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(54) **A FORMING TOOL, METHOD OF ASSEMBLING A FORMING TOOL AND METHOD FOR CALIBRATING SUCH A FORMING TOOL**

(57) A forming tool (1) comprising a housing (2), a lid (3), and a container assembly (4). The container assembly is placed in an encapsulation between the housing and the lid (3) and has an axial dimension preventing the lid from reaching the housing thereby forming a gap. Tension rods are arranged circumferentially around the container assembly to pull the lid (3) towards the housing. The structure and particularly the gap allows the container assembly to be fixed in the encapsulation by bending of the lid within its elastic deformation range and thereby

allows easy, fast, and precise mounting of the container assembly and thereby facilitates swift adaption of the tool to different types of workpieces by replacement of the container assembly. The tool further facilitates easy disassembly and maintenance of the container assembly for continued manufacturing of a workpiece and thereby potentially provides a reduction in downtime.

The invention also relates to a method of assembling a forming tool and to a method for calibrating such a forming tool.

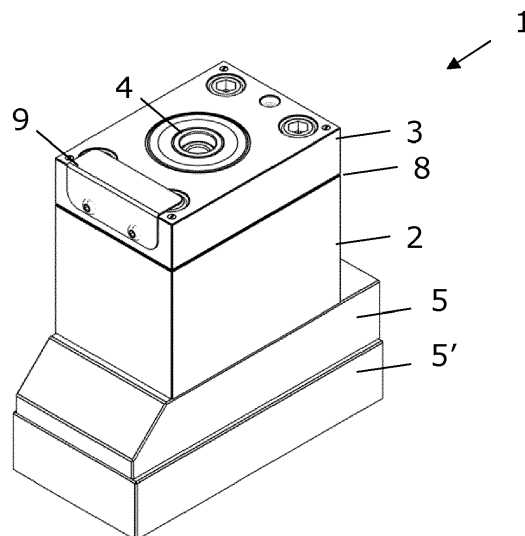


Fig. 1

Description

INTRODUCTION

- 5 **[0001]** The present disclosure relates to a forming tool for a forming process, e.g., for metal forging, sinter pressing, deep drawing, punching or similar die-related processes.

BACKGROUND

- 10 **[0002]** Forming is a manufacturing process involving the shaping of metal using localized compressive forces. The process can be cold, warm, or hot. The present disclosure particularly relates to cold forming. Traditional products include high loaded parts for various industries. Forging is a process involving application of very high pressure and optionally heat to form an object in a die. In closed-die forging, the metal is placed in a die resembling a mould.
- 15 **[0003]** To obtain low tolerances of the workpiece, the tool must be capable of remaining in a fixed position and withstand deformation. Additionally, forging is carried out at very high-speed, automated, processes for mass production. Fast and precise replacement of the die in the forming machine is therefore important. Typically, the forming machines contains a plurality of dies, and space consumption is therefore also an important issue.
- [0004]** The present disclosure is mostly related to forging.

20 SUMMARY

- [0005]** It is an object of embodiments of the invention to improve fast adaption of the tool to different types of workpieces and to provide a forming tool facilitating low tolerance manufacturing. It is a further object to save space at the forming machine. It is a further object to improve forming tools with respect to strip wound containers.
- 25 **[0006]** According to these and other objects, the invention, in a first aspect, provides a forming tool comprising a housing, a lid, and a container assembly.
- [0007]** The lid comprises a lower surface arranged towards an upper surface of the housing, and the container assembly is arranged in an encapsulation between the housing and the lid.
- 30 **[0008]** The lid is pulled towards the housing by a compression-structure comprising a plurality of tension rods. The tension rods are arranged circumferentially around the container assembly such that they pull the lid towards the housing in a direction which will be referred to herein as "an axial direction". Herein, axial direction is the direction of the pressing, punching, or hammering when forming a workpiece in the forming tool.
- [0009]** The container assembly creates a distance between the housing and the lid, i.e., it has an axial dimension preventing the lid from abutting the housing. Since the lid is carried by the container assembly, a gap is defined between
- 35 the housing and the lid.
- [0010]** Herein, the term "deformation" refers to the change in size or shape of an object, "displacement" is the absolute change in position of a point on the object, and "deflection" is the relative change in external displacements on an object.
- [0011]** Strain is the relative internal change in shape of an infinitesimally small cube of material and can be expressed as a non-dimensional change in length or angle of distortion of the cube. Strain relates to the forces acting on the cube,
- 40 which are known as stress, by a stress-strain curve. The relationship between stress and strain is generally linear and reversible up until the yield point and the deformation is elastic.
- [0012]** The present invention utilizes that the linear relationship for a material is known. This may be referred to as "Young's modulus". Above the yield point, some degree of permanent distortion remains after unloading and is termed plastic deformation. The determination of the stress and strain throughout a solid object is given by the field of strength
- 45 of materials and for a structure by structural analysis.
- [0013]** The structure and particularly the gap allows the container assembly to be fixed in the encapsulation by bending of the lid within its elastic deformation range. When mounting the container assembly, it will therefore be sufficient to place the container assembly in the encapsulation and subsequently bend the lid within its elastic deformation zone by use of the tension rods. The lid will thereby apply pressure on the container assembly in the axial direction, and the
- 50 pressure is defined by a deformation characteristic which is essentially stable over time and only varies insignificant based on external conditions such as temperature variations. The characteristics depend inter alia on Young's modulus and the shape of the lid.
- [0014]** The gap between the housing and the lid thereby allows easy, fast, and precise mounting of the container assembly and thereby facilitates swift adaption of the tool to different types of workpieces by replacement of the container assembly. The tool further facilitates easy disassembly and maintenance of the die for continued manufacturing of a workpiece and thereby potentially provides a reduction in downtime.
- 55 **[0015]** When the tool is designed, the axial force for a specific degree of deformation is determined, and when this axial force is desired, the tension rods are tensioned until the corresponding deformation is obtained. The tool may e.g.,

include a table of the kind shown in table 1 below:

Table 1

GAP reduction (mm)	COMPRESSIVE FORCE (N)
10	100
11	120
12	140
13	160

[0016] Table 1 indicates a resulting axial compressive force obtained by different reductions of the gap between the upper surface of the housing and the lower surface of the lid.

[0017] Since the bending occurs within the range of elastic deformation, the gap may particularly be shaped and sized such that bending outside the elastic range, i.e., into the plastic range, is not possible. This can be ensured by allowing the lid to reach a spacer structure or to reach the housing, i.e., to eliminate the gap, before the deformation becomes plastic.

[0018] The forming tool may therefore comprise at least one spacer insertable between the lid and the housing. This will allow a well-defined limit for the elastic deformation when the lid reaches the spacer, and further, it may facilitate a parallel arrangement of the lid on the housing where the lid is deformed symmetrically relative to the container assembly such that the compressive force becomes uniformly distributed on the container assembly.

[0019] The housing is to be mounted onto a mounting plate of a forming machine. The housing may be made in one or more pieces. Centrally, the housing defines a cavity for receiving a lower part of the container assembly, and through holes may be provided for the tension rods. These holes may particularly be located in the corners, i.e., circumferentially about the cavity for the container assembly.

[0020] The parallel layout of the lid and thus the symmetrical distribution of the compressive force on the container assembly can be achieved when at least one of the at least one spacers is arranged at each tension rod, and all spacers may have the same length.

[0021] The spacers may be insertable between the housing and the lid to create a fixed distance available for the elastic deformation. The compression-structure may then be configured to bend the lid to an extent where said spacer is squeezed between the housing and the lid. The spacer may particularly be replaceable or adjustable to allow a variable space for the elastic deformation and thereby allow a variable force of compression of container assembly between the lid and the housing.

[0022] The forming tool may comprise a plurality of sets of spacers with different length between each set, i.e., spacers of a first set of spacers have identical length and spacers of a second set of spacers have identical length but have a length which is different from the length of the spacers of the first set of spacers. This may allow adjustment of the compressive force by selection of a spacer length which matches the required compressive force. Accordingly, the forming tool can be adapted to different needs of compressive force simply by replacing spacers of one set of spacers with spacers of another set of spacers.

[0023] The lid may be made in one piece and comprises a cavity for an upper part of the container assembly. The cavity is typically formed as part of a through hole with a cross sectional size which is reduced in an upwards direction from the lower surface which faces the housing towards an opposite outer surface in the upper end of the forming tool. The narrow cross section near the outer surface is smaller than the cross section of the container assembly which can therefore not pass through the hole, but on the contrary will rest on a step between the wider cross section near the lower surface and the narrower cross section near the outer surface. By definition herein, the cavity in the lid is that part of the through hole in the lid into which the container assembly can enter.

[0024] The cavity of the housing and the cavity of the lid together makes an encapsulation for the container assembly between the housing and the lid.

[0025] Additionally, it may comprise through holes for the tension rods. These through holes are aligned with the through holes in the housing and allow the tension rods to extend from the lid into the housing and thereby press the lid towards the housing.

[0026] The container assembly may typically comprise a plurality of distinct elements, typically with a die-insert in the centre. The die-insert defines a die cavity which defines the shape of the work piece which is intended to be produced by use of the forming tool. The die-insert is typically enclosed in a container, e.g., comprising one or more stress reducing elements, e.g., in strip wound containers.

[0027] Prestressing is a factor affecting life of a forming tool. Use of single, double, or even triple ring systems with rings of wound material can generate compressive stresses e.g., on steel or tungsten carbide die-inserts. This reduces tensile stresses under loading. Strip wound forging container assemblies are circular, and relative to such containers,

the use of tension rods arranged circumferentially around the container assembly may reduce the size of the forming tool, particularly since most forming machines are made for a rectangular or quadrangular space to be utilized by the forming tool. Such a rectangular or quadrangular space is used optimally by tension rods located in the free corners appearing when a circular container assembly is inserted in a rectangular or quadrangular space. The forming tool is therefore particularly suitable for strip wound containers.

[0028] The container assembly may particularly have an upper surface forming a slanted outer edge which enters the cavity of the lid, and on which the lid is resting.

[0029] The container assembly has an axial dimension exceeding the axial dimension of the cavity into the housing and the cavity in the lid, and the container assembly thereby keeps the lid at a distance from the housing and creates a gap between the housing and the lid.

[0030] The lower surface of the lid and the upper surface of the housing may be plane surfaces, but since there will always be a gap between the lower surface and the upper surface, it is not essential for these surfaces to be plane.

[0031] The forming tool further comprises a compression-structure comprising a plurality of tension rods arranged circumferentially around the container assembly. The tension rods may particularly extend from above the lid and be threaded into the housing or into an anchor rod fixed in or below the housing.

[0032] The housing and lid may particularly have a rectangular or quadrangular cross section transverse to the axial direction, and the container assembly may particularly be circular and arranged centrally in the rectangular or quadrangular housing and lid. The tension rods may be arranged in the free corners. Accordingly, the forming tool may particularly comprise four tension rods, one in each of the four free corners.

[0033] The compression-structure may be configured with sufficient strength to bend the lid to an extent where said gap between the housing and the lid is at least pointwise eliminated, e.g., eliminated at each tension rod.

[0034] The spacer structure may comprise a plurality of spacers, e.g., one arranged in each corner of the housing or in each corner of the lid. Each spacer may be pin-shaped and have a wide section and a narrow section.

[0035] Each spacer may e.g., be arranged with the wide section in a depression or bore in the upper surface of the housing or in the lower surface of the lid. They may be held resiliently in place by an elastically deformable O-ring between each spacer and the bore in which it is located.

[0036] In one embodiment, the spacer is arranged in a bore in one of the housing or lid and the narrow section forms a tip extending towards, and into a bore in the other one of the lid or housing. In this way, the spacer may not only create space but also guide the lid towards a correct position on the housing by entering a bore in both the housing and the lid.

[0037] Each spacer may e.g., be arranged in a bore in the housing such that the wide section ends at a specific distance above the upper surface of the housing. The narrow section extends from the wide section into a bore in the lid. The wide section defines the distance between the lid and the housing when the lid is deformed to the desired degree.

[0038] The bore in the lid may form a through hole in the lid, and the dimensions may be selected such that the tip of the spacer is flush with the outer surface of the lid when the deformation of the lid is correct.

[0039] At the tip, the spacer may have a geometric feature which can engage with a tool which is inserted from the outer surface of the lid. In this way, it can be tested if the lid is deformed to the degree where it compresses the spacer between the lid and the housing. When this degree of deformation is reached, the spacer becomes solidly fixed and rotation or other movement of the spacer relative to the lid and housing is no longer possible. The geometric feature may be a notch or slot which can be reached by a screwdriver etc. The tool may comprise a plurality of sets of spacers having different length. Depending on the desired compressive force, the correct length of spacer may be chosen, and when the lid is compressed to the possible extent considering the selected spacer, the correct compressive force has been obtained.

[0040] The elimination or reduction of said gap between the lid and the housing or said squeezing of the spacer may be provided by bending the lid at least at one point for each rod.

[0041] Each tension rod may be threaded into a corresponding lower fixation point in the housing, and they may extend in individual bores in the housing.

[0042] The lower fixation point may be formed by an anchor rod extending in a bore through the housing. The anchor rod may be inserted into the housing from a bottom surface of the housing, where the housing is arranged against the mounting plate of the forming machine.

[0043] The cavity in the lid, i.e., that part of the lid which receives an upper part of the container assembly may have a particular shape. As mentioned previously, the cavity may be defined by a through hole in the lid, and the through hole may have a sidewall extending from the outer surface to the lower surface of the lid.

[0044] When considered in the axial direction, i.e., from the outer surface towards the lower surface of the lid, this side wall may form at least two radial steps separating a first axial section of the through hole from a second axial section of the through hole and separating the second axial section of the through hole from a third axial section of the through hole.

[0045] A first of the two steps separates the first section from the second section. The first axial section has the smallest radial dimension. This section is at and near the outer surface, and the axial dimension is smaller than the axial dimension of the container assembly which prevents the container assembly from entering the first axial section.

[0046] The second axial section has an intermediate radial dimension, and it is located between the first axial section and the third axial section. The intermediate radial dimension is larger than the radial dimension of the container assembly but only just enough for the container assembly to slide into the second section, i.e., with very little or no gap between the sidewall and the container assembly.

[0047] The second step separates the second axial section from the third axial section. The third axial section has the largest radial dimension which may continue all the way to the lower surface. The largest radial dimension is radially larger than the container assembly and therefore provides a gap between the sidewall and the container assembly.

[0048] The first radial step is formed by a first surface portion of the sidewall. This first surface portion may extend non-perpendicular to the axial direction, e.g., at an angle between about 20-50 degrees. It may however be perpendicular to the axial direction. This surface portion is arranged in contact with an upper surface of the container assembly, and the lid is therefore carried by the container assembly via this first surface portion.

[0049] The sidewall defines a second surface portion which is not abutting an upper surface of the container assembly and which defines the second and third axial sections.

[0050] The upper surface portion of the container assembly, i.e., that surface of the container assembly which is arranged directly against the first surface portion of the lid may be sloping, i.e., non-perpendicular to the axial direction. It may particularly have the same angle of inclination to the axial direction as the first surface portion. Alternatively, the upper surface portion of the container assembly is not sloping but extends perpendicular to the axial direction.

[0051] The container assembly may comprise a die-insert defining a forming cavity, and at least one compression ring surrounding the die-insert. At least one compression ring may be formed as a strip wound container to provide a radial pre-stress against an outer surface of the die-insert.

[0052] Said sloping upper surface portion of the container assembly may particularly extend from the container assembly insert into at least one of the at least one compression rings.

[0053] The compression-structure may be configured to provide an axial tension being symmetric about a centre axis. This provides an interface between the lid and the container assembly which is parallel with the mounting plate of the machine. It could be obtained e.g., with tension rods being symmetrically arranged relative to an axis extending centrally through the container assembly, i.e., an axis in the direction of pressing or punching by the machine onto the die-insert in the container assembly.

[0054] In a second aspect, the invention provides a method of assembling a forming tool in a forming machine. The method comprises:

- providing a housing, a lid, the housing and the lid being provided such that they define an encapsulation when the lid is arranged with a lower surface towards an upper surface of the housing;
- providing a compression-structure comprising a plurality of tension rods;
- providing a container assembly having an axial dimension;
- arranging the container assembly in an encapsulation between the housing and the lid;
- providing tension in each tension rod between a lower fixation point in or below the housing and an upper fixation point in or above the lid.

wherein the container assembly is provided such that the axial dimension prevents the lid from abutting the housing and thereby defines a gap between the housing and the lid.

[0055] The tension in each tension rod may be applied until the lid bends by elastic deformation such that at least one point of the lower surface of the lid comes in contact with the upper surface of the housing or until a spacer is squeezed between said lower surface of the lid and upper surface of the housing.

[0056] The method may comprise any step being implicit in light of the forming tool according to the first aspect of the invention, including the step of measuring the ratio between deformation of the lid and obtained axial compressive force, e.g., included in a table of the kind indicated by table 1 above.

[0057] In a third aspect, the invention provides a method of calibrating a tool according to the first aspect. The method comprises the step of defining a plurality of tension forces obtained by different tensions in the tension rods, and determining for each value, a corresponding deflection of the lid. The data set can be presented in a graph or in a table and it can later be used for easily determining the tension by measuring the gap between the lid and the housing when replying the container assembly.

LIST OF DRAWINGS

[0058] The disclosure will now be described in further detail with reference to the accompanying drawings in which:

Fig. 1 illustrates in a perspective view, a forming tool comprising a housing, a lid, and a container assembly;

Fig. 2 illustrates the forming tool when the lid is lifted off from the housing and the container assembly is removed;

Fig. 3 illustrates main components of the tool;

5 Figs. 4 and 5 illustrate a cross section through the lid;

Fig. 6 illustrates the forming tool when the lid is lifted off from the housing and the container assembly inserted and with a distance structure for controlling the degree of deformation of the lid;

10 Fig. 7 illustrates the forming tool when the lid is lifted off from the housing and the container assembly inserted and with a distance structure for controlling the degree of deformation of the lid and with anchor rods;

Fig. 8 is an exploded view of the container assembly and the compression structure;

15 Figs. 9a, 9b illustrate a gap between the housing and the lid;

Figs. 10, 11 illustrate details of the spacer structure;

Figs. 12, 13 illustrates details of the compression structure;

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Fig. 14 is a cross section through the tool;

Fig. 15 illustrates a calibration tool for calibration of the forming tool; and

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Fig. 16 illustrates a calibration graph.

DETAILED DESCRIPTION OF THE DRAWINGS

30 **[0059]** Fig. 1 illustrate a forming tool 1 in a perspective view and Fig. 2 illustrates a cross section. The forming tool comprises a housing 2, a lid 3, and a container assembly 4.

[0060] In use, the forming tool is attached to a mounting plate 5, 5' of a forming machine, e.g., a multi-stage forming machine. The illustrated forming tool is useful for fast precise change of the forming tool for rebuilding the forming machine and thus enabling a flexible manufacturing with easy change of work pieces. Change-over times is reduced by the efficient attachment and adjustment, and the machine down time can be kept as short as possible.

35 **[0061]** Referring to Figs. 1-3 illustrates the forming tool when attached to the mounting plate 5' of the forming machine. The mounting plate may have a dimension allowing attachment of a plurality of forming tools - only one is illustrated in the appended figures.

[0062] Referring to Fig. 2, the lid 3 defines a lower surface 6. The lower surface is a plane surface arranged towards an upper surface 7 of the housing. A spacing structure shown in Figs. 6-7 provides a distance between the lower surface 6 and the upper surface 7. The distance is indicated by the thick line 8 (Fig. 1) separating the housing 2 from the lid 3, and it is more clearly seen in Figs. 6a and 6b. A safety clip 9 is attached to protect the tension rods.

40 **[0063]** A cavity is formed in the housing, and a through hole 35 is formed in the lid. When the lid is arranged on the housing, the cavity and the through hole coextend each other and defines an encapsulation for the container assembly.

[0064] Fig. 2 illustrates the housing and lid without the container assembly, and Fig. 3 illustrates the housing 2 and the mounting plate 5, 5'. The mounting plate is constituted by an upper mounting plate element 5 and a lower mounting plate element 5'.

[0065] The housing 2 and the upper mounting plate element 5 form through holes 33, 34 and defines a cavity when attached to the lower mounting plate element 5'. The through hole 35 through the lid is aligned with the cavity in the housing and forms an encapsulation for the container assembly.

50 **[0066]** The housing holds an upper backing member 21 and a lower backing member 22. The backing members transfer compressive forces directly to the mounting plate of the machine.

[0067] Fig. 4 illustrates in a perspective view, a cross section through the lid and particularly shows that the through hole defines a sloping inner surface section extending from a narrow surface opening 41 in outer surface 42 towards a large surface opening 43 in the lower surface 6.

55 **[0068]** Fig. 5 illustrates the cross section in a front view and reveals further details of the inner wall of the through hole 35 through the lid 3. The inner surface comprises the sloping inner surface section 51, an upper narrow section 52 and a lower wider section 53 joined by the lower step 54. The upper narrow section 52 is joined with the sloping inner surface section 51 by the upper step 55.

[0069] Herein, we refer to the following definitions related to the cavity which is formed by the lid. The cavity lid is that part of the cavity being above the lower wider section 53. This part of the lid is adapted to engage the container assembly.

[0070] The lower wider section 53 has a diameter approximately of the size of the diameter of the through hole in the housing. This diameter is slightly larger than the diameter of the container assembly. The upper narrow section 52 has a diameter which is very close to the diameter of the container assembly. When the container assembly is arranged in the cavity, the upper part of the container assembly extends into the upper narrow section and thereby becomes sideways locked in the cavity. The lower part of the container assembly extending in the through hole of the housing and in the lower wider section 53 does not touch the sidewall of the through hole in the housing and the lower wider section 53.

[0071] By the structure illustrated in the cross section in Fig. 5, the lid forms a cavity which can receive an upper part of the container assembly 4 while a lower part of the container assembly is received in the cavity in the housing 2.

[0072] The sloping inner surface section 51 defines a first surface portion 51 of the cavity lid. This surface portion is non-perpendicular to the axial direction indicated by the dotted line 56 and will abut an upper surface of the container assembly, when the lid is arranged on the container assembly.

[0073] The cavity in the lid 3 forms a second surface portion which is not abutting an upper surface of the container assembly, namely the upper narrow section 52. The cavity thereby forms a first section 52 abutting the container assembly and a second section 53 not abutting the container assembly. The second section is closer to said lower surface of the lid than the first section.

[0074] Fig. 6 illustrates the housing 2 with the container assembly 4 and the lid arranged above the housing and ready to be lowered onto the housing. The housing is fitted with a spacing structure in the form of 4 spacers arranged in cavities of the housing - one in each corner of the housing.

[0075] The spacers guide the position of the lid and comprises a thickened portion on which the lid, eventually, will rest. The thickened portion is, eventually being squeezed between the lid and the housing when the lid is urged towards the housing by use of the compression structure.

[0076] Each distance spacer is arranged in a depression in the upper surface of the housing or in the lower surface of the lid.

[0077] Fig. 7 illustrates the forming tool, now with four anchor rods 71 arranged one at each corner and configured for receiving a tension rods for urging the lid towards the housing. The anchor rods 71 form lower fixation points in the housing for the tension rods, and form part of the claimed compression-structure. Other means may be applied as an alternative to the anchor and tension rods.

[0078] The mounting procedure for mounting a container assembly in the forming tool is as follows:

- a) the container assembly is arranged in the cavity of the housing,
- b) the lid is arranged on the container assembly such that the container assembly extends into the through hole of the lid until the container assembly reaches the sloping inner surface section 51 and the lid thereby rests on the container assembly.
- c) The tension rods are attached through the holes 72 of the lid and engage into the anchor rods 71 inserted in the housing 2.
- d) The tension rods are used for pulling the lid in the axial direction indicated by the arrow 73 towards the housing until the spacers are squeezed between the lid and the housing. At this point, the lid is deformed to a specific and well-known degree, and the force from the lid onto the container assembly is therefore well-known. This well-known force is obtained without the use of any measurement instruments and the mounting of the container assembly in the forming tool is therefore easy and precise.

[0079] The force is a result of elastic deformation of the lid, and it is essential for creating the well-known force that a gap exists between the housing and the lid, i.e., that the lid is allowed to deform.

[0080] Fig. 8 illustrates an exploded view showing the four anchor rods 71 with the corresponding tension rods 81 for urging the lid towards the housing. The anchor rods 71 extend through bores in the housing and are fixed either in the mounting plate 5 of the forming machine or in the lower housing element 32 of the housing. The anchor rods form lower fixation points in the housing for the tension rods

[0081] The container assembly comprises a die-insert 82 defining a shape forming cavity 83, and a container surrounding the die-insert and provides a radial compression of the die-insert.

[0082] Fig. 8 illustrates the container in the form of a strip wound container. This container comprises a ring 84 surrounding the die-insert 82 and providing a radial pre-stress against an outer surface of the die-insert. A wound element 85 surrounds the ring 84. The wound element 84 is protected by an outer ring 86 encapsulating the compression ring and forming a radial outer surface of the container assembly.

[0083] Figs. 9a and 9b illustrates the gap 91 between the lid and the housing when the lid rests on the container assembly. The size of the gap is reduced by use of the tension rods 81 such that the lid 3 deforms elastically and thereby exerts a well-known force onto the container assembly 4.

[0084] Fig. 10 illustrates a set of four spacers constituting a spacer structure, and Fig. 11 illustrates a single spacer in an enlarged view.

[0085] Each spacer forms a wide section 101 and a narrow section 102. The wide section is arranged in the bore 103 of the housing and extends out of the bore. The lid comprises through holes 104 into which the narrow section extends. When the lid is deformed to the desired degree, it reaches the upper surface 105 of the wide section and the tip 106 of the narrow section is flush with the outer surface 42 of the lid. The spacer comprises a geometric feature in the form of a notch 107. since the bore 104 constitutes a through hole in the lid, the notch is accessible from the outer surface of the lid, and by use of a screwdriver, it can be tested if the spacer is compressed between the housing 2 and the lid 3, and the desired degree of deformation of the lid has been reached. The groove 108 is made for holding an O-ring which may provide a resilient attachment of the spacer in the bore 103.

[0086] Fig. 12 illustrates a tension rod and a spacer 121 arranged between the tension and the outer surface 42 of the lid 3. Fig. 13 illustrates an enlarged view of the spacer in which the lower surface 131 of the spacer is curved to thereby match a curvature of the lid when it becomes deformed.

[0087] Fig. 14 illustrates a cross section through the tool.

[0088] Fig. 15 illustrates a calibration tool 150 which can be attached to the lid 3 and measure deformation. The deformation of the lid expands the gap 151 between the elongate elements 152, and the gap is measured by the gauge 153.

[0089] Fig. 16 illustrates a calibration graph showing ratio between axial force and deflection of the lid. Axial force is along the abscissa and deflection of the lid along the ordinate. The calibration can be performed when making the forming tool, and when the forming tool is subsequently used, replacement of a container assembly can be carried out swiftly and safely by deflecting to a specific distance between the housing and the lid depending on the desired compression force. The distance can be found by use of the graph.

LIST OF EMBODIMENTS

[0090]

1. A forming tool (1) comprising a housing (2), a lid (3), and a container assembly (4), the lid comprising a lower surface arranged towards an upper surface of the housing and defining an encapsulation for the container assembly between the housing and the lid, the forming tool further comprising a compression-structure comprising a plurality of tension rods arranged circumferentially around the container assembly and configured to pull the lid (3) in an axial direction towards the housing, and wherein the container assembly has an axial dimension preventing the lid from abutting the housing and thereby defining a gap between the housing and the lid, wherein the compression-structure is configured to bend the lid by elastic deformation of the lid to thereby reduce a size of said gap between the housing and the lid.

2. The forming tool according to embodiment 1, comprising at least one spacer insertable between the lid and the housing to define a well-defined limit for the elastic deformation.

3. The forming tool according to embodiment 2, wherein at least one of the at least one spacers is arranged at each tension rod.

4. The forming tool according to embodiment 3, wherein all spacers have identical length to define a uniform gap.

5. The forming tool according to embodiments 2-4, wherein the spacers are arranged symmetrically relative to the container assembly such that the compressive force becomes uniformly distributed on the container assembly when the lid is compressed into contact with the spacers.

6. The forming tool according to any of embodiments 2-4, comprising a plurality of sets of spacers, wherein spacers of one set of spacers have identical length and spacers of different sets have different length such that one value of compressive force becomes uniformly distributed on the container assembly when the lid is compressed into contact with spacers from one set of spacers, and such that another value of compressive force becomes uniformly distributed on the container assembly when the lid is compressed into contact with spacers from another set of spacers.

7. The forming tool according to any of embodiments 2-6, wherein each spacer is arranged in a depression in the upper surface of the housing or in the lower surface of the lid.

8. The forming tool according to any of the preceding embodiments, wherein the compression-structure is configured

to bend the lid to an extent where said gap between the housing and the lid is at least pointwise eliminated.

9. The forming tool according to any of the preceding embodiments, wherein each tension rod is threaded into a corresponding lower fixation point in the housing.

10. The forming tool according to any of the preceding embodiments, wherein each tension rod extends in a bore in the housing.

11. The forming tool according to embodiment 9 or 10, wherein the lower fixation point is formed by an anchor rod extending in a bore through the housing.

12. The forming tool according to any of the preceding embodiments, wherein the lid forms a cavity for receiving an upper part of the container assembly (4), the cavity in the lid forming a cavity lid and a cavity sidewall extending from the cavity lid to said lower surface (6) of the lid (3).

13. The forming tool according to embodiment 12, wherein the cavity lid comprises a first surface portion (51) extending non-perpendicular to the axial direction (56) and abutting an upper surface of the container assembly.

14. The forming tool according to embodiment 12 or 13, wherein the cavity lid forms a second surface portion which is not abutting an upper surface of the container assembly.

15. The forming tool according to any of embodiments 13-14, wherein the container assembly comprises an upper surface portion (51) which is sloping non-perpendicular to the axial direction.

16. The forming tool according to any of embodiments 13-14, wherein the container assembly comprises an upper surface portion (51) which is perpendicular to the axial direction.

17. The forming tool according to any of embodiments 12-16, wherein the cavity sidewall forms a first axial section (52) with no gap between the sidewall and the container assembly and a second axial section (53) with a gap between the sidewall and the container assembly.

18. The forming tool according to embodiment 17, wherein the second section is closer to said lower surface of the lid than the first section.

19. The forming tool according to any of the preceding embodiments, wherein the container assembly (4) comprises a die-insert (82) defining a forming cavity (83), a compression ring (84) surrounding the die-insert (82) and providing a radial pre-stress against an outer surface of the die-insert (82).

20. The forming tool according to embodiment 15 and 19, wherein the sloping upper surface portion of the container assembly extends from the die-insert into the compression ring.

21. The forming tool according to any of the preceding embodiments, wherein the compression-structure is configured to provide an axial tension being symmetric about a centre axis (10).

22. The forming tool according to any of the preceding embodiments, configured for forging.

23. A method of assembling a forming tool (1) in a forming machine, the method comprising:

- providing a housing (2, a lid (3), the housing and the lid being provided such that they define an encapsulation when the lid is arranged with a lower surface towards an upper surface of the housing;
- providing a compression-structure comprising a plurality of tension rods;
- providing a container assembly (4) having an axial dimension;
- arranging the container assembly in an encapsulation between the housing and the lid (3);
- providing tension in each tension rod between a lower fixation point in or below the housing and an upper fixation point in or above the lid,

wherein the container assembly is provided such that the axial dimension prevents the lid from abutting the housing and thereby defines a gap between the housing and the lid.

24. The method according to embodiment 23, wherein the tension in each tension rod is applied until the lid bends by elastic deformation such that at least one point of the lower surface of the lid contacts the upper surface of the housing or until a spacer is squeezed between said lower surface of the lid and upper surface of the housing.

25. The method according to embodiment 23 or 24, wherein spacers of identical length are arranged symmetrically relative to the container assembly and the tension rods are tensioned until the lid is compressed into contact with the spacers, to thereby create a uniform distribution of the compressive force on the container assembly.

26. The method according to any of embodiments 23-26, further comprising the step of forming an object in the container assembly by forging.

27. A method for calibrating a tool according to any of embodiments 1-22, the method comprising establishing a data set comprising a plurality of tension forces and corresponding deflections of the lid.

Claims

1. A forming tool (1) comprising a housing (2), a lid (3), and a container assembly (4), the lid comprising a lower surface arranged towards an upper surface of the housing and defining an encapsulation for the container assembly between the housing and the lid, the forming tool further comprising a compression-structure comprising a plurality of tension rods arranged circumferentially around the container assembly and configured to pull the lid (3) in an axial direction towards the housing, and wherein the container assembly has an axial dimension preventing the lid from abutting the housing and thereby defining a gap between the housing and the lid, wherein the compression-structure is configured to bend the lid by elastic deformation of the lid to thereby reduce a size of said gap between the housing and the lid.
2. The forming tool according to claim 1, comprising at least one spacer insertable between the lid and the housing to define a well-defined limit for the elastic deformation.
3. The forming tool according to claim 2, wherein at least one of the at least one spacers is arranged at each tension rod.
4. The forming tool according to claim 3, wherein all spacers have identical length to define a uniform gap.
5. The forming tool according to claims 2-4, wherein the spacers are arranged symmetrically relative to the container assembly such that the compressive force becomes uniformly distributed on the container assembly when the lid is compressed into contact with the spacers.
6. The forming tool according to any of claims 2-4, comprising a plurality of sets of spacers, wherein spacers of one set of spacers have identical length and spacers of different sets have different length such that one value of compressive force becomes uniformly distributed on the container assembly when the lid is compressed into contact with spacers from one set of spacers, and such that another value of compressive force becomes uniformly distributed on the container assembly when the lid is compressed into contact with spacers from another set of spacers.
7. The forming tool according to any of claims 2-6, wherein each spacer is arranged in a depression in the upper surface of the housing or in the lower surface of the lid.
8. The forming tool according to any of the preceding claims, wherein the compression-structure is configured to bend the lid to an extent where said gap between the housing and the lid is at least pointwise eliminated.
9. The forming tool according to any of the preceding claims, wherein the lid forms a cavity for receiving an upper part of the container assembly (4), the cavity in the lid forming a cavity lid and a cavity sidewall extending from the cavity lid to said lower surface (6) of the lid (3).
10. The forming tool according to claim 9, wherein the cavity lid comprises a first surface portion (51) extending non-perpendicular to the axial direction (56) and abutting an upper surface of the container assembly.
11. A method of assembling a forming tool (1) in a forming machine, the method comprising:

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- providing a housing (2, a lid (3), the housing and the lid being provided such that they define an encapsulation when the lid is arranged with a lower surface towards an upper surface of the housing;
- providing a compression-structure comprising a plurality of tension rods;
- providing a container assembly (4) having an axial dimension;
- arranging the container assembly in an encapsulation between the housing and the lid (3);
- providing tension in each tension rod between a lower fixation point in or below the housing and an upper fixation point in or above the lid,

wherein the container assembly is provided such that the axial dimension prevents the lid from abutting the housing and thereby defines a gap between the housing and the lid.

12. The method according to claim 11, wherein the tension in each tension rod is applied until the lid bends by elastic deformation such that at least one point of the lower surface of the lid contacts the upper surface of the housing or until a spacer is squeezed between said lower surface of the lid and upper surface of the housing.

13. The method according to claim 11 or 12, wherein spacers of identical length are arranged symmetrically relative to the container assembly and the tension rods are tensioned until the lid is compressed into contact with the spacers, to thereby create a uniform distribution of the compressive force on the container assembly.

14. The method according to any of claims 11-13, further comprising the step of forming an object in the container assembly by forging.

15. A method for calibrating a tool according to any of claims 1-10, the method comprising establishing a data set comprising a plurality of tension forces and corresponding deflections of the lid.

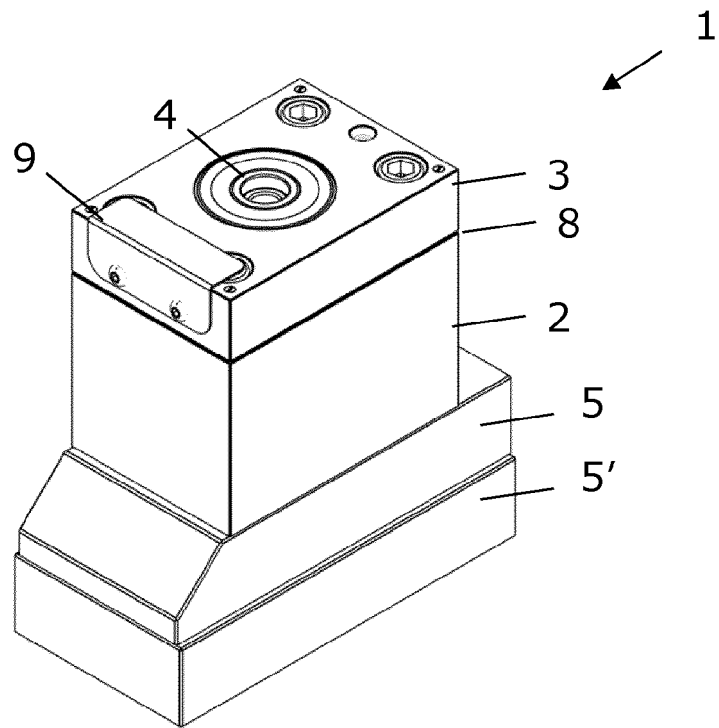


Fig. 1

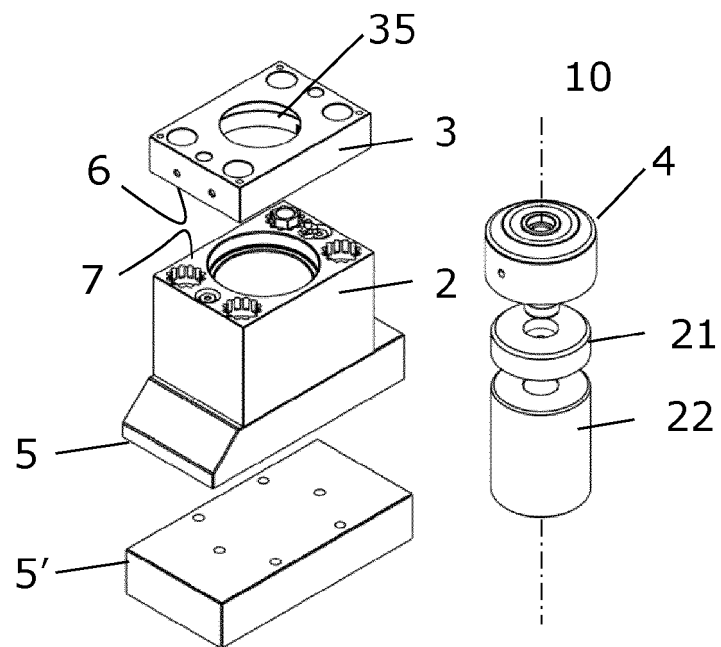


Fig. 2

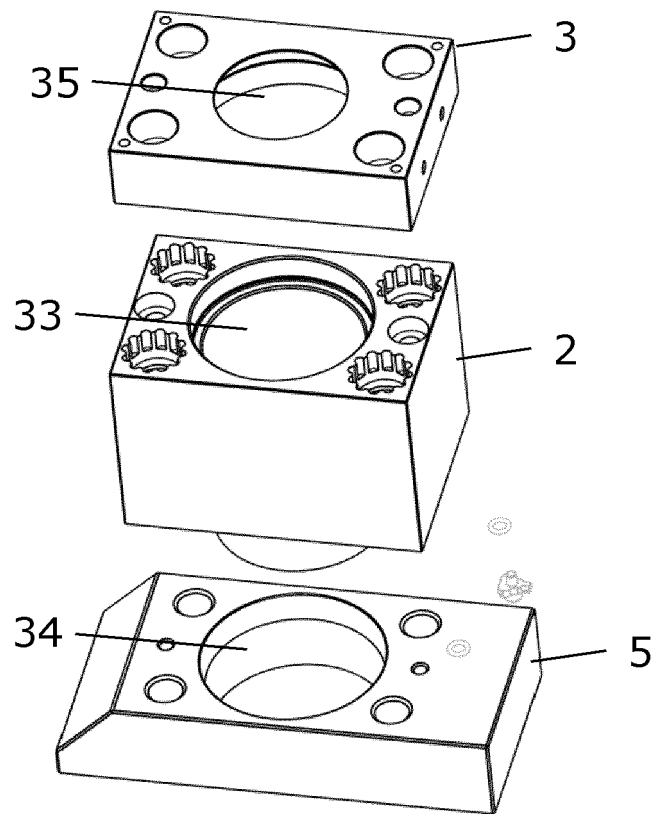


Fig. 3

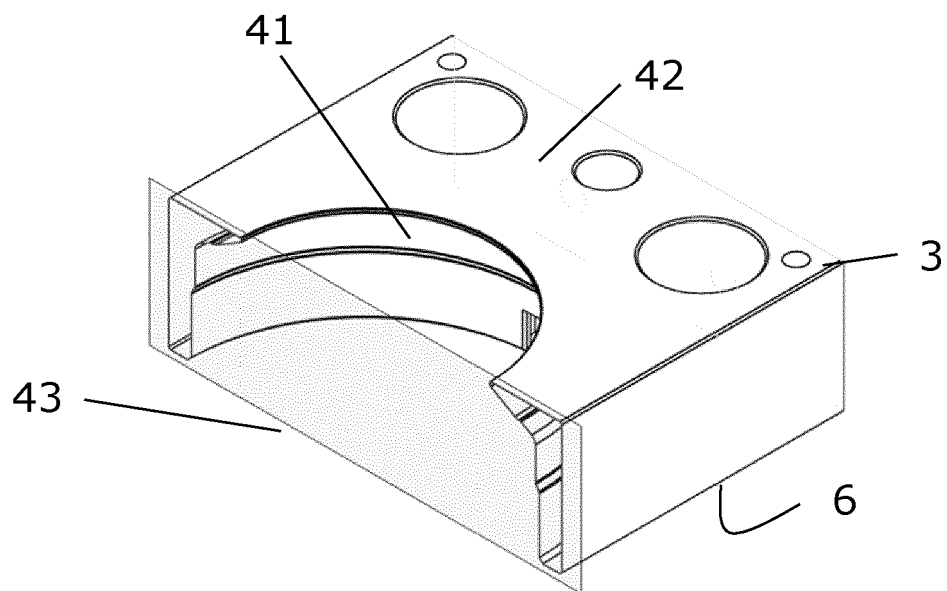


Fig. 4

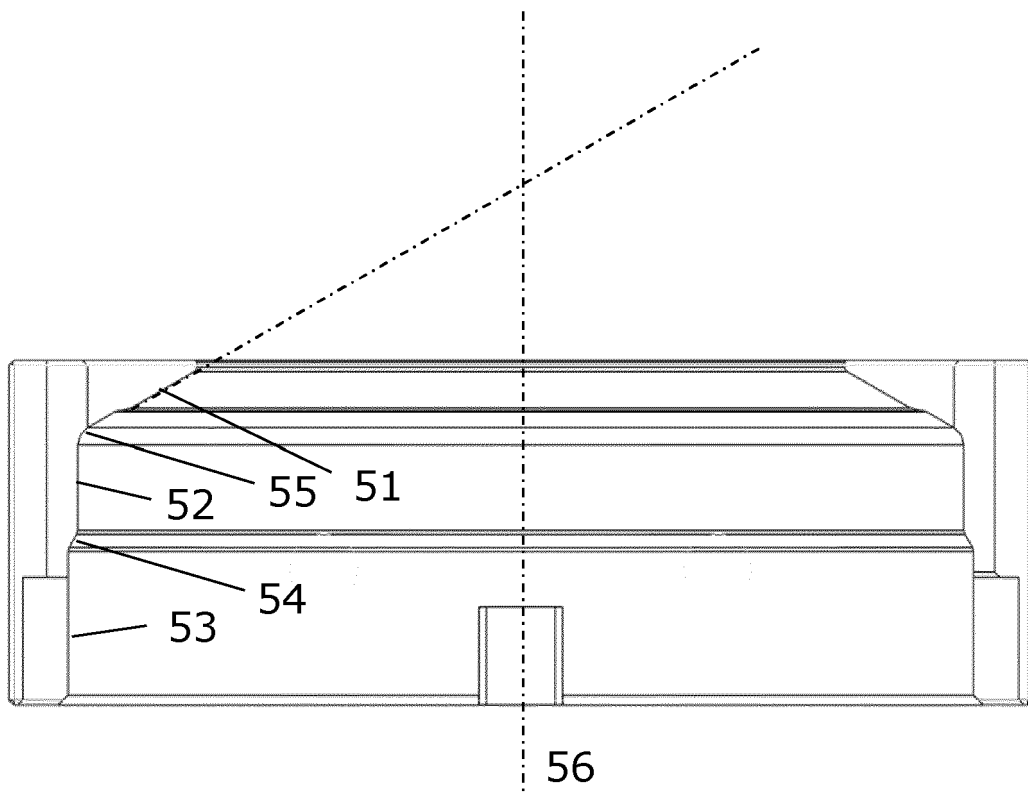


Fig. 5

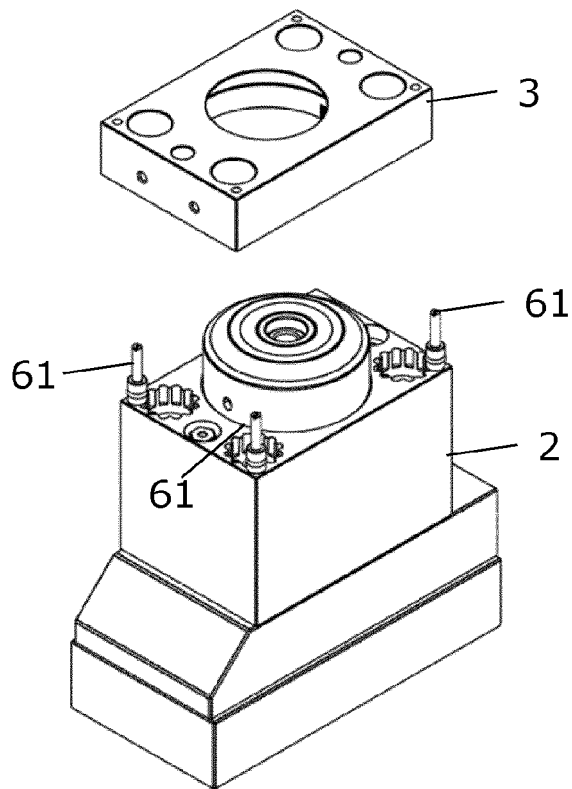


Fig. 6

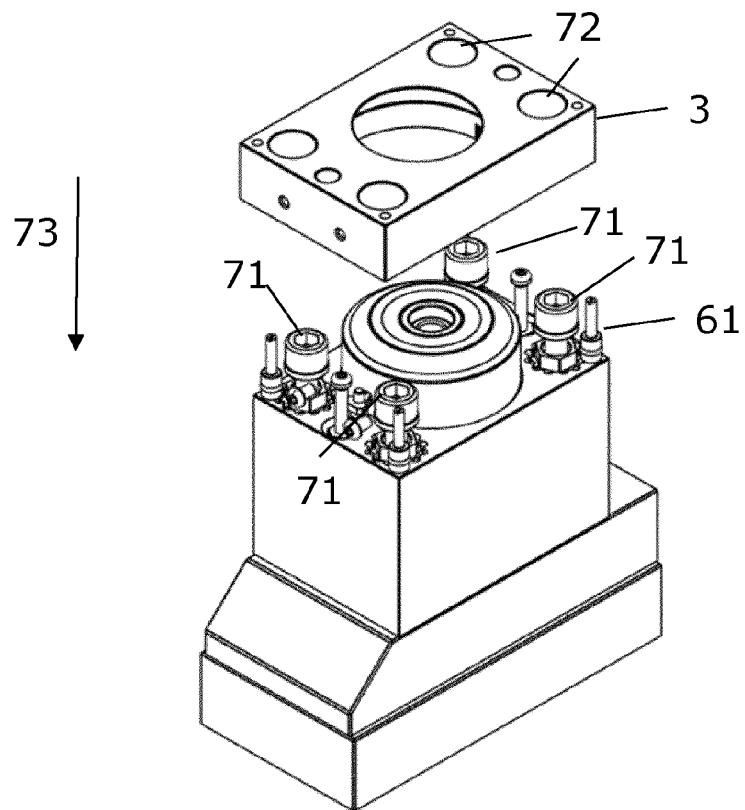


Fig. 7

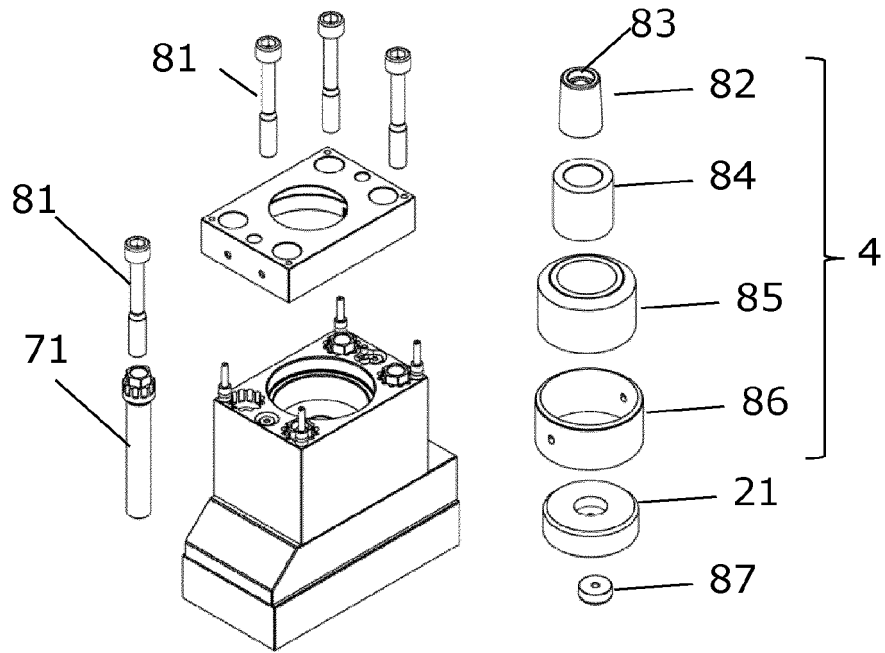


Fig. 8

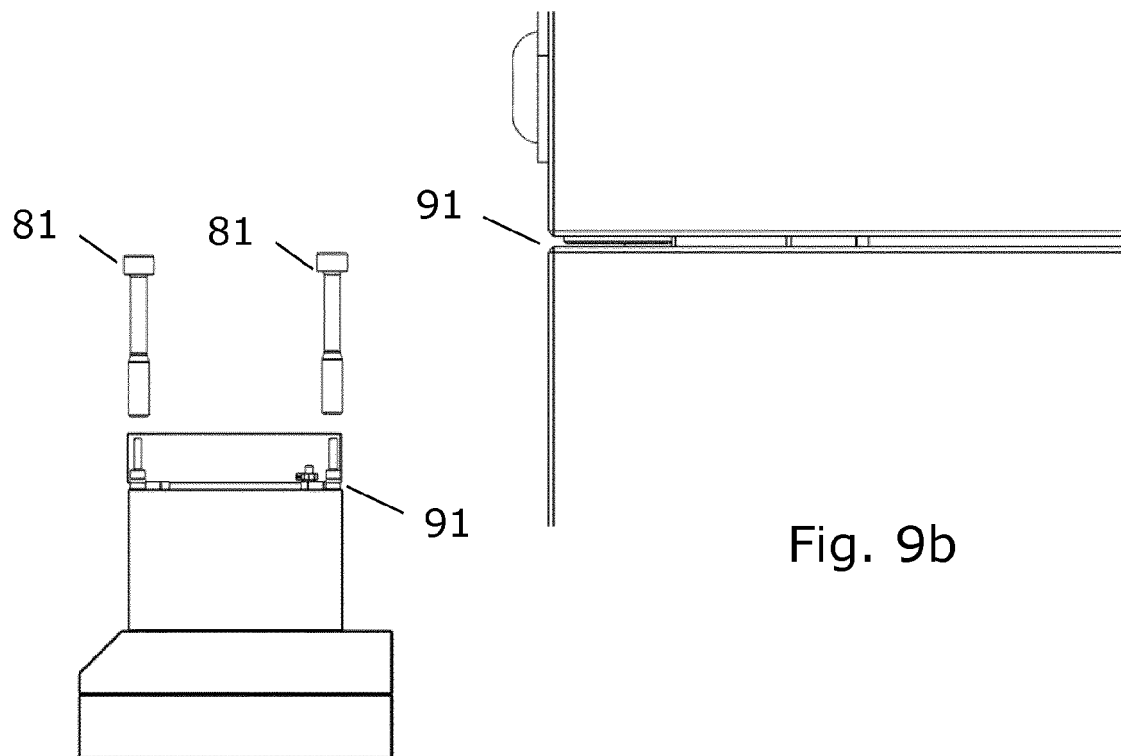


Fig. 9a

Fig. 9b

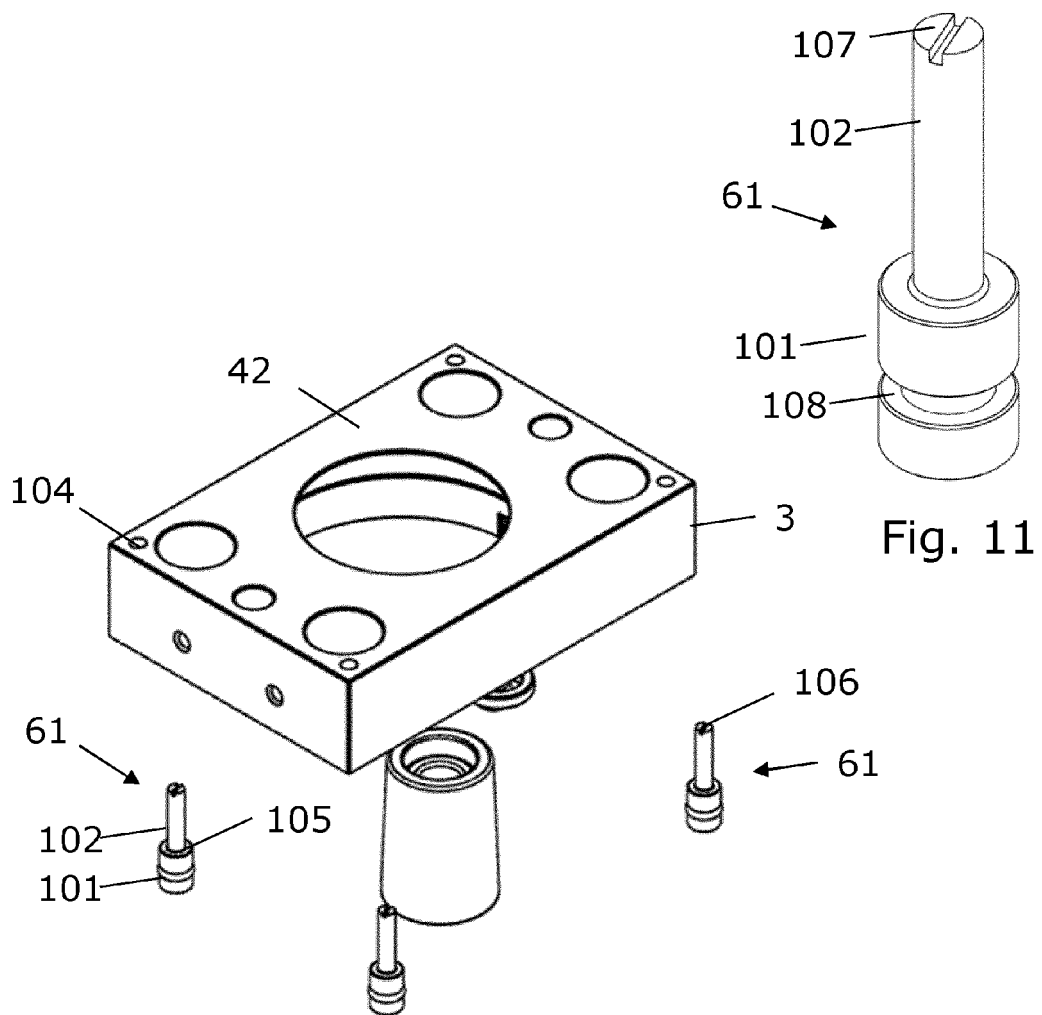


Fig. 10

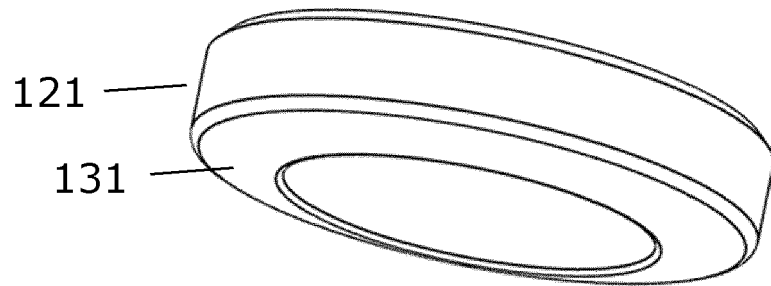


Fig. 13

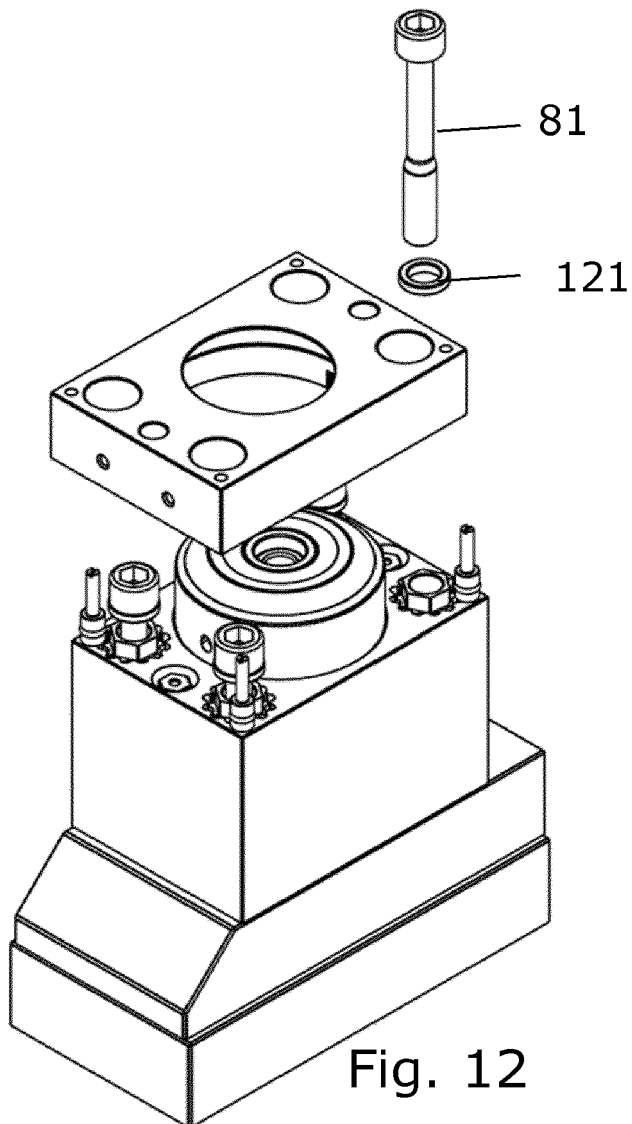


Fig. 12

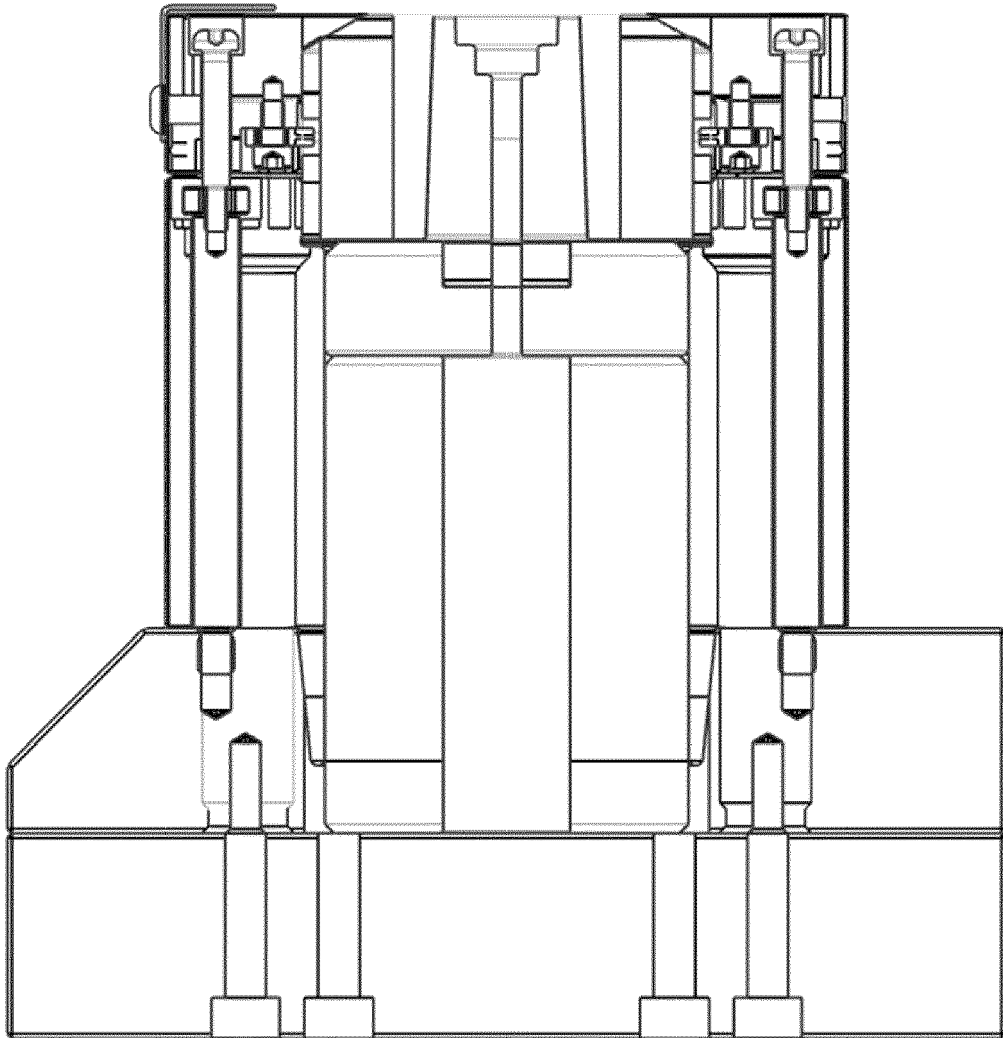


Fig. 14

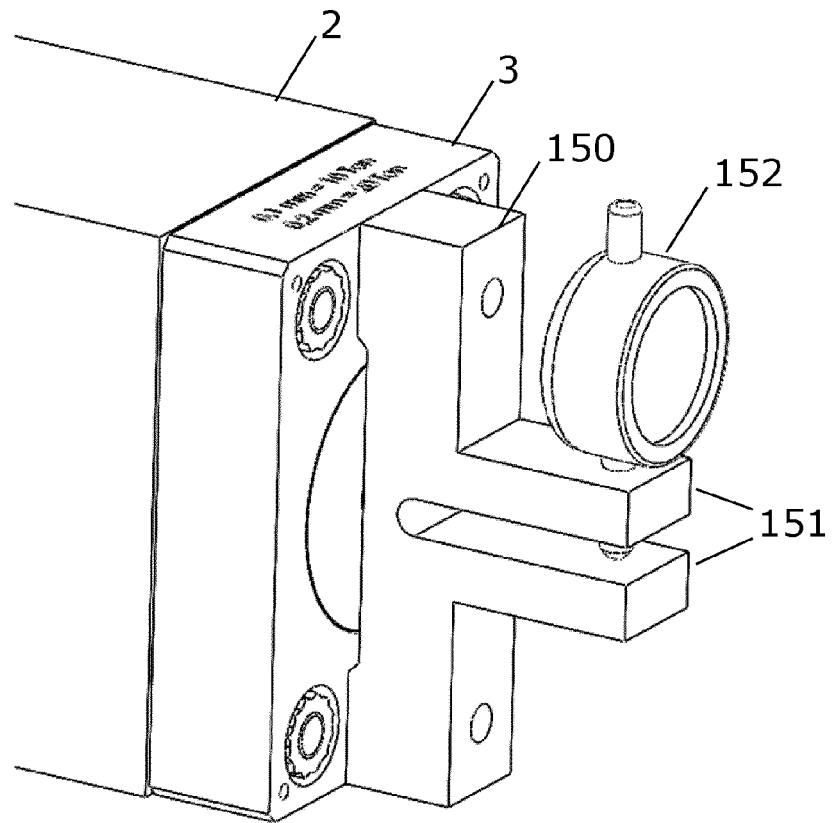


Fig. 15

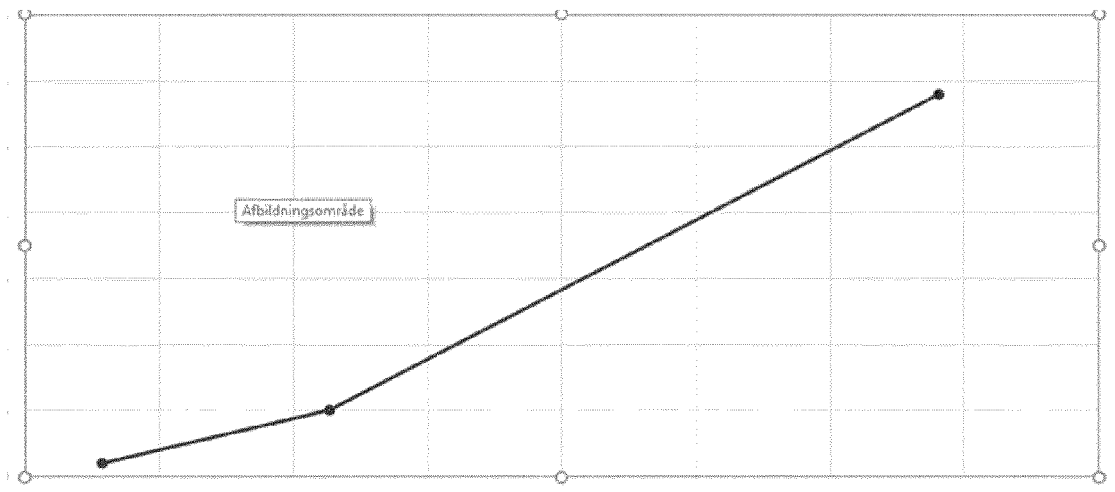


Fig. 16



EUROPEAN SEARCH REPORT

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X	JP S58 76355 U (UNKNOWN) 23 May 1983 (1983-05-23)	1, 9, 11, 14	INV. B21J13/02
A	* paragraph [0002]; figure 4 *	2-8, 10, 12, 13, 15	B21C25/02 B21J9/02 B21D37/14

X	CN 106 513 453 B (UNIV SHANDONG SCIENCE & TECH) 16 October 2018 (2018-10-16)	1, 11	B30B15/02 B21J13/03
A	* figure 1 *	2-10, 12-15	

X	CN 202 387 762 U (UNIV HEFEI TECHNOLOGY) 22 August 2012 (2012-08-22)	1, 9, 11	
A	* figure 1 *	2-8, 10, 12-15	

X	JP 2009 160596 A (SHOWA DENKO KK) 23 July 2009 (2009-07-23)	1, 9, 11	
A	* paragraph [0020] - paragraph [0025] * * paragraph [0028] * * paragraph [0037]; figure 2 *	2-8, 10, 12-15	

			TECHNICAL FIELDS SEARCHED (IPC)
			B21J B21C B21D B30B
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 October 2022	Examiner Ritter, Florian
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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27-10-2022

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