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(54) FORGING APPARATUS AND METHOD

(57) The present invention provides a method of upset forging comprising inserting a stock material into a die, the stock material having a free axial portion with upper and lower surfaces. Next, a punch is used to apply an axial (e.g. horizontal) compression force against the free axial portion of the stock material whilst constraining the upper and lower surfaces of the free axial portion. The constraining positon restricts movement of the free axial portion in a direction substantially perpendicular (e.g. vertical) to the axial compression force thus preventing buckling of the free axial portion.

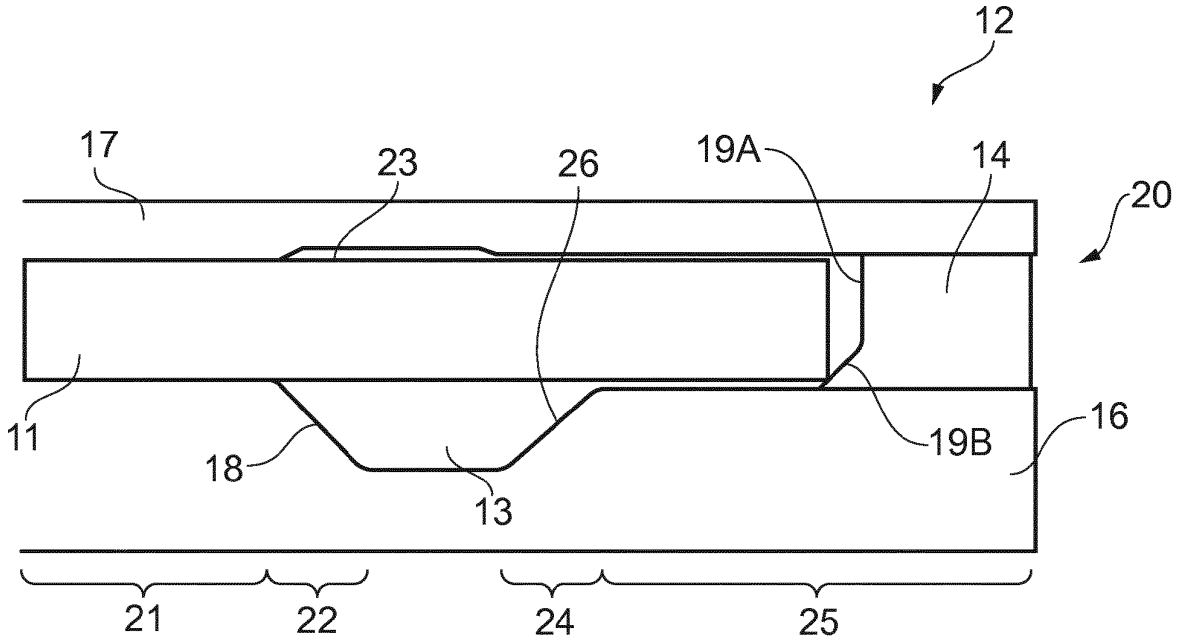

FIG. 3

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Description

[0001] The present disclosure relates to an upset forging method and a die and apparatus for an upset forging method for producing components such as a gas turbine fan blades having a root section.

Background

[0002] Upset forging or heading is a process in which a stock material which may be in the form of a plate, bar or wire is held within a die and subjected to an axial force using a punch in order to reduce its axial length and increase the cross sectional area at its axial end portion.

[0003] In apparatus for known upset forging methods shown in Figure 1, the stock material 1 is held within a split die 2 and protrudes unsupported into a cavity 3 defined by the die. A punch 4 then compresses the axial end 5 of the stock material 1 reducing its length within the cavity 3 and increasing its cross-sectional area to match that of the portion of the cavity 3 into which the stock material 1 is compressed.

[0004] Because the stock material is unsupported within the cavity, it is prone to buckling upon application of the axial compression force. In order to avoid this buckling, an industry standard forging ratio of 3:1 for the length: thickness of the stock material within the cavity is used.

[0005] It is known to use such a method for forming a root section of a fan blade for use in a gas turbine engine. The blade has an aerofoil section and a thicker root section for mounting in a fan disc. It is known to produce the thicker root section of the fan blade using upset forging where a plate or bar of stock material (e.g. titanium) is subjected to a force at its axial end portion to increase the cross-sectional area to form the root section.

[0006] When forming a root section of a fan blade using upset forging, it is often necessary to use a stock material e.g. a plate or bar stock material having a thickness that is larger than required for the (uncompressed) aerofoil section in order to provide enough volume of material to form the root section whilst observing the 3:1 forging ratio to avoid buckling. This means that the resulting aerofoil section requires processing to reduce its thickness after formation of the root section. This processing typically involves machining the aerofoil section to reduce its thickness which increases wastage of the stock material and thus increases costs. Costs are also increased by the need to transport and handle stock material that is thicker (and heavier) than required by the final aerofoil section.

[0007] A typical die and punch for producing a root section of a fan blade is shown in Figure 2. The lower surface of the titanium plate 1' is supported on a bottom plate 6 of the split die 2' and the punch 4' compresses the axial end 5' of the titanium plate 1' to reduce its length within the cavity 3' and to increase its cross sectional area to match the profile defined by the bottom plate 6 and top plate 7 of the split die 2', the inner end wall 8 of the cavity 3' and the contact surface 9 of the punch 4'.

[0008] As explained above, in method using the die and punch shown in Figure 2, the ratio of the length (L): thickness (T) of the titanium plate 1' is less than 3:1 in order to avoid buckling of the plate 1' upwards towards the top plate 7 of the split die 2' during application of the axial force.

[0009] The present disclosure aims to provide a method of and apparatus for upset forging that increases the forging ratio to >3:1 so that a thinner plate/bar of stock material having a longer length within the cavity can be used without a risk of buckling.

Summary

[0010] In a first aspect, there is provided a method of upset forging comprising inserting stock material into a die, such that the stock material has a holding portion and a free axial portion with upper and lower surfaces, the holding portion held in a holding section of the die preventing movement of the stock material in the holding section both in a parallel and perpendicular direction relative to the axial compression force, and using a punch to apply an axial compression force against the free axial portion whilst constraining the upper and lower surfaces of the free axial portion during forging of the free axial portion so as to restrict movement of the free axial portion in a direction substantially perpendicular to the axial compression force.

[0011] The method of upset forging may comprise inserting a portion of stock material into a die, the portion of stock material having a free axial end with upper and lower surfaces, and using a punch to apply an axial compression force against the free axial end of the portion of stock material whilst constraining the upper and lower surfaces of the free axial end so as to restrict movement of the free axial end in a direction substantially perpendicular to the axial compression force.

[0012] By providing a method that allows constraint of the stock material at its free axial portion (for example the free axial end or the end to be upset forged) during the application of the compression force, buckling is prevented even when an increased length of stock material is used. The free axial portion may not contact the die before the compression force is applied. The free axial portion may be unconstrained by the die before the compression force is applied. The present inventors have found that a forging ratio of length: thickness in excess of 4.5:1 can be achieved. The length may be the axial length of the free axial portion. This allows a thinner, longer plate/bar of stock material to be used in the die whilst still allowing the formation of an enlarged cross-sectional profile section having the required volume.

[0013] The free axial portion may be insulated by the gap between its upper and lower surfaces and the die before the axial compression force is applied. The free axial portion may be much hotter than the die.

[0014] During forging of the free axial portion the axial

compression force is applied. The free axial portion may compress in an axial direction. The free axial portion may expand in a direction perpendicular to the axial direction. The free axial portion may expand such that it contacts the constraining section of the die. The free axial portion may expand such that it fills the constraining section of the die.

[0015] The upper and lower surfaces may be first and second surfaces.

[0016] For example, the method can be used to form a fan blade using a thinner plate/bar of titanium stock material (for example) whilst still allowing the formation of a root section of a fan blade having the required volume. The aerofoil section (which is formed of the uncompressed portion of the stock material) requires less post-forging machining resulting in less wastage of stock material.

[0017] An axial length of the free axial portion is greater than 3 times (optionally 4 or 4.5 times) a thickness of the free axial portion.

[0018] Furthermore, the use of thinner plates/bars of stock material reduces transport and handling costs of the stock material prior to forging.

[0019] The method comprises inserting the stock material into a holding section of the die i.e. a section in which a stock material can be held/secured during upset forging. The holding section is adapted to prevent movement of the stock material both in a parallel and perpendicular direction relative to the axial compression force.

[0020] In some embodiments, the method is for forming a fan blade for a gas turbine engine and the method comprises applying an axial compression force to compress the free axial portion of the stock material to form a root section having an increased cross-sectional area. In these embodiments, the stock material may be titanium, e.g. a titanium sheet or bar.

[0021] In some embodiments, the die is horizontally arranged and the axial compression force is a horizontal force. In these embodiments, the method comprises preventing vertical movement of the free axial portion of the stock material by constraining the upper and lower surfaces of the free axial portion.

[0022] In some embodiments, the method comprises inserting the stock material into the die such that the free axial portion is positioned within a constraining section of the die. The constraining section is adapted to prevent movement of free axial portion of the stock material in a perpendicular direction relative to the axial compression force but to allow axial compression. The constraining section does not contact the free axial portion before application of the axial compression force. The constraining section contacts the free axial portion upon application of the axial compression force to constrain the free axial portion as it if formed.

[0023] In some embodiments, the method comprises inserting the stock material between a first plate and a second plate of a split die, the first and second plates defining the holding section and constraining section with a cavity axially interposed between the two sections. The first and second plates in the constraining section define an opening at the second axial end into which the punch is inserted. The cavity may comprise a forging feature. The forging feature may be a recess. The cavity may comprise a cavity constraining feature.

[0024] In some embodiments, method comprises inserting the stock material between the first plate and the second plate of the split die in the holding section where the first and second plates are spaced by a first spacing, the first spacing equalling the thickness of the portion of the stock material.

[0025] In some embodiments, method comprises inserting the stock material between the first plate and the second plate of the split die such that it extends through the cavity, the first and second plates being spaced by a second spacing in the cavity, the second spacing being greater than the first spacing.

[0026] The volume of the stock material held within the constraining section will equal the volume of the cavity (less the volume of the stock material extending through the cavity).

[0027] In some embodiments, method comprises inserting the free axial portion of the stock material between the first plate and the second plate of the split die in the constraining section where the first and second plates are spaced by a third spacing, the third spacing being up to 5% greater than the first spacing. In some embodiments, the third spacing substantially matches the first spacing.

[0028] The method further comprises compressing the axial end portion of the stock material into the cavity such that its cross-sectional profile increases and adopts the profile defined by the cavity.

[0029] In a second aspect, there is provided a die for upset forging by axial compression of a stock material having a free axial portion with upper and lower surfaces, said die having a holding section at a first axial end for securing the stock material and a constraining section at a second axial end, the holding section and constraining section being axially spaced by a cavity, the constraining section for constraining the upper and lower surfaces of the free axial portion so as to restrict movement of the free axial portion in a direction perpendicular to the axial compression.

[0030] The first axial end of the die provides a holding section i.e. a section in which a stock material can be held/secured during upset forging. The holding section is adapted to prevent movement of the stock material both in a parallel and perpendicular direction relative to the axial compression/axis of the die.

[0031] In some embodiments the die comprises a first plate and a second plate. The first and second plates in the constraining section define an opening at the second axial end for receiving a punch. The constraining section extends from the cavity to the opening.

[0032] In some embodiments, the first and second plates are spaced by a first distance in the holding sec-

tion. The first spacing will equal the thickness of the portion of the stock material. They are spaced by a second spacing in the cavity and a third spacing in the constraining section. The second spacing is greater than the first and third spacing i.e. the spacing between the first and second plates in the constraining section and the holding section is less than the spacing between the plates defining the cavity.

[0033] In some embodiments, the first and third spacings are approximately equal i.e. the spacing between the plates in the constraining section substantially matches the thickness of the stock material. In some embodiments, the third spacing is up to 5 % greater than the first spacing.

[0034] In some embodiments, the die has a diverging section distal the opening (for receiving the punch) in which the first and second plates diverge from the first spacing of the holding section to the increased second spacing of the cavity between the plates.

[0035] In some embodiments, the die further comprises a converging section proximal the opening (for receiving the punch) in which the first and second plates converge to form the constraining section for constraining the movement of the free axial portion of the stock material in a direction perpendicular to the axis of the die (i.e. the axis extending through the cavity between the holding section and the constraining section).

[0036] In some embodiments, the die comprises a first plate and a second plate, the die having a first axial end at which the first and second plates define an opening for receiving a punch, the die having a diverging section distal the opening in which the first and second plates diverge from a first spacing to an increased spacing to form a cavity between the plates, wherein the die further comprises a converging section proximal the opening in which the first and second plates converge to form a constraining portion extending from the cavity to the opening, the constraining portion having a spacing between the first and second plates that is less than the spacing between the first and second plates in the cavity.

[0037] The volume the constraining section will be equal to or greater than the volume of the cavity (less the volume of the stock material extending through the cavity).

[0038] In some embodiments, the first plate is substantially planar. In these embodiments, the diverging section is formed by the second plate diverging from the first plate, the second plate creating an inner end wall defining the cavity distal the opening. The converging section of the die may be formed by the second plate converging towards the first plate, the second plate creating a second inner end wall defining the cavity proximal the opening. The first and second end walls may have equal and opposite inclines i.e. the second plate may be symmetrical about the axial centre of the cavity.

[0039] In some embodiments, the die is horizontally arranged. The first plate may be an upper plate and the second plate may be a lower plate. In horizontally arranged dies, the holding section is adapted to prevent horizontal and vertical movement of the stock material and the constraining section is adapted to prevent vertical movement (but to allow horizontal compression).

[0040] In some embodiments, the first/upper plate comprises a recess defining an enlarged portion of the cavity.

[0041] In a third aspect, there is provided a forging apparatus comprising a die according to the second aspect, and a punch for applying an axial compression force against the free axial portion of the stock material.

[0042] The punch is received in the opening at the second axial end formed by the plates in the constraining section.

[0043] It has a contact surface facing the cavity of the die, the contact surface having a height (in the direction extending between the first and second plates) substantially equal to the third spacing between the first and second plates in the constraining section.

[0044] The contact surface may be a planar surface, an inclined surface or it may have a planar portion and an inclined portion meeting at a join.

[0045] In an aspect there is provided a method of manufacturing a component, the method comprising the method of upset forging according to the previous aspect.

[0046] The component may be a blade for a gas turbine engine. For example, the component may be a fan blade.

[0047] The skilled person will appreciate that except where mutually exclusive, a feature described in relation to any one of the above aspects may be applied mutatis mutandis to any other aspect. Furthermore except where mutually exclusive any feature described herein may be applied to any aspect and/or combined with any other feature described herein.

Brief Description of the Drawings

[0048] Embodiments will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows a prior art upset forging apparatus;

Figure 2 shows a prior art upset forging apparatus for forming a root portion of a blade for a gas turbine engine;

Figure 3 shows a first embodiment of an upset forging apparatus according to the third aspect for forming a root portion of a blade for a gas turbine engine; and

Figure 4 shows a sectional side view of a gas turbine engine.

Detailed Description and Further Optional Features

[0049] Figure 1 shows a die 12 for forming a root sec-

tion of a fan blade by upset forging of a portion (sheet or bar) of titanium 11 having a thickness of around 20.8 mm.

[0050] The die 12 comprises a lower plate 16 and an upper plate 17. They extend along the axis of the die from a first axial end defining an opening 20 for receiving a punch 14 to a holding section 21 at a second axial end of the die 12. In the holding section 21, the upper and lower plates 16, 17 are spaced by a first spacing equal to the thickness of the portion of titanium 11 such that the portion of titanium is held/secured in the holding section 21. Both horizontal and vertical movement of the portion of titanium are prevented by the holding section 21.

[0051] The die 12 has a diverging section 22 distal the opening 20 in which the upper and lower plates 16, 17 diverge from the first spacing to an increased spacing to form a cavity 13 between the plates 16, 17. The lower plate 16 diverges away from the substantially planar upper plate 17 and forms an inclined first inner end wall 18.

[0052] The substantially planar upper plate defines a shallow recess 23 which provides a slightly enlarged section of the cavity 13.

[0053] The portion of titanium 11 extends from the holding section 20 at the diverging section 22 and into the cavity 13.

[0054] The die 12 further comprises a converging section 24 proximal the opening 20 in which the upper and lower plates 16, 17 converge to form a constraining section 25 extending from the cavity 13 to the opening 20. The lower plate 16 converges back towards the substantially planar upper plate 17 and forms an inclined second inner end wall 26. The first and second inner end walls 18, 19 are substantially mirror images of one another i.e. the lower plate 16 is substantially symmetrical about the axial centre of the cavity 13.

[0055] The constraining section 25 has a spacing between the upper and lower plates 16, 17 that is less than the spacing between the upper and lower plates in the cavity 13. The spacing between the upper and lower plates 16, 17 in the constraining section substantially matches the first spacing i.e. the spacing between the plates 16, 17 in the holding section and thus the thickness of the portion of titanium 11.

[0056] The portion of titanium extends through the cavity 13 and into the constraining section 25 where it is vertically restrained by the upper and lower plates 16, 17. The total length of the portion of titanium 11 extending from the diverging section equals 95mm.

[0057] A punch 14 is inserted into the opening 20 between the upper and lower plates 16, 17 at the first axial end of the die 12. The die 14 has a contact surface 19 which has a vertical portion 19A and an inclined portion 19B. The height of the punch 14 matches the spacing between the upper and lower plates 16, 17 in the constraining section 25.

[0058] The die 14 is forced towards the second axial end of the die 12 and the contact surface 19 compresses the portion of titanium 11 into the cavity 13. Even though the forging ratio of length: thickness of 4.57:1 exceed the industry standard of 3:1, buckling of the portion of titanium 11 is prevented by the vertical constraint (perpendicular to the axis of the die) provided by the constraining section 25. Only horizontal movement of the portion of titanium 11 (along the axis of the die) is allowed within the constraining section.

[0059] The cavity 13 (including the recess 23), first and second inner end walls 18, 26 and the contact surface 19 define the impression of the profile of the root section of the fan blade and the compressed titanium 11 is forced into this enlarged cross-sectional profile to form the root section. The portion of titanium 11 remaining uncompressed in the holding section 22 can be machined to form the aerofoil section of the fan blade.

[0060] With reference to Figure 4, a gas turbine engine is generally indicated at 30, having a principal and rotational axis 31. The engine 30 comprises, in axial flow series, an air intake 32, a propulsive fan 33, an intermediate pressure compressor 34, a high-pressure compressor 35, combustion equipment 36, a high-pressure turbine 37, an intermediate pressure turbine 38, a low-pressure turbine 39 and an exhaust nozzle 40. A nacelle 41 generally surrounds the engine 30 and defines both the intake 32 and the exhaust nozzle 40.

[0061] The gas turbine engine 30 works in the conventional manner so that air entering the intake 32 is accelerated by the fan 33 to produce two air flows: a first air flow into the intermediate pressure compressor 34 and a second air flow which passes through a bypass duct 42 to provide propulsive thrust. The intermediate pressure compressor 34 compresses the air flow directed into it before delivering that air to the high pressure compressor 35 where further compression takes place.

[0062] The compressed air exhausted from the high-pressure compressor 35 is directed into the combustion equipment 36 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through, and thereby drive the high, intermediate and low-pressure turbines 37, 38, 39 before being exhausted through the nozzle 40 to provide additional propulsive thrust. The high 37, intermediate 38 and low 39 pressure turbines drive respectively the high pressure compressor 35, intermediate pressure compressor 34 and fan 33, each by suitable interconnecting shaft.

[0063] The blades of the fan 33, compressors 34, 35, or turbines 37, 38, 39 may be manufactured using an upset forging apparatus as shown in Figure 3. It is particularly contemplated that the blades of the fan will be manufactured using the apparatus shown in Figure 3.

[0064] Other gas turbine engines to which the present disclosure may be applied may have alternative configurations. By way of example such engines may have an alternative number of interconnecting shafts (e.g. two) and/or an alternative number of compressors and/or turbines. Further the engine may comprise a gearbox provided in the drive train from a turbine to a compressor and/or fan.

[0065] It will be understood that the invention is not limited to the embodiments above-described and various modifications and improvements can be made without departing from the concepts described herein. Except where mutually exclusive, any of the features may be employed separately or in combination with any other features and the disclosure extends to and includes all combinations and sub-combinations of one or more features described herein.

Claims

1. A method of upset forging comprising inserting stock material into a die, such that the stock material has a holding portion and a free axial portion with upper and lower surfaces, the holding portion held in a holding section of the die preventing movement of the stock material in the holding section both in a parallel and perpendicular direction relative to the axial compression force, and using a punch to apply an axial compression force against the free axial portion whilst constraining the upper and lower surfaces of the free axial portion during forging of the free axial portion so as to restrict movement of the free axial portion in a direction substantially perpendicular to the axial compression force.

2. A method according to claim 1, wherein an axial length of the free axial portion is greater than 3 times (optionally 4 or 4.5 times) a thickness of the free axial portion.

3. A method according to claim 1 or claim 2 for forming a fan blade for a gas turbine engine, the method comprising applying an axial compression force to compress the free axial portion of the stock material to form a root section having an increased cross-sectional area.

4. A method according to any one of claims 1 to 3 comprising inserting the stock material into the die such that the free axial portion is positioned within a constraining section of the die and preventing movement of the free axial portion of the stock material in a perpendicular direction relative to the axial compression force during forging of the free axial portion whilst allowing axial compression of the free axial portion.

5. A method according to any one of the previous claims comprising inserting the stock material between a first plate and a second plate of a split die where the first and second plates are spaced by a first distance in the holding section, the first spacing equalling the thickness of the portion of the stock material.

6. A method according to claim 5 comprising inserting the free axial portion of the stock material in the constraining section where the first plate and second plate are spaced by a third spacing, the third spacing being up to 5% greater than the first spacing.

7. A method according to any one of claims 1 to 6 comprising preventing vertical movement of the free axial portion of stock material by vertically constraining the upper and lower surfaces of the free axial portion during forging of the free axial portion upon application of a horizontal compression force.

8. A die for upset forging by axial compression of a stock material having a holding portion and a free axial portion with upper and lower surfaces, said die having a holding section at a first axial end for securing the holding portion and a constraining section at a second axial end, the holding section and constraining section being axially spaced by a cavity, the constraining section for constraining the upper and lower surfaces of the free axial portion so as to restrict movement of the free axial portion in a direction substantially perpendicular to the axial compression.

9. A die according to claim 8 wherein the holding section is adapted to prevent movement of the stock material both in a parallel and perpendicular direction relative to the axial compression.

10. A die according to claim 8 or 9 comprising a first plate and a second plate spaced by a first distance in the holding section, a second spacing in the cavity and a third spacing in the constraining section, wherein the first and second plates in the constraining section define an opening at the second axial end for receiving a punch and the constraining section extends from the cavity to the opening.

11. A die according to claim 10 wherein the second spacing is greater than the first and third spacing.

12. A die according to claim 10 or 11 wherein the third spacing is up to 5% greater than the first spacing.

13. A die according to claim 12 wherein the first and third spacings are approximately equal.

14. A die according to any one of claims 10 to 13 wherein the die has a diverging section distal the opening in which the first and second plates diverge from the first spacing of the holding section to the increased second spacing of the cavity and/or a converging section proximal the opening in which the first and second plates converge to form the constraining section.

15. A forging apparatus comprising a die according to

any one of claims 8 to 14, and a punch for applying an axial force against the free axial portion of the stock material.

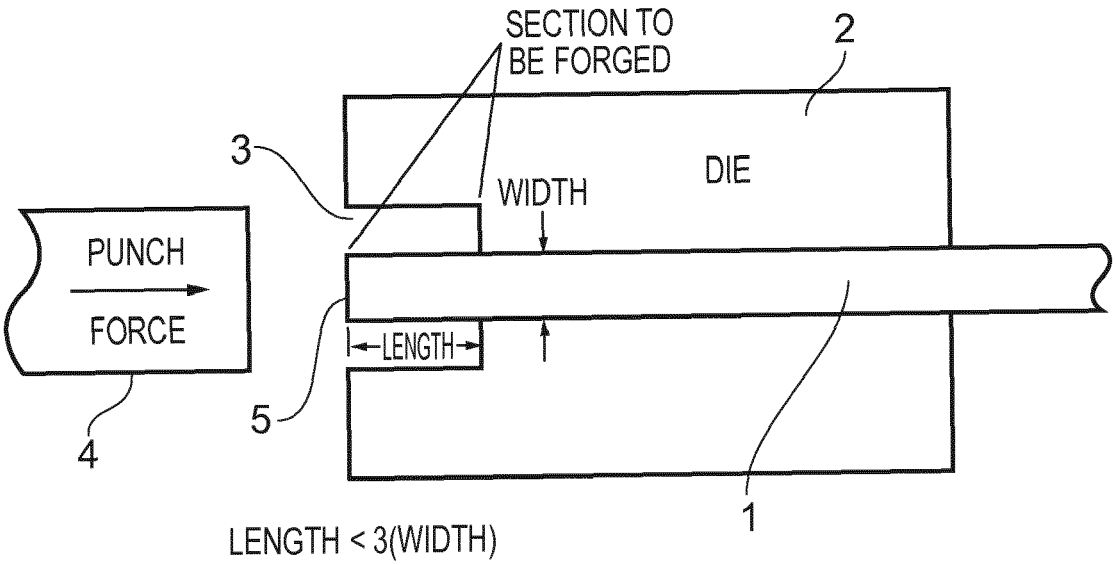
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FIG. 1

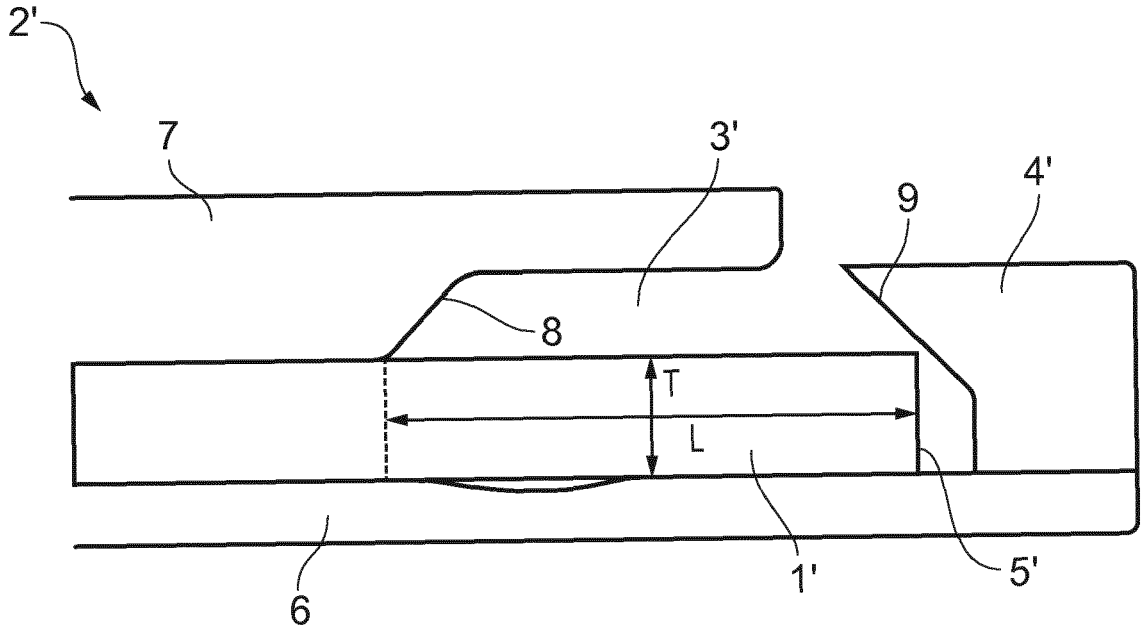
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FIG. 2

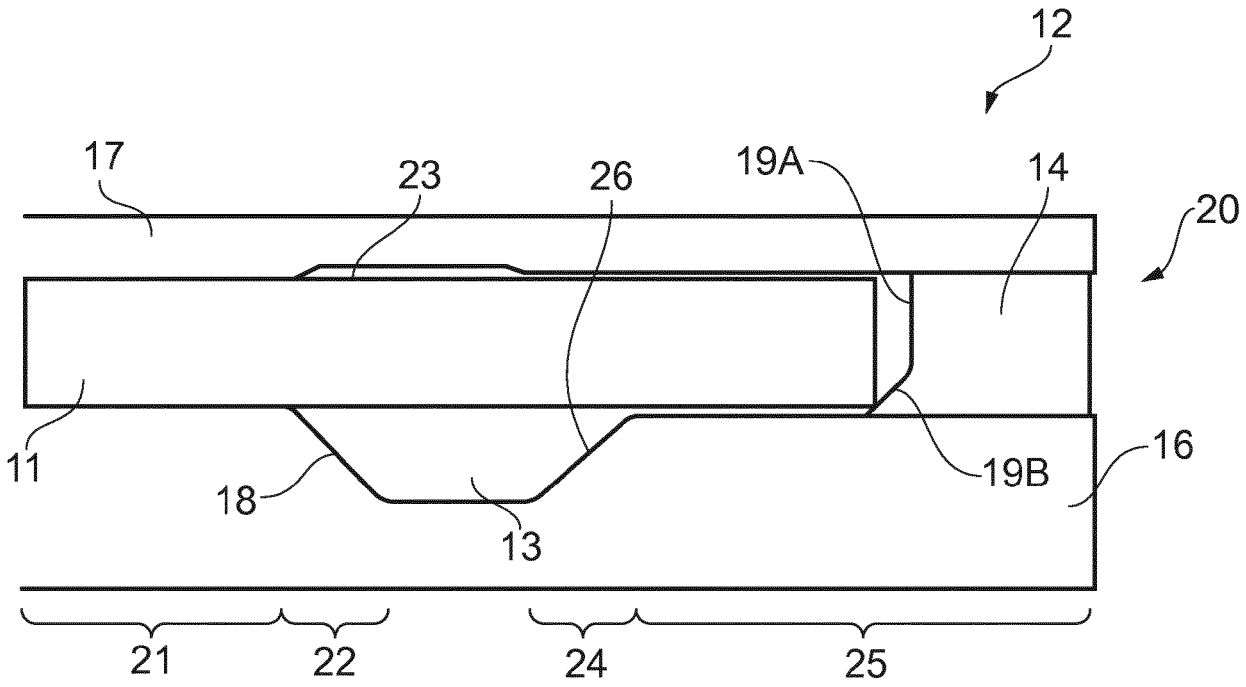

FIG. 3

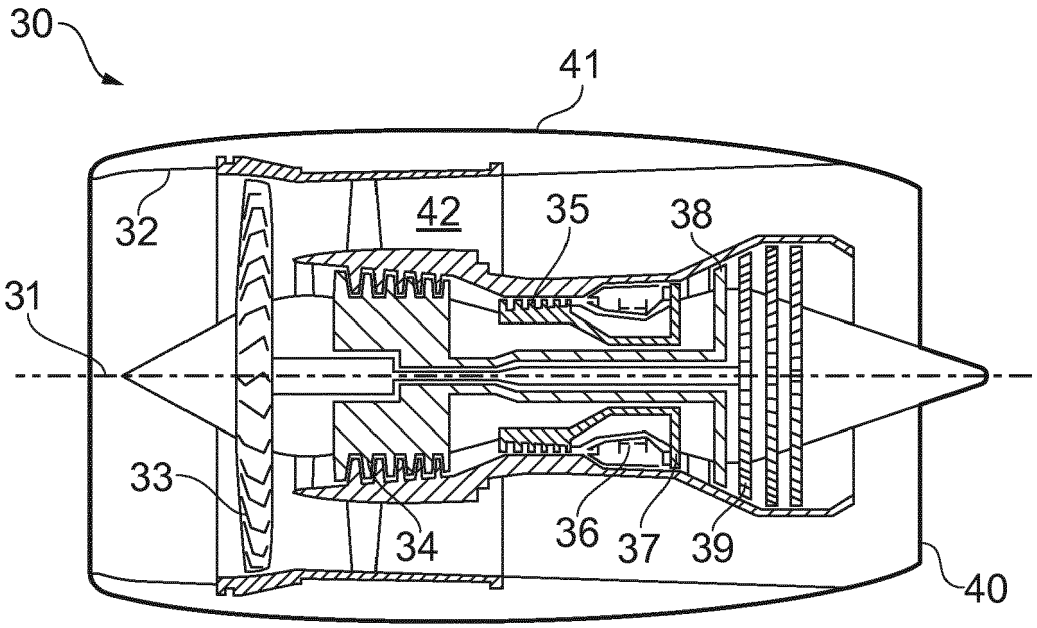

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 7755

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 Y	EP 1 844 875 A1 (SHOWA DENKO KK [JP]) 17 October 2007 (2007-10-17) * paragraphs [0213], [0215], [0224] - [0235]; figures 3-5 *	1,2,4,5, 7-9,12, 15 6,12	INV. B21J5/08 B21K3/04 B21J13/02
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TECHNICAL FIELDS SEARCHED (IPC)

B21J
B21K

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	9 October 2018	Charvet, Pierre

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 18 16 7755

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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