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(54) "MULTI-EFFECT" FORMING TOOLING FOR HIGH-TEMPERATURE FORMING

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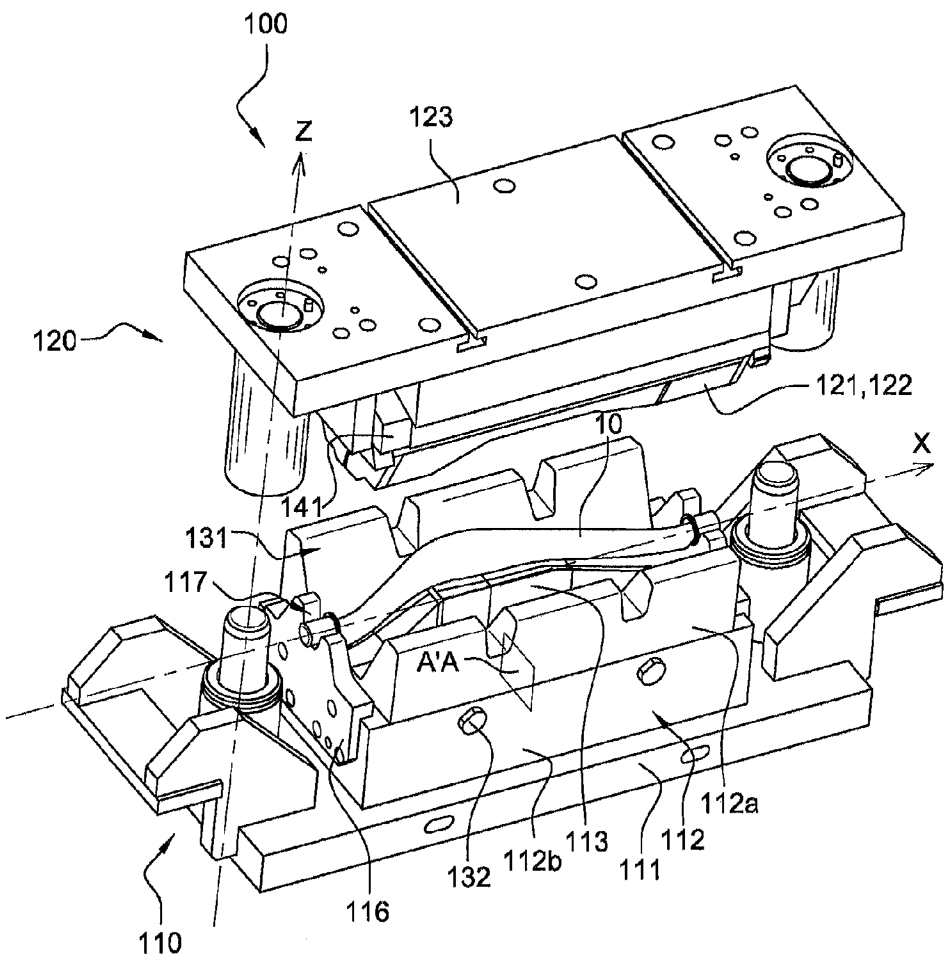
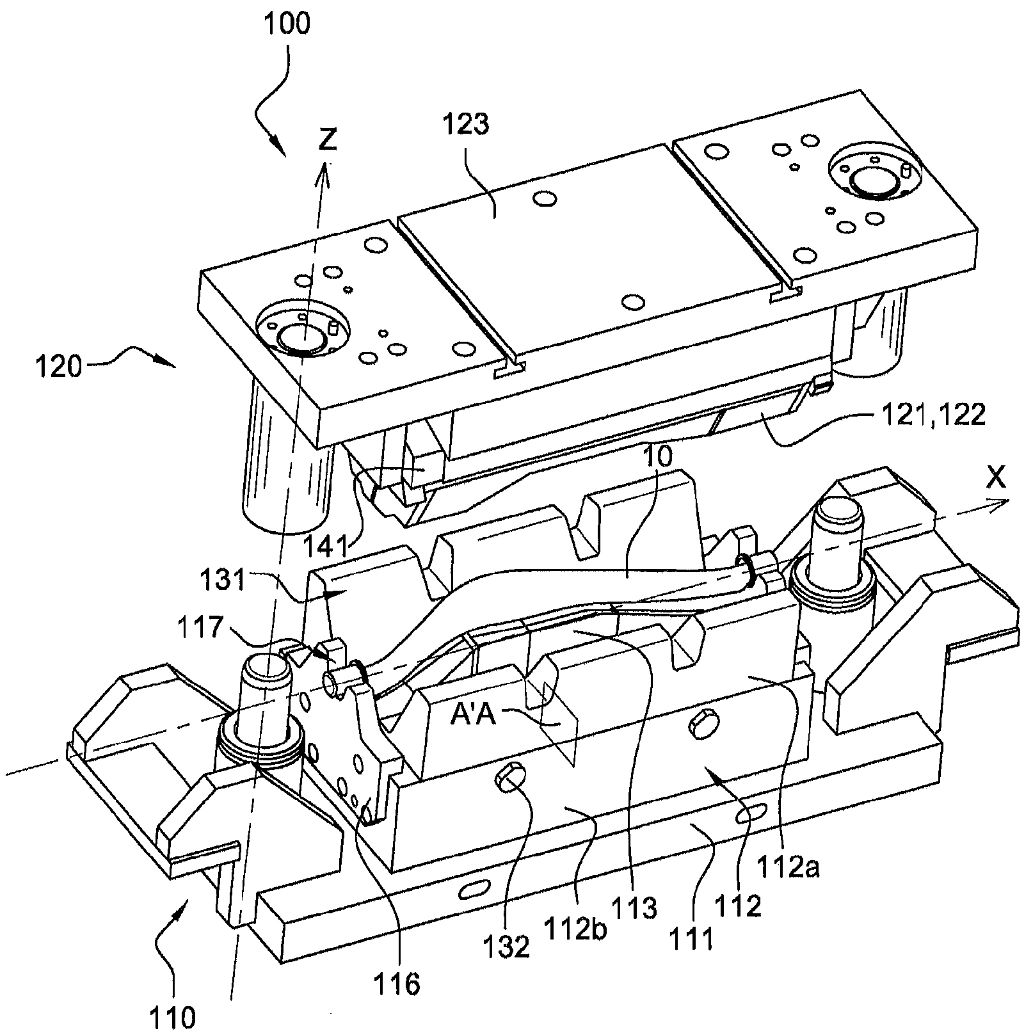
(57) **ABSTRACT**

A forming tooling including a fixed part and a moving part set in action by a one-way press, in a first direction, the tooling varying between an open position and a closed position in which the moving part applies pressure to the fixed part; the moving part including moving dies capable of starting to deform the metal workpiece through a translational movement of the dies in a second direction simultaneous with the translational movement of the dies in the first direction during closure of the tooling, the moving dies being capable of moving away from the metal workpiece through a reverse translational movement of the moving dies, in the second direction, simultaneously with the translational movement of the moving dies in the first direction during opening of the tooling.




100
Z
123
120
121,122
10
X
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117
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116
132
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110

Fig. 1

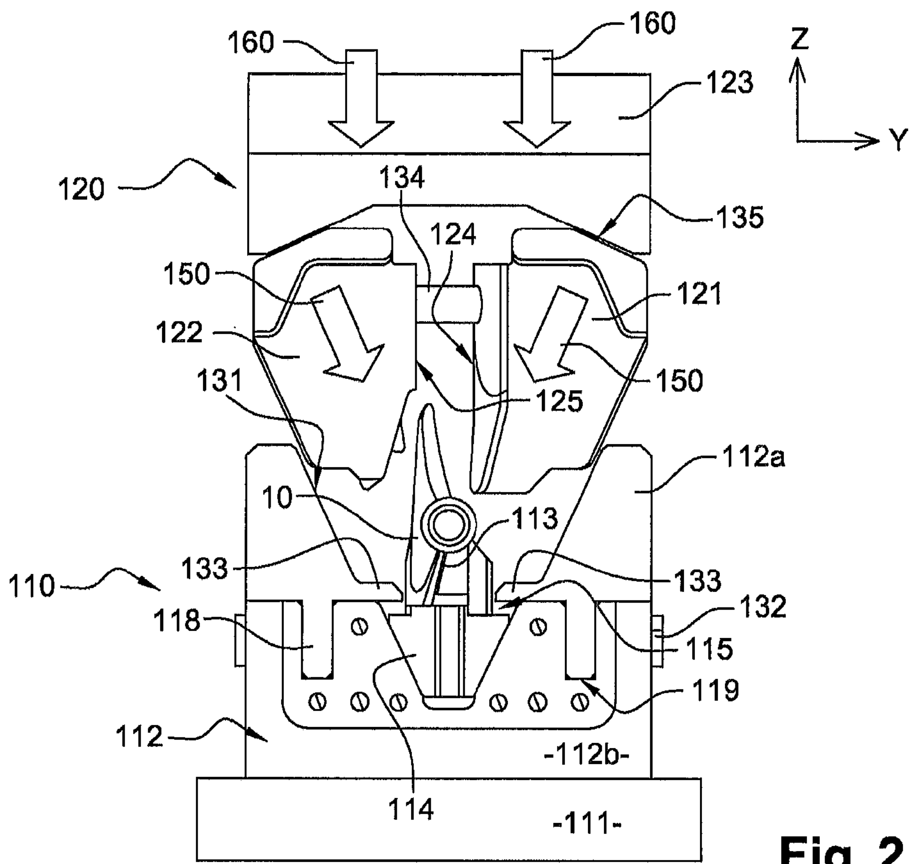
160
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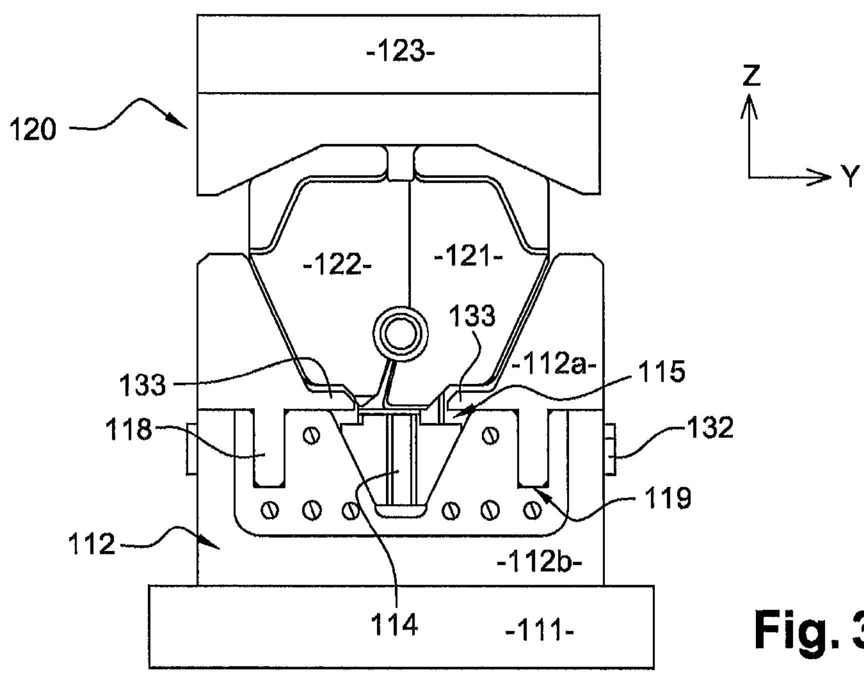
Fig. 2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114
-111-

Fig. 3

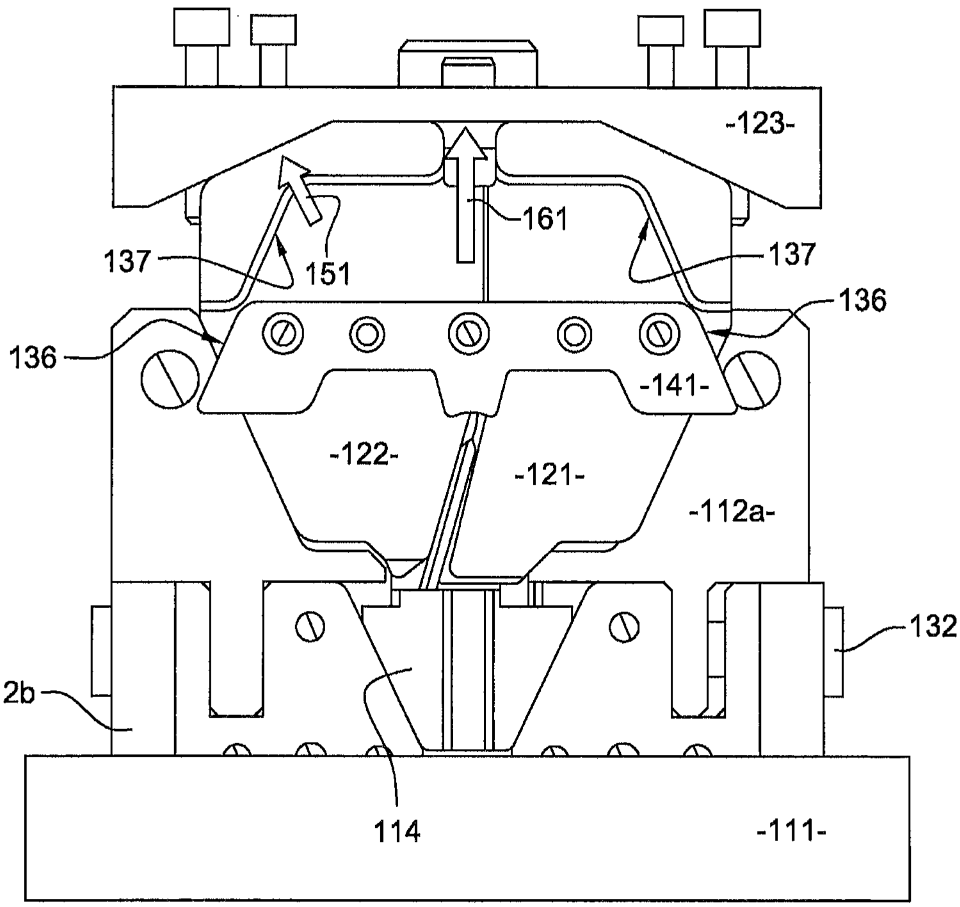

Fig. 4

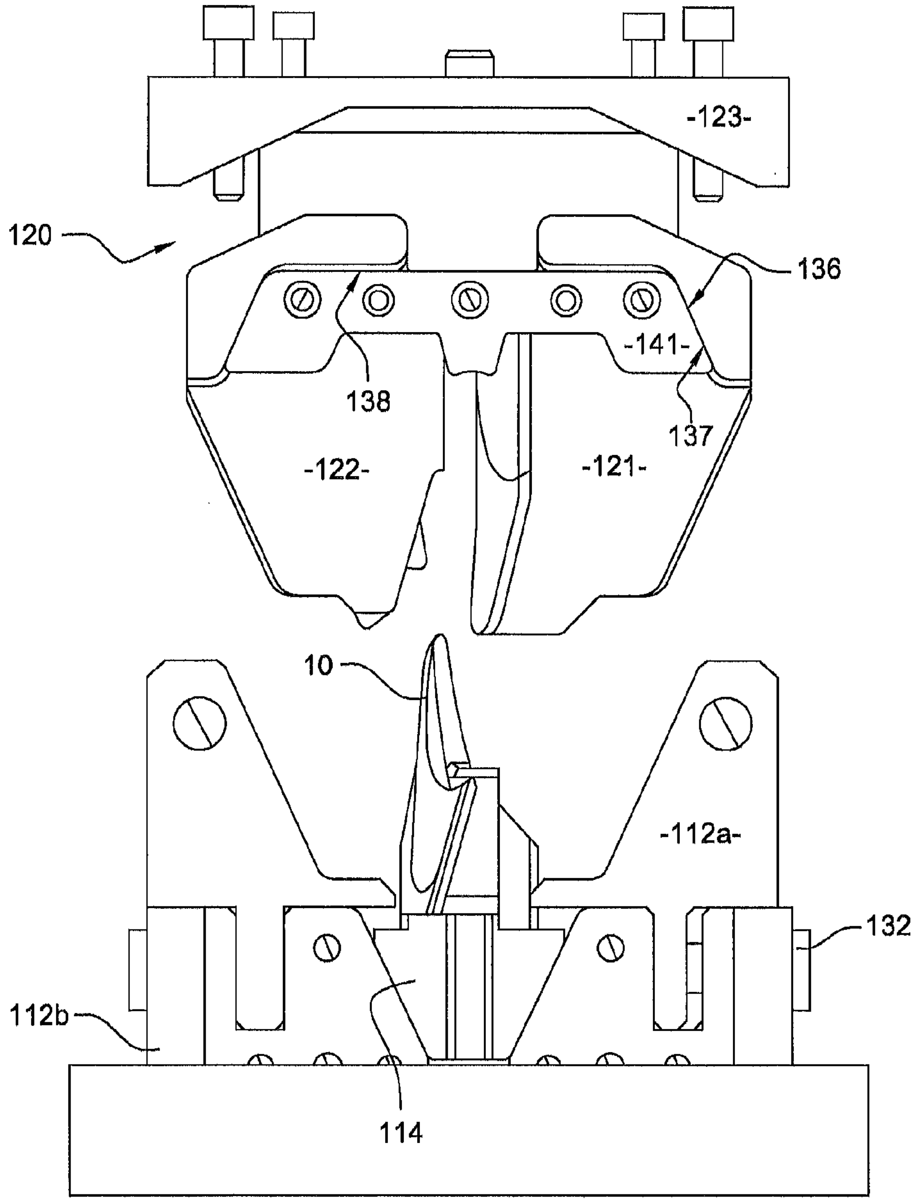

Fig. 5

"MULTI-EFFECT" FORMING TOOLING FOR HIGH-TEMPERATURE FORMING

[0001] The present invention relates to a "multi-effect" forming tooling for high-temperature forming of metal workpieces such as for example a metal reinforcement for a composite or metal turbine engine blade.

[0002] The "multi-effect" forming tooling according to the invention is particularly suitable for shaping workpieces with a complex geometrical shape such as a metal reinforcement for the leading edge of a turbine engine blade.

[0003] The field of the invention is particularly that of turbine engines and more specifically that of turbine engine fan blades, in composite or metallic material, wherein the leading edge comprises a metal structural reinforcement.

[0004] However, the invention is also applicable to the production of any workpieces with a complex geometrical shape and to the production of metal reinforcements intended to reinforce a leading edge or a trailing edge of a blade from any type of turbine engine, whether terrestrial or aeronautical, particularly a helicopter turboshaft or a jet turbine engine.

[0005] It is noted that the leading edge corresponds to the anterior part of an aerodynamic profile that faces the flow of air and divides the air flow into a lower surface air flow and an upper surface air flow. The trailing edge corresponds to the posterior part of an aerodynamic profile where the lower surface and upper surface flows meet.

[0006] Turbine engine blades, particularly fan blades, undergo significant mechanical stresses, particularly connected to the rotation speed, and must satisfy strict weight and volume conditions. One of the options contemplated for reducing the blade weight is the use of composite materials for their manufacture.

[0007] Equipping fan blades of a turbine engine, made in composite materials, with a metal structural reinforcement extending over the entire height of the blade and beyond their leading edge as mentioned in document EP1908919 filed by SNECMA is known. Such a reinforcement enables the composite blading to be protected during an impact by a foreign body on the fan, such as, for example, a bird, hail or else stones.

[0008] In particular, the metal structural reinforcement protects the leading edge of the composite blade by preventing delamination and fiber breakage risks or else damage by fiber/matrix debonding.

[0009] Conventionally, a turbine engine blade comprises an aerodynamic surface extending, in a first direction, between a leading edge and a trailing edge and, in a second direction substantially perpendicular to the first direction, between a foot and a top of the blade. The metal structural reinforcement follows the form of the leading edge of the aerodynamic surface of the blade and extends in the first direction beyond the leading edge of the aerodynamic surface of the blade to follow the profile of the lower surface and the upper surface of the blade and in the second direction between the foot and the top of the blade.

[0010] In a known manner, the metal structural reinforcement is a metal workpiece in titanium made entirely by milling from a block of material.

[0011] However, the metal reinforcement for the leading edge of the blade is a complex piece to make, necessitating many refinishing operations and complex equipment involving significant production costs.

[0012] In this context, the invention aims to resolve the problems mentioned above, by proposing a "multi-effect" forming tooling capable of forming metal workpieces at high temperature, such as a metal reinforcement of the leading edge or trailing edge of a turbine engine blade enabling simplification of the manufacturing process and a significant reduction in the costs of producing such a workpiece by proposing a "multi-effect" tooling implemented by a single action press.

[0013] For this purpose, the invention proposes a "multi-form" forming tooling capable of high temperature forming of metal workpieces, said tooling comprising a fixed part and a moving part set in action by a one-way press, in a first direction, said tooling varying between an open position and a closed position in which the moving part applies pressure to said fixed part; Said tooling being characterized in that said moving part comprises moving means capable of initiating deformation of said metal workpiece through a translational movement of said means in a second direction Y simultaneous with the translational movement of said means in said first direction during said closure of said tooling, said moving means being capable of moving away from said metal workpiece through a reverse translational movement of said moving means, in said second direction, simultaneously with the translational movement of said moving means, in said first direction, during said opening of said tooling.

[0014] One-way press is understood to refer to a single action press only comprising one working axis, generally the vertical axis with relation to the bearing plane of the press, as opposed to double or else triple action presses, respectively comprising two or three working axes oriented in different directions.

[0015] "Multi-effect" is understood to refer to deformation in several directions intervening in several places on the workpiece simultaneously in opposition to single action deformation resulting from a single stress applied locally in a single direction.

[0016] Thanks to the invention, it is possible to carry out multi-effect deformation (i.e., simultaneously in different directions) by means of an inexpensive single action press, under high temperature conditions, i.e., the temperatures necessary for forging the workpieces to be produced.

[0017] In the advantageous case of producing a metal reinforcement for a turbine engine blade, the workpiece is deformed and twisted in several directions in a single operation with a single action press at a temperature greater than 850° C. (on the order of 940° C. for the production of a titanium reinforcement). Therefore, the tooling according to the invention obviates the need for a complex production of reinforcements by a method of milling in the mass from flats requiring large volumes of material and, consequently, the tooling enables the quantities of raw materials necessary for producing such a metal reinforcement to be reduced.

[0018] The metal reinforcement with a complex shape is made in a simple and quick manner from a preform obtained from a simple metal bar and a succession of forging steps such as described, in particular, in patent application SNECMA FR1055066. The preform is then shaped in a three-dimensional manner at high temperature in the "multi-effect" tooling by means of a single action press.

[0019] Therefore, the tooling according to the invention enables multi-effect deformation (i.e., simultaneously in different directions) to be carried out by means of an inexpensive single action press, under high temperature conditions, i.e., beyond 850° C.

[0020] The "multi-effect" tooling according to the invention may also present one or more of the characteristics below, considered individually or according to all technically possible combinations:

- **[0021]** said tooling is an isothermal tooling capable of forging at a temperature greater than 850° C.;
- **[0022]** said fixed part comprises a die presenting two inclined walls capable of displacing said moving means in said second direction Y during said closure of said tooling;
- **[0023]** each of said moving means comprises an inclined face parallel to one of said inclined walls of said die of the fixed part;
- **[0024]** said moving part comprises at least one spacer integral with the movements of said is moving part capable of moving away from said workpiece in said second direction Y during said opening of said tooling;
- **[0025]** said fixed part comprises means capable of forming a reference enabling said metal workpiece to be positioned in said tooling;
- **[0026]** said tooling is capable of forming a metal reinforcement for the leading edge or trailing edge of a turbine engine blade;
- **[0027]** each of said moving means comprises an imprint representative of one of the external faces of said reinforcement for the leading edge or trailing edge of a turbine engine to be produced.

[0028] Other characteristics and advantages of the invention will more clearly emerge from the description given below, for indicative and in no way limiting purposes, with reference to the attached figures, among which:

[0029] FIG. **1** is a perspective view of the forming tooling according to the invention illustrated in its open position;

[0030] FIG. **2** is a side view of the tooling according to the invention during a closing phase;

[0031] FIG. **3** is a side view of the forming tooling according to the invention in its closed position;

[0032] FIG. **4** is a side view of the forming tooling according to the invention illustrating the tooling during an opening phase;

[0033] FIG. **5** is a side view of the tooling according to the invention illustrating the forming tooling in its open position.

[0034] In all figures, common elements bear the same reference numbers, unless otherwise indicated.

[0035] FIG. **1** is a perspective view of the forming tooling **100** according to the invention illustrated in its open position.

[0036] The forming tooling **100** is conventionally formed by a lower part **110**, representing the fixed part of tooling **100**, and an upper part **120**, representing the moving part of tooling **100**.

[0037] The forming tooling **100** represented, by way of example, in all figures is a tooling enabling a titanium reinforcement for the leading edge of a turbine engine blade to be made.

[0038] The tooling is intended to be assembled on a single action press (not represented), of the forging press type, comprising a single working axis, generally the vertical axis, illustrated in FIG. **1** by the Z axis.

[0039] According to other embodiments, the tooling may also be mounted on any type of pressure forging machine comprising a single working axis.

[0040] In general, a forged workpiece is fabricated by placing a preform or a blank between two dies, an upper die and a lower die, each comprising an appropriate imprint (or cavity), and then by moving the two dies closer together with a pressure sufficient to deform the preform until a workpiece whose geometry corresponds to that of the imprints is obtained, the forging operation being carried out with the heated tooling, i.e. a tooling at a temperature greater than 850° C. for producing a titanium workpiece and advantageously at a temperature on the order of 940° C. (plus or minus 10%).

[0041] The lower part **110** of the tooling comprises, in particular:

- **[0042]** a lower support **111** capable of being connected to the single action press (not represented);
- **[0043]** a lower die **112** presenting an imprint **113** suitable for fabricating a leading edge reinforcement;
- **[0044]** two support plates **116** bordering both sides of the lower die **112**, each of which comprises, in its upper part, a notch **117** capable of forming a reference for positioning the preform **10** before the tooling is closed.

[0045] In FIG. **2**, illustrating a side view of the forming tooling according to the invention illustrated in its open position, some elements, such as the support plates **116**, are not represented in order to enable the layout of the lower die **112** to be seen more clearly.

[0046] The lower die **112** is formed by:

- **[0047]** a first lower part **112*b*** connected to support **111**, for example by a screw assembly comprising at least two longitudinal grooves **119**, at the level of its upper face distributed on both sides of the longitudinal center line of the lower part **112*a***, illustrated by the X axis;
- **[0048]** a second upper part **112*a*** presenting at the level of its lower face positioning lugs **118** enabling the upper part **112*a*** to be positioned in the grooves **119** of the lower part **112*b***; each lug **118** having the complementary shape of the shape of the longitudinal grooves **119** of the first lower part **112*a***.

[0049] The second upper part **112*a*** is connected to the first part by connection means **132** forming pins and traversing both the first lower part **112*a*** at the level of the longitudinal grooves **119** and the positioning lugs **118** of the upper part **112*b***.

[0050] The lower die **112** comprises a punch **114**, the upper part of which forms an imprint **113** in conformance with the inner geometry of the leading edge of the turbine engine blade.

[0051] The lower part **112*b*** of the die **112** presents a flare, substantially in the shape of an isosceles trapezoid, capable of receiving the base of the punch **114**, also in a trapezoidal shape, and capable of centering the punch **114** in die **112**.

[0052] The base of the punch **114** is trapped between the lower part **112*a*** and the upper part **112*b*** of the die **112**, and more specifically in a space **114** bordered on the one hand by the flare of the lower part **112*a*** and on the other hand by two horizontal lugs **133** projecting inside the upper part of tooling **110**.

[0053] Thus, these two horizontal lugs **133** of the upper part **112*b*** perform a stop function only allowing a certain vertical displacement (i.e., in the Z axis represented in FIG. **1**) of the base of punch **114** in the defined space **115**.

[0054] The clearance thus created advantageously enables a calibrated displacement between these different pieces of die **112**, creating a punch **114** floating in space **115** that is capable of facilitating the unmolding of the workpiece made in tooling **100**.

[0055] Other transversal and longitudinal displacements of punch **114** are respectively blocked by the tapered shape of the lower part **112***a* receiving the base of punch **114** as well as by the support plates **116** bordering both sides of punch **114**.

[0056] Support plates **116** are connected to the lower part **112***a* of die **112** by conventional connection means used in this type of forging press tooling.

[0057] The upper part **120** of the tooling comprises, in particular:

- [0058] an upper support **123** capable of being connected to the single action press (not represented);
- [0059] two upper dies **121** and **122**, each of which presents an imprint, respectively referenced **124** and **125**, corresponding to the outer geometry of one of the faces of the reinforcement for the leading edge of a turbine engine blade to be produced.

[0060] The two upper dies **121** and **122** have the characteristic of generating a complex movement different from the displacement imposed by the single action press.

[0061] FIG. **2** more specifically illustrates the respective movements of the two dies **121**, **122**, by arrows referenced **150**, during closing of the press, in which the opening/closing displacement is symbolized by vertical arrows **160**.

[0062] In fact, the two upper dies **121**, **122** perform a translational movement in the Y axis, during displacement of the upper support **123** in the Z axis. The translational movement of upper dies **121**, **122** during closing of the press is allowed by the complementary shape of upper dies **121**, **122** and the lower die **112**.

[0063] Face **131** of the lower die **112** that inwardly faces tooling **100** forms a slope on which upper dies **121**, **122** slide during closing of the press, by generating a transverse displacement complementary to the vertical displacement in the Z axis.

[0064] The transverse movement of upper dies **121**, **122** is relatively guided by a guide **134**, for example a free cylindrical pin, enabling the two upper dies **121**, **122** to be guided during closing and during opening of the press.

[0065] Consequently, the two upper dies **121**, **122** initiate the deformation and possibly the twisting of preform **10**, introduced in the tooling, during the closing of the tooling and from the start of the closing phase of tooling **100**.

[0066] The upper dies **121** and **122** comprise a bearing surface **135** on their upper part, on which the support **123** transmits the thrust of the press. This bearing surface is oriented substantially perpendicularly to the direction of thrust of the upper dies **121**, **122**, illustrated by arrows **150**. The orientation of this bearing surface **135** limits the torque generated on upper dies **121**, **122** and thus prevents the upper dies **121**, **122** from twisting when the press is closed.

[0067] FIG. **3** illustrates the forming tooling **100** described previously in the closed position.

[0068] As the upper part **120** of tooling **100** rises, in the opening phase, as illustrated in FIGS. **4** and **5**, two spacers **141** (only one is shown) integral with the upper support **123** enable, by virtue of their shape, the two upper dies **121**, **122** to be moved away from the forged workpiece.

[0069] The spacers **141** present an outer beveled surface **136** forming a slope and producing a bearing surface capable of sliding on upper dies **121**, **122** during opening of tooling **100**. Therefore, during the upward movement of upper tooling **120**, the spacers **141** rise vertically, according to the arrow referenced **161**, illustrated in FIG. **4**, enter in contact with upper dies **121**, **122** and then push in this manner upper dies **121**, **122** in a transverse direction, perpendicular to the direction of opening of tooling **100**. When the spacers **141** are in contact with the two upper dies **121**, **122**, they have a surface **137** supported on the outer surface **136** of spacers **141**, such that the upward movement of spacers **141** moves, under the effect of gravity, the upper dies **121**, **122** apart by sliding both on the surface **136** of spacer **141** and on the bearing face **131** of lower die **112** in the direction illustrated by the arrow referenced **151**. FIGS. **4** and **5** respectively illustrate the tooling in the low position during the upward movement phase of the press and the tooling in the high position during the upward movement phase of the press.

[0070] In the high position, as illustrated in FIG. **5**, the upper dies are positioned supported on spacers **141** by means of horizontal stops **138** and slopes **137**. Therefore, the device is operational for forming the next workpiece.

[0071] Thanks to the invention, the automatic spacing (as opposed to manual spacing by an operator) enables the tooling to be quickly prepared to form the next workpiece without operator intervention and without cooling of the tooling.

[0072] In order to facilitate unmolding of the workpiece produced, particularly cold produced, imprint **113** may be constituted of a plurality of movable or removable sections capable of being individually disassembled.

[0073] In order to facilitate unmolding, it is also possible to initially prepare the tooling **100** by depositing a protective layer on imprints **113**, **124**, **125** so as to prevent the forged workpiece from adhering to the tooling **100**. By way of example, this protective layer may be a layer of aluminum oxide.

[0074] The invention was particularly described for making a metal reinforcement for a composite turbine engine blade; however, the invention is also applicable for making a metal reinforcement for a metal turbine engine blade.

[0075] The invention was particularly described for making a metal reinforcement for a leading edge of a turbine engine blade; however, the invention is also applicable for making a metal reinforcement of a trailing edge of a turbine engine blade.

[0076] Other advantages of the invention are, in particular, as follows:

- [0077] reduced production costs;
- [0078] reduced production time;
- [0079] simplified manufacturing process;
- [0080] reduced tooling costs;
- [0081] reduced material costs.

1. A multi-form forming tooling capable of high temperature forming of a metal workpiece, said tooling comprising a fixed part and a moving part to be set in action by a one-way press, in a first direction, said tooling varying between an open position and a closed position in which the moving part applies pressure to said fixed part, wherein said moving part comprises moving dies constructed and arranged to initiate deformation of said metal workpiece through a translational movement of said dies in a second direction simultaneous with the translational movement of said dies in said first direction during said closure of said tooling, said moving dies constructed and arranged to move away from said metal workpiece through a reverse translational movement of said moving dies, in said second direction, simultaneously with the translational movement of said moving dies, in said first direction, during said opening of said tooling.

2. The multi-form forming tooling according to claim **1**, wherein said tooling is an isothermal tooling capable of forming at a temperature greater than 850° C.

3. The multi-form forming tooling according to claim **1** wherein said fixed part comprises a die presenting two inclined walls capable of displacing said movable dies in said second direction during said closing of said tooling.

4. The multi-form forming tooling according to claim **3**, wherein each of said movable dies comprises an inclined face parallel to one of said inclined walls of said die of the fixed part.

5. The multi-form forming tooling according to claim **1** wherein said movable part comprises at least one spacer integral with the movements of said moving part capable of moving said movable dies of said workpiece apart in said second direction during said opening of said tooling.

6. The multi-form forming tooling according to claim **1**, wherein said fixed part comprises means capable of forming a reference enabling said metal workpiece to be positioned in the tooling.

7. The multi-form forming tooling according to claim **1**, wherein said tooling is capable of forming a metal reinforcement for the leading edge or trailing edge of a turbine engine blade.

8. The multi-form forming tooling according to claim **7**, wherein each of said movable dies comprises an imprint representative of one of the outer faces of said reinforcement for the leading edge or trailing edge of a turbine engine to be produced.

9. The multi-form forming tooling according to claim **6**, wherein said means capable of forming a reference enabling said metal workpiece to be positioned in the tooling includes one or more support plates.

10. A multi-form forming tooling capable of high temperature forming of a metal workpiece, said tooling comprising a fixed part and a moving part to be set in action by a one-way press, in a first direction, said tooling varying between an open position and a closed position in which the moving part applies pressure to said fixed part, wherein said moving part comprises moving means capable of initiating deformation of said metal workpiece through a translational movement of said means in a second direction simultaneous with the translational movement of said means in said first direction during said closure of said tooling, said moving means being capable of moving away from said metal workpiece through a reverse translational movement of said moving means, in said second direction, simultaneously with the translational movement of said moving means, in said first direction, during said opening of said tooling.

11. The multi-form forming tooling according to claim **10**, wherein said moving means include a plurality of moving dies.

* * * * *