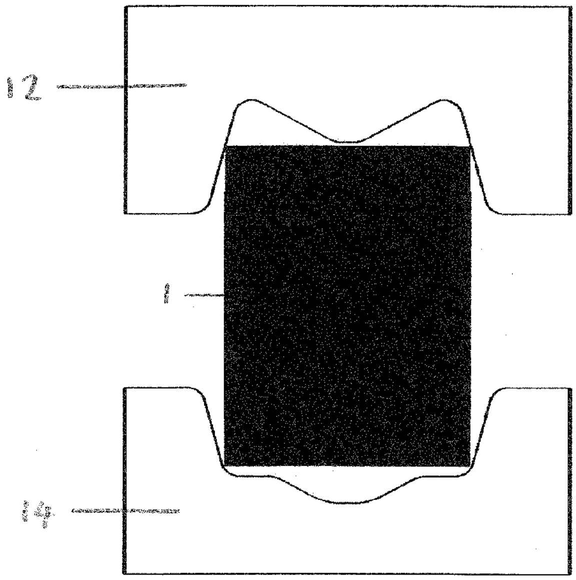

Fig. 1

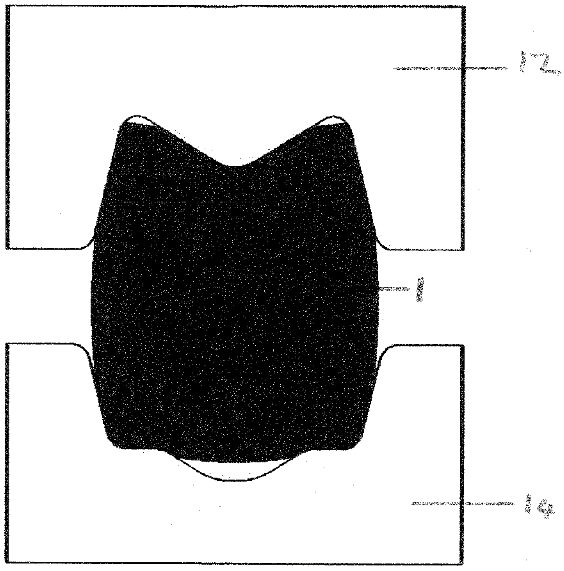

Fig. 2

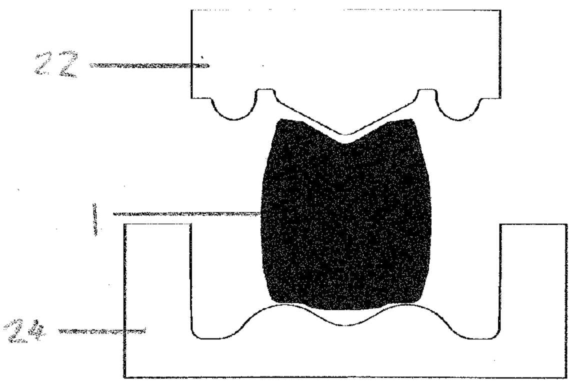

Fig. 3

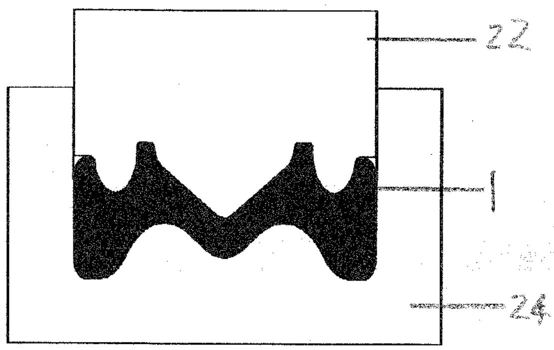

Fig. 4

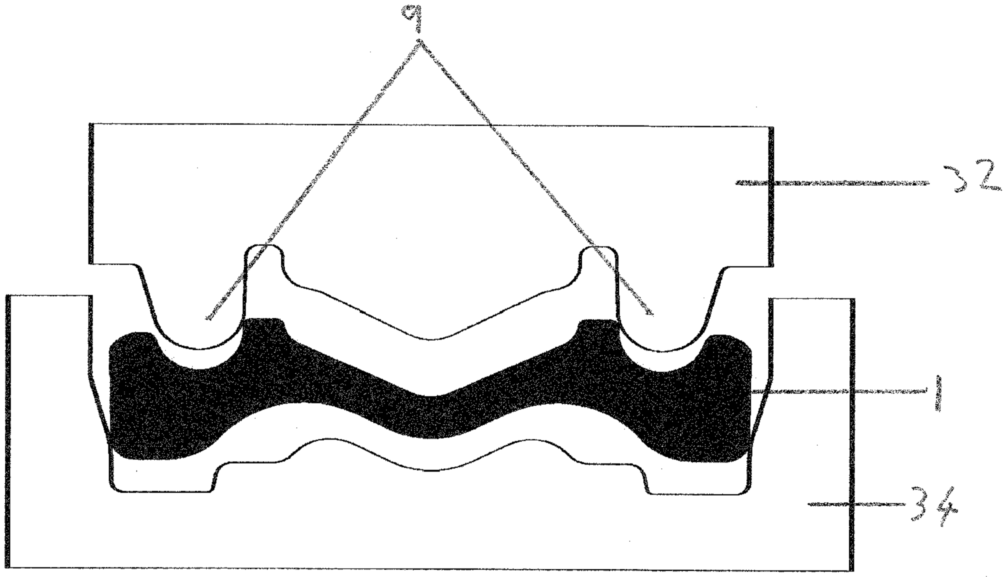

Fig. 5

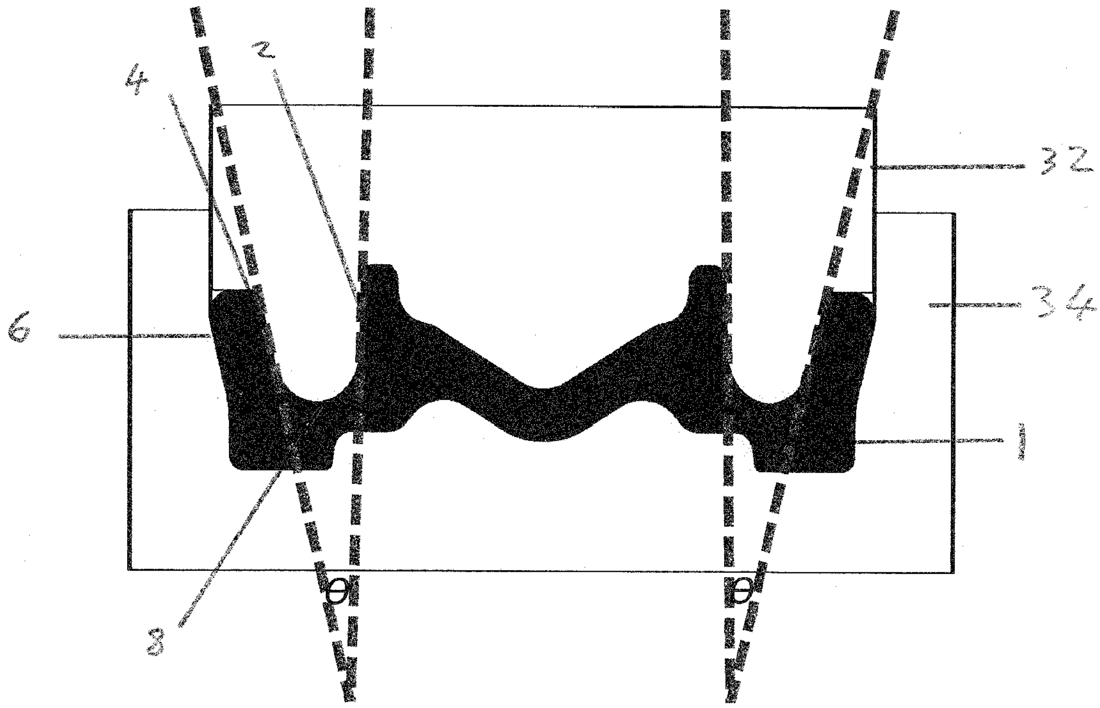

Fig. 6

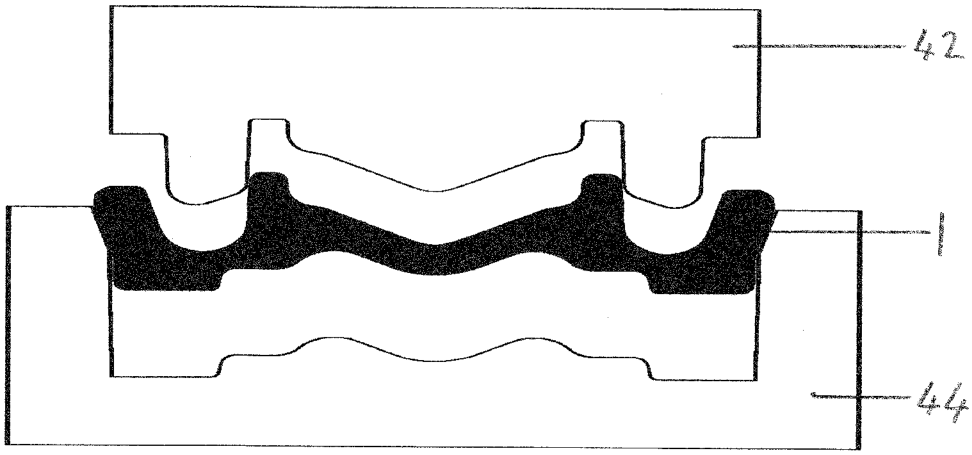

Fig. 7

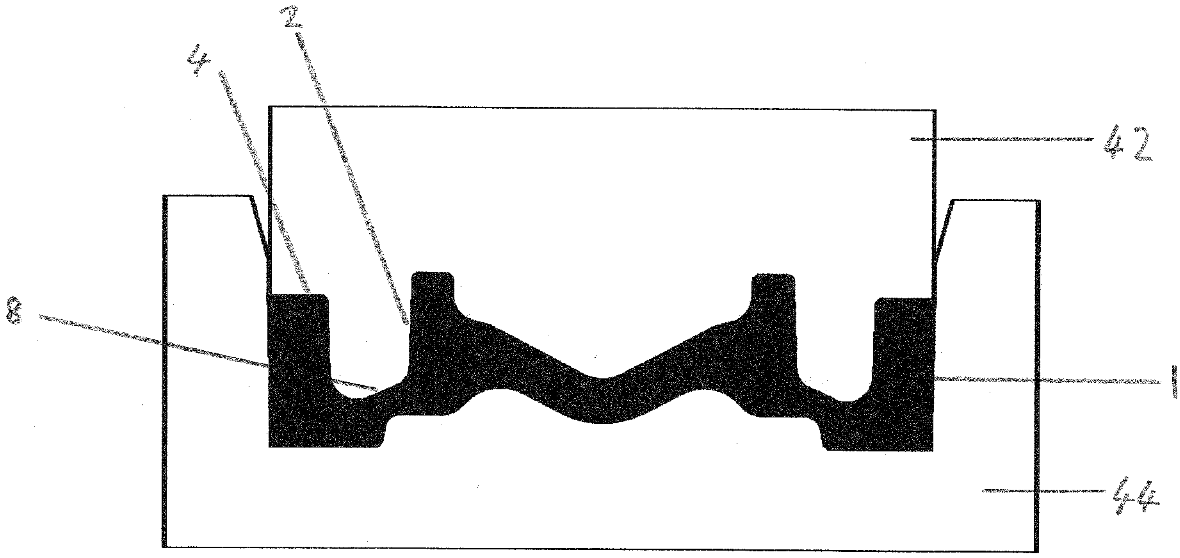

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 17 17 2656

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	US 2 539 903 A (GRUETJEN FREDERICK A) 30 January 1951 (1951-01-30) * column 1, line 1 - line 4 * * column 1, line 22 - line 29 * * column 2, line 9 - line 52 * * column 3, line 15 - line 50; figures 1-6,9 * -----	1-14	INV. B21K1/18
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			TECHNICAL FIELDS SEARCHED (IPC)
			B21K

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	22 November 2017	Ritter, Florian

CATEGORY OF CITED DOCUMENTS

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