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[54] METHOD AND DEVICE FOR THE PRECISION SHAPING OF A METAL PART

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[51] **Int. Cl.** **B21j 5/02**

[58] **Field of Search** 72/354, 356, 357, 332

[56] **References Cited**

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Attorney, Agent, or Firm—Ernest G. Montague; Karl F. Ross; Herbert Dubno

[57] **ABSTRACT**

The present method for the shaping of a metal part comprises the following steps performed with the device according to the invention:

a. the length of the initial blank to be shaped is somewhat greater than that desired for the end product, with substantially constant cross-sectional surface areas, but with transverse dimensions (width and thickness) such that upon completion of the first-step shaping operation these last-mentioned dimensions are slightly inferior, at all points, to those of the desired part;

b. in a first step, the shaping operation is performed by applying to the part in a direction substantially perpendicular to the longitudinal axis thereof a force sufficient for shaping the part between one or two dies and one or more punches defining therebetween a cavity capable of providing the end shape of the part to be obtained after the longitudinal elastic release thereof, the shaping stroke being limited by external stop members;

c. in a second step, without relieving the rigid closing of said cavity, the part contained therein is stabilized by applying to one or either end of said part in the direction of the axis thereof, an upsetting force sufficient to cause said part to be shortened to a limited extent determined by stop means or an antagonistic force, and to cause the very slight swelling effect resulting from the application of said upsetting force to be absorbed by said cavity, the upsetting stress being relieved before or simultaneously with the cavity closing stress.

2 Claims, 17 Drawing Figures

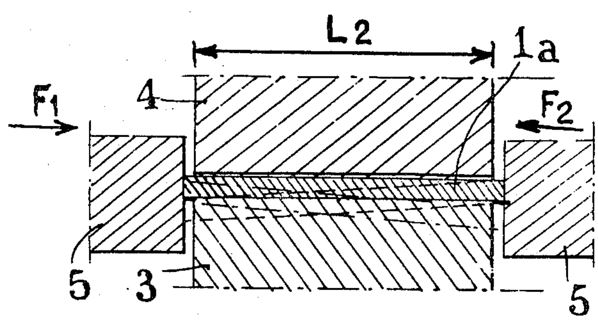


Fig.1

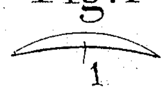
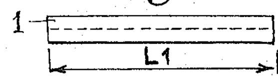


Fig. 2



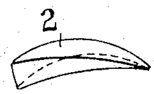


Fig. 3

Fig. 4

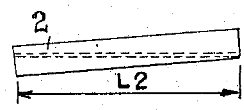


Fig. 5

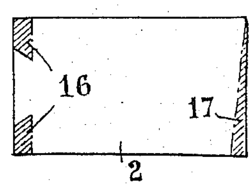


Fig. 6

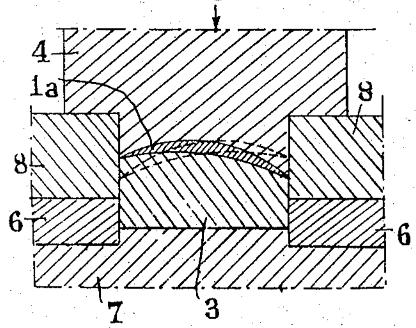


Fig.7

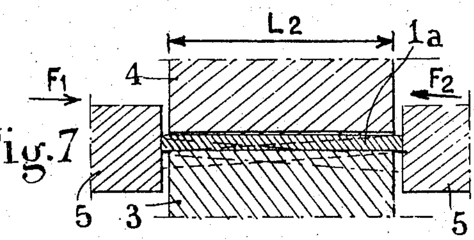
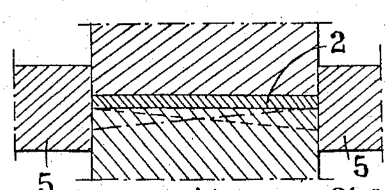


Fig.8



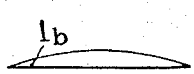


Fig.9

Fig.13

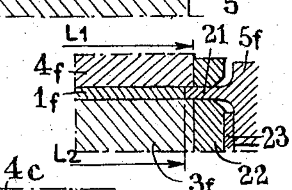


Fig.11

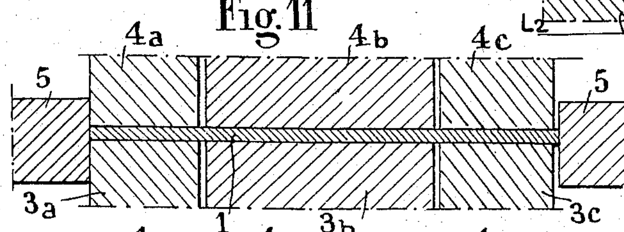


Fig.12

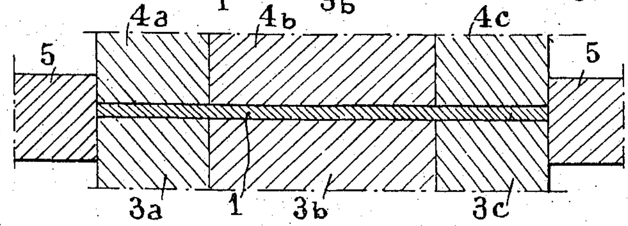


Fig.14A Fig.14B

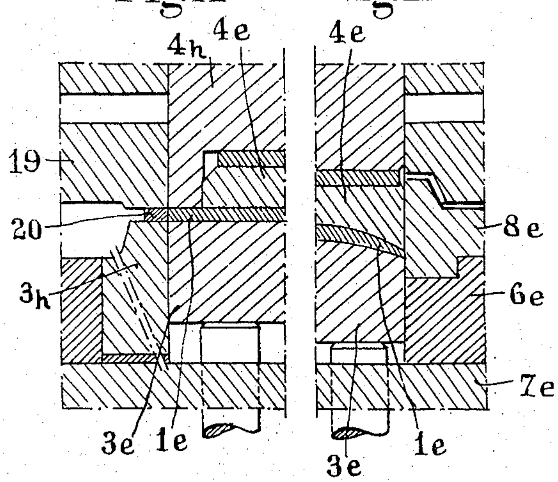


Fig.10

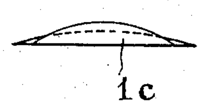


Fig.10A

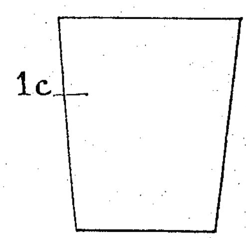
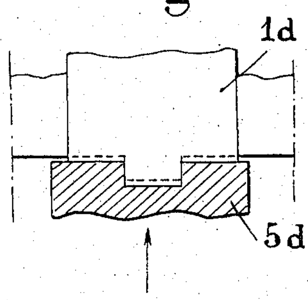


Fig.15



METHOD AND DEVICE FOR THE PRECISION SHAPING OF A METAL PART

The present invention relates to a novel method intended for accurately shaping a metal part from a piece of sheet-metal, a. This method is particularly adapted for the making of parts with a cross-sectional surface area is substantially constant throughout its length.

Such parts are made in general by pressing a blank or the like between a die and a punch of which the shapes are somewhat accentuated with respect to those of the end product to be obtained, so as to compensate empirically for the elastic return (relaxation) of the part after the punch has been removed therefrom. In this case, the desired shape is a result of a kind of equilibrium between the internal flexion and torsional static stress produced in opposition on either side of neutral fiber or axis.

However, for various reasons the shapes of the parts thus obtained are not definitely uniform so that particularly expensive retouch operations had to be performed. To avoid these inconveniences it was suggested to shape these parts by pressing them between two heated dies having the final shape of the desired part. Thus the heat effect removes the stress causing the undesired distortion, but this stress elimination is selective with respect to the previous stress and is a function of time, so that incomplete and variable results are obtained.

Another known proposition consisted in stabilizing the parts shaped between a pair of dies by exerting on these parts a stretching effort to neutralize internal tensions. However, the dimensions of the parts thus obtained are unreliable in the longitudinal direction since it is not possible to apply with precision a definitely identical elongation to each part.

This prior art method is also objectionable in that it is also attended by a relatively high percentage of reject or scraps in the manufacture of these parts, for a certain area must be reserved at the ends of each part to permit the gripping thereof by means of traction clamps or pliers. Moreover, the equipment necessary for carrying out this method is relatively complicated and costly.

It is therefore the essential object of the present invention to provide a method of producing shaped parts of the type set forth hereinabove, which is capable of stabilizing these parts in their final and desired shape without having to cope with the various inconveniences mentioned hereinabove.

To this end, the present method is characterised in that:

a. the length of the initial blank to be shaped is somewhat greater than that desired for the end product, with substantially constant cross-sectional surface areas, but with transverse dimensions (width and thickness) such that upon completion of the first-step shaping operation these last-mentioned dimensions are slightly inferior, at all points, to those of the desired part;

b. in a first step, the shaping operation proper is performed by applying to the part in a direction substantially perpendicular to the longitudinal axis thereof a force sufficient for shaping the part between one or two dies and one or more punches reserving therebetween a cavity capable of providing the end shape of the part to be obtained after the longitudinal elastic release thereof, the shaping stroke being limited by external stop members;

c. in a second step, without relieving the rigid closing of said cavity, the part contained therein is stabilized by applying to one or either end of said part, in the direction of the output axes thereof, an upsetting force sufficient to cause said part to be shortened to a limited extent determined by stop means or an antagonistic force, and to cause the very slight swelling effect resulting from the application of said upsetting force to be absorbed by said cavity, the upsetting stress being relieved before, or simultaneously with the cavity closing stress.

The present invention is also concerned with a shaping device specially designed for carrying out the method set forth hereinabove. A typical and exemplary form of embodiment of this device will now be described together with a typical application of the present method for making a turbine blade, this description being given with reference to the attached drawing, in which:

FIGS. 1 and 2 are an end view and a slide elevational view, respectively, of a metal section or blank suitable for making a turbine blade by applying the method of this invention;

FIGS. 3 and 4 are an end view and a side elevational view respectively of the same turbine blade upon completion of the shaping thereof;

FIG. 5 is a plan view from above of the blade;

FIG. 6 is a diagrammatic cross-sectional view of the device utilized for making this turbine blade for carrying out the method of the invention;

FIGS. 7 and 8 are longitudinal sectional views of the same device, shown before and after the final operation consisting in stabilizing the part, respectively;

FIGS. 9 and 10 are end views showing two different section contours adapted to be used for making the blade shown in FIGS. 3 and 4;

FIGS. 10A is a plan view from above of the piece of metal section shown in FIG. 10;

FIGS. 11 and 12 are longitudinal sectional views of another embodiment of the device utilized for carrying out the method of this invention;

FIGS. 13 is a fragmentary longitudinal section showing another embodiment of the device;

FIGS. 14A and 14B are fragmentary views, in longitudinal section and cross-section, respectively, of another embodiment of the device, and

FIG. 15 is a fragmentary plan view from above of one end of a tenon blade shaped by applying the method of this invention, with the corresponding upsetting punch.

As mentioned hereinabove, FIGS. 1 and 2 illustrate a metal blank (workpiece) 1 adapted to be used for making the part through the method of the present invention, which, in this example, is a turbine blade 2 shown in FIGS. 3 and 4. The shape of this blade departs from that of the initial section 1 by differences in the curvature and in the angular relationship of its various cross-sections with respect to one of its edges taken as a reference, so that this blade has a more or less curved twisted shape. Moreover, it is known that very strict tolerances are imposed upon the shape of parts of this character. of this invention. The piece 1 utilized herein has a length L_1 slightly greater than the length L_2 of the part to be obtained, as measured before its elastic expansion, this length L_2 being therefore smaller than the length of the final piece. On the other hand, the various cross-sectional areas of this section are substantially constant, but its dimensions are very slightly inferior at all points of this section with respect to those of the part to be obtained.

This metal section element is firstly shaped between a die **3** and a punch **4**, the punch being actuated by a press or any other suitable machine. The die is fitted in a plate **6** carried by a support **7** (FIG. **6**). On either side of the space occupied by the punch and die assembly guide members **8** are provided for limiting the width of the part to be shaped, and stop members are also provided for limiting the closing stroke of the corresponding cavity.

When the punch **4** has nearly completed its working stroke, it leaves in relation to the die **3** a cavity having the outer contour of the turbine blade to be obtained before its elastic expansion. However, this cavity comprises a slight clearance about the part **1** after the shaping thereof, in order to permit the subsequent slipping thereof between the punch and die and also to permit a slight swelling of this part when the abovementioned upsetting stresses are applied to its ends. Moreover, according to an essential feature of this invention, the cavity formed between the punch and die is open at at least one end. More particularly this cavity is open at either ends in the example illustrated.

The length of the punch and die assembly is equal to the length L_2 of the part to be made, before its elastic expansion, this length L_2 comprising the metal scraps to be subsequently cut off from its two ends for finishing the part (see FIG. **5**). Under these conditions, when the metal section is positioned in the die and punch assembly its ends project slightly outwards as illustrated in FIG. **7**.

Registering with these ends are a pair of extrusion punches **5** adapted to move simultaneously in the longitudinal direction as shown by the arrows F_1 and F_2, these punches being adapted to bear on plate **6**.

Of course, the shaping punch and the die may consist of a single member or of several members each adapted to travel in a specific direction.

In a first step of the method of this invention the operation consisting in performing the shaping proper of the part is carried out. To this end, the section blank **1** is positioned between the punch and die.

After the pressing operation, an element **1a** having the shape of the desired turbine blade is obtained, but the ends of this part project slightly from the punch and die assembly. Of course, the internal stress existing in this element as a consequence of the mechanical shaping thereof between the punch **4** and die **3** would normally tend to cause said part to resume its initial shape if the force closing the punch **4** were released.

However, during a second step of the present method this element is stabilized in its final shape by applying an upsetting or extrusion stress to its two ends by using two punches **5** therefor. During this operation, the punch **4** is kept under stress between the abutment-forming guide member **8**.

When the upsetting punches **5** complete their stroke, so as to abut the registering faces of the punch and die, the element disposed between these two members eventually assumes the final and desired contour and shape of the turbine blade, but before its elastic expansion. Thus, this element can be removed, after relieving the upsetting stress and subsequently the closing stress. In fact, the part is now stabilized in its final shape due to the upsetting stress applied thereto.

Thus, by simply determining the length to be driven back or upset from the length of the part and from its mechanical and physical properties, it is possible after adequate tests and developments to shape accurately and rapidly not only ordinary metals but also low-elongation and high-elasticity metals.

It may be emphasized that the clearance provided in the method of this invention between the part and the cavity is sufficient to permit the longitudinal slip during the upsetting step, that upon completion of this upsetting step the slight swelling of the part has reduced this clearance, and that the part itself, during its elastic expansion and due to this very expansion is liable, owing to its shape and length, to have its desired high precision somewhat impaired. It is the purpose of the retractable tool means shown in FIGS. **11** and **12**, which are adapted to follow longitudinal deformations, to solve this specific problem.

The minimum percentage, under normal working conditions, of this reduction in length may range from about 1 percent to about 5 percent, but it may also be as high as 10 percent and more in specific cases involving if necessary the use of retractable dies. Of course, the degree of upsetting of the metal in the shaped element may be adjusted by modifying accordingly the length of the section or blank which projects from the die or is inscribed in the retractable die.

Instead of limiting the upsetting case only by using abutment means, a safety force may be interposed, if desired.

It may be pointed out that the upsetting stresses are exerted in a direction other than that corresponding to the pressure applied through the shaping punch **4**, that is, in the axial direction of the end of the part to be shaped.

In the above-described example, the axes along which stresses are exerted are merged into one and lie in a plane perpendicular to the direction of travel of the shaping punch **4**. But a different arrangement could be contemplated as a function of the shape of the part to be obtained and also of the general direction of the ends to which the upsetting forces are to be applied.

Necessarily, the ends of the upsetting punch and those of the part to be shaped must coincide as much as possible to that the upsetting stress be properly applied. To this end, it is possible to provide for the stress surface a shape consistent with that of the final part to be obtained. In this case, the blank ends may be cut beforehand to the desired shape as illustrated in FIG. **15** in the case of blank **1***d*. But in this case the corresponding upsetting punch **5***d* must have the same shape. Thus, a subsequent cutting or trimming of the ends may be avoided.

However, the initial blank or rough piece may correspond to a simple rectilinear cutting operation performed at right angles to the axis of the metal section. Thus, upon completion of the shaping operation, a sinuous contact surface to be reproduced on the tool means may be obtained. However, this solution compulsorily involves a complementary cutting step.

If permitted by the particular shape of the part to be obtained, one may also shape the blank in a tool equipment also designed for cutting or trimming the ends of the workpiece at the end of the working stroke.

Besides, FIGS. **14A** and **14B** illustrate a typical form of embodiment of a shaping tool adapted to perform the cutting operation at the same time.

In addition to a shaping punch **4e** and a die **3e** both disposed between the lateral guide members **8e** on the fitting plate **6e** and the carrier or base plate **7e**, there is provided a cutting blade die **3h** registering with the blade punch **4h** at either end, or at least at one end. A movable plate **19** adapted to act as a blank clamping member is then fitted in position. Thus, at the end of the stroke accomplished by the shaping punch **4e** the end portions **20** to be removed are trimmed off.

After removing these cut end portions, the corresponding workpiece is stabilized by exerting upsetting stresses against its opposite ends, as described hereinabove.

In the embodiment illustrated in FIGS. **6** to **8**, the upsetting stress necessary for stabilizing the corresponding workpiece is exerted through punch means adapted to engage the opposite ends of the workpiece. Of course, this implies that said ends project from the corresponding cavity. However, it would also be possible to exert upsetting stresses by means of punch means adapted to penetrate into the ends of the corresponding cavity. This arrangement is illustrated in FIG. **13.**

In this example, the blank **1f** shaped between the punch **4f** and the corresponding die **3f** does not project from the end illustrated outside the cavity formed between these two members. In fact, after the shaping operation this blank is simply flush with the corresponding ends of these members. However, this end is freely open and registering therewith is an upsetting punch **5f** carrying a blade **21** adapted to engage the end of blank **1f** and then penetrate into the cavity reserved between the punch and die in order to produce the desired upsetting action.

At the end of this operation, the initial length L_1 of the corresponding blank **1f** is reduced to the value L_2; preferably, a guide member **22** may be provided for the blade **21** of upsetting punch **5f**. Moreover, a stop member **23** permits of determining very accurately the end of the punch stroke.

By using an upsetting of this character, i.e., a punch adapted to penetrate into the cavity reserved between the shaping punch and the die, it is possible to perform the trimming operation at the ends of the corresponding blank on the same tool means, after the shaping operation and before the stabilizing operation.

The method of this invention is applicable to the shaping of parts of variable length. However, in the case of relatively long parts, the punch and die may be divided into several sequential sections as shown at **3a**, **3b**, **3c**, for the die and **4a**, **4b** and **4c** for the punch (FIGS. **11** and **12**). The component elements of these two assemblies may be urged initially away from each other to obtain a suitable relative spacing thereof, as shown in FIG. **11**, by using spring means on the like.

With this arrangement it is possible to use tool means open at either ends or closed at one end and open at the other end (see FIG. **11**), or closed at both ends.

Thus a retractable tool assembly is obtained which follows the movements of the blank material during the second step of the method of this invention.

Of course, the present method should not be construed as being strictly limited to the manufacture of blades, notably turbine stator blades. In fact, as already explained in the foregoing, this method may be applied to the manufacture of any elements or parts comprising a substantially constant cross-sectional surface area throughout its length, and these elements or parts may be extremely diversified.

Besides, it may be pointed out that the present method and the means for carrying out same permit of manufacturing workpieces and the like, of the type broadly mentioned hereinabove, whether from a blank having a shape approaching the desired final shape or from a metal section having simply a continuous cross-sectional contour.

Thus, it is clear that the upsetting stresses applied for shaping the part could be exerted in directions forming a certain angle with one another, in the case of a curved or bent part, as seen in plan view from above, or in side elevational view, or a combination of these two views. On the other hand, it would be possible, in this case, to exert an upsetting stress against only one end of the part to be stabilized, provided that the opposite end is properly held against movement during this step.

What is claimed as new is as follows:

1. A method of forming and stress-relieving a sheet-metal blank comprising the steps of:

a. pressing a sheet-metal blank, having a length between 1 and 10 percent greater than that of the finished article to be produced, in a die cavity between a pair of dies relatively movable transversely to said blank to bend said blank and apply bending stress thereto, while confining said blank in a die cavity having a width and thickness corresponding to that of said article and slightly exceeding at all points those of said blank by causing said dies to engage respective abutments, at least one edge of said blank projecting laterally from said cavity; and

b. pressing a tool into said edge to upset said blank and cause the material thereof to fill said cavity by swelling, thereby relieving said bending stress.

2. An apparatus for shaping and stress-relieving a sheet-metal blank, comprising:

a pair of relatively displaceable dies including at least one movable die shiftable transversely to said blank to bend the latter;

means for displacing the movable die transversely to said blank;

abutment means for said movable die limiting the displacement thereof to confine said blank in a cavity from which said blank projects at least along one side thereof, said cavity having a thickness and width slightly greater than these of said blank at all points and corresponding to the thickness and width of the article to be produced whereby said blank is maintained under bending stress in said cavity;

at least one punch shiftable transversely to said blank and adapted to remove material along a side of said blank, said punch defining said cavity with said dies and said abutment means; and

an upsetting tool shiftable laterally of said cavity and engageable with said edge to upset said blank and cause it to swell and fill said cavity while relieving the bending stress of said blank.

* * * * *