# United States Patent [19]

**Meleka et al.**

[11] **3,707,754**

[45] **Jan. 2, 1973**


## [54] METAL WORKING


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[73] Assignee: **Secretary of State for Defence**



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[30] **Foreign Application Priority Data**

Aug. 11, 1969 Great Britain.....34,943/69

[52] **U.S. Cl.**.....**29/156.8 H,** 72/286, 72/364

[51] **Int. Cl.** .....**B23p 15/02**

[58] **Field of Search** ....29/156.8 H; 416/178; 72/286, 72/342, 364



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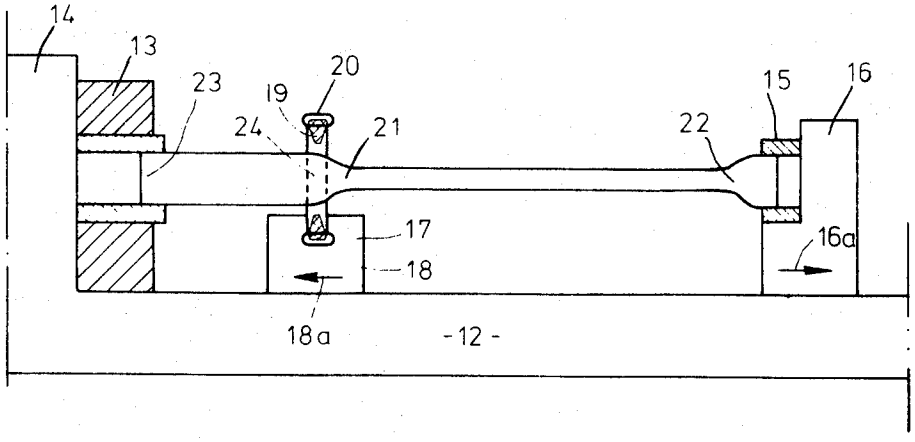
[57] **ABSTRACT**

A method of die-less drawing of metal under tensile load by applying localized heating to a transition zone at which elongation occurs. The temperature applied lies between defined limits and the strain rate obtained also lies between defined limits.


**4 Claims, 10 Drawing Figures**



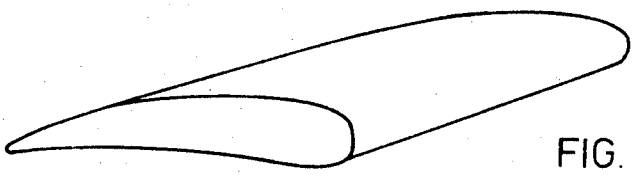


FIG. 1

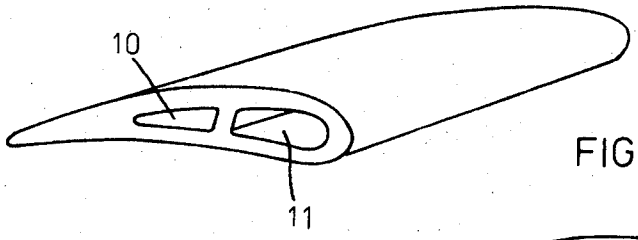



FIG. 2

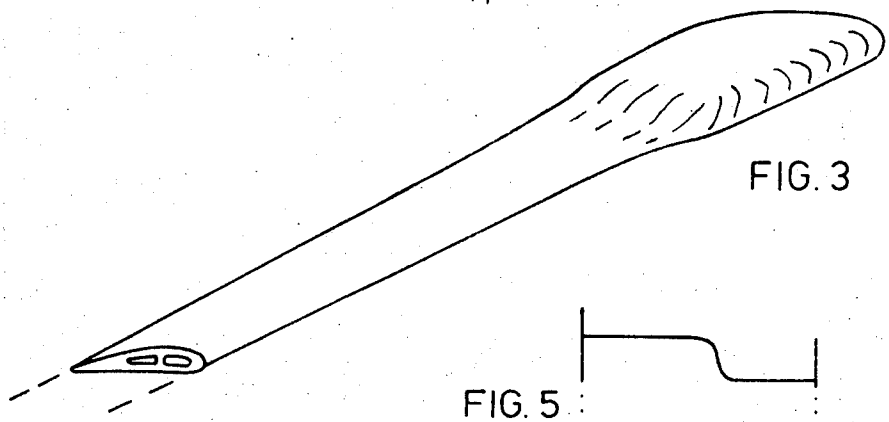


FIG. 3



FIG. 5

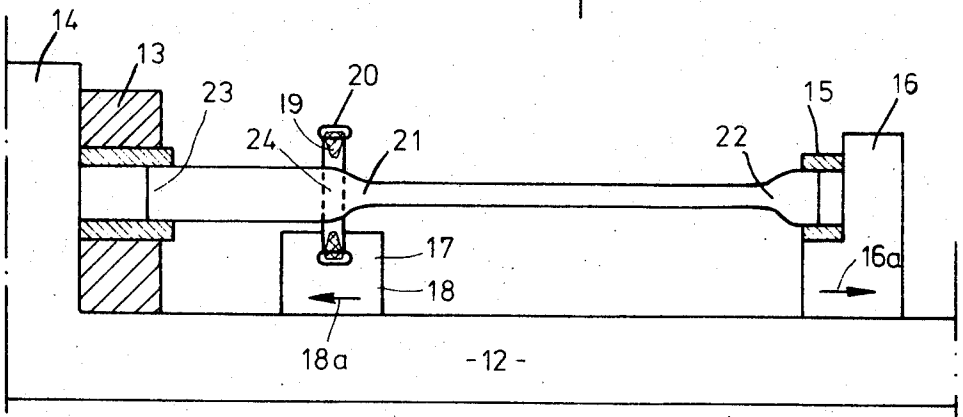



FIG. 4

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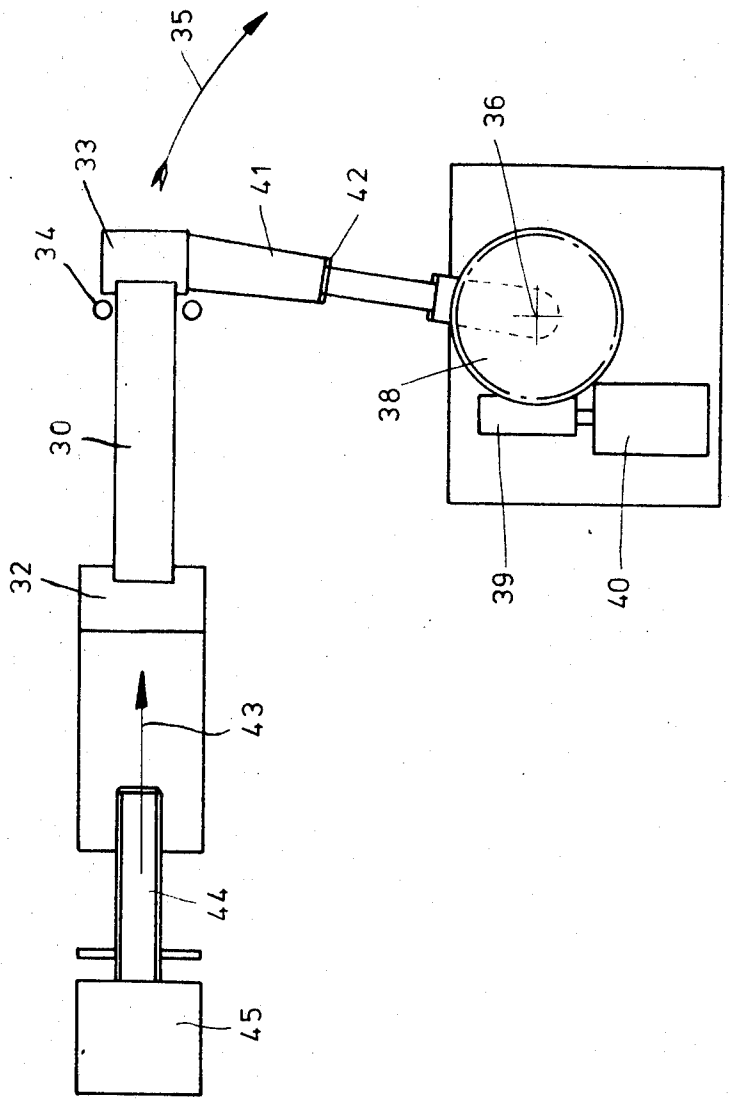


FIG. 6

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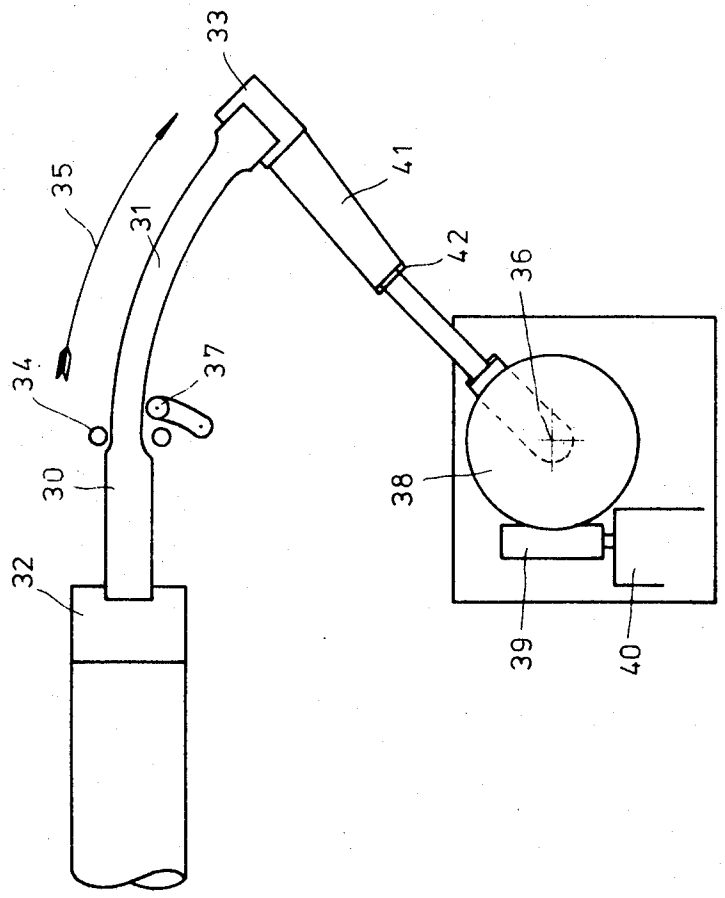


FIG. 7

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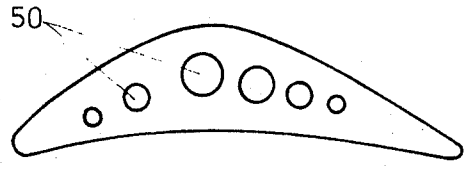


FIG. 8

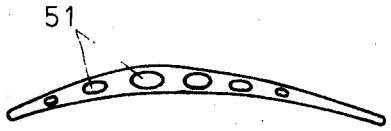


FIG. 9

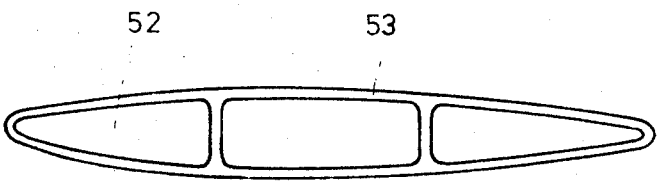


FIG. 10

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# METAL WORKING

This invention relates to the working of metal.

According to this invention there is provided a method of drawing a metal work-piece comprising applying a tensile load to the work-piece whilst heating the work-piece locally, the temperature to which the work-piece is heated lying between upper and lower limits as herein defined, the temperature and tensile load together being such as to cause local elongation of the work-piece at a strain rate lying between upper and lower limits as herein defined, and maintaining the location of heating relative to the work-piece so as to produce a required shape and elongation.

This method may be performed using apparatus which includes means for applying local heating to the work-piece, further means for applying the tensile load to the work-piece and an arrangement for causing relative motion between the work-piece and the heating means so as to produce the required shape and elongation.

Constructional forms of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. 1 shows a work-piece blank having the basic form required for making a fluid flow blade,

FIG. 2 shows apertures machined in the blank of FIG. 1,

FIG. 3 shows the blank of FIGS. 1 and 2 after elongation,

FIG. 4 shows a longitudinal section through a draw-bench for elongating the blank,

FIG. 5 is a section through part of the blank of FIG. 4 and shows a further stage in the performance of the method, and

FIGS. 6 and 7 show apparatus for producing arcuate elongated articles,

FIG. 8 is a typical cross-section of a work-piece having circular holes before being drawn in the apparatus of FIG. 4,

FIG. 9 is a cross-section of the work-piece of FIG. 8 after the drawing operation, and,

FIG. 10 is a cross-section of a work-piece having an alternative configuration of holes which can be produced by the method of the present invention.

Referring to the drawings, the blank of FIG. 1 is formed by forging or machining from raw material to the shape shown.

The blank is internally machined to provide longitudinal passages **10, 11** as shown in FIG. 2, by means of electro-chemical machining or any other suitable process.

The passages **10, 11** may extend wholly through the blank or, alternatively, may be blind passages extending to a position short of one end of the blank.

The blank is then placed in a draw-bench **12** with one end held securely in jaws **13** of a fixed machine head **14** and the other end gripped in jaws **15** of a movable saddle **16** so as to enable a tensile load to be applied between its ends. A source **17** of local heating is mounted on a movable saddle **18**. The heating source **17** comprises an open single turn **19** of copper wound with the turns **20** of an induction coil and shaped to concentrate the heating substantially into a single plane of application to the blank. In an alternative arrangement (not shown) the whole operation may be performed within a vacuum chamber of an electron beam machine using an annular cathode surrounding the blank and focused to provide substantially planar heating of the blank. Alternatively, any other suitable form of heating, such as a ring of localized gas burners, may be used.



Before elongation starts, the saddle **18** with heating source **17** is positioned close to the saddle **16**. Heat and tension are applied and as the saddle **16** moves to the right in the direction of the arrow **16***a* in FIG. 4 to extend the blank, the saddle **18** moves to the left in the direction of its arrow **18***a* so as to maintain heating at the area of transition of cross-section. The movements of the two saddles **16** and **18** may be achieved by means of lead screws (not shown) of the draw-bench.

By varying the relative rate of movement of the two saddles **16** and **18** we are able to produce an elongated component of varying cross-section along its length. This is accomplished by altering the speed of one or both of the lead screws driving saddles **16** and **18**. Thus, a fluid flow blade having a thicker cross-section at its root than at its tip can be produced by this method. Also, a blade of tapering cross-section can be produced by machining the blank so that the portion **21** at one end is thicker than the portion **22** at the other end, and then elongating the blank at a uniform rate. The end part **23** of the blank, which remains in the machine head **14** and therefore cannot be elongated, forms the root of the blade and can finally be machined to the desired shape. In addition, the root so formed has the passages **10, 11** still extending through it and suitable to be connected for cooling air supply or for other services.

To assist in the formation of the final required shape at the root of an aerofoil blade the smooth transition shape at **24** can be changed into a sharper shoulder. This is achieved by reversing the movement of saddles **16** and **18** so as to cause local upsetting of the material and this results in the final cross-section shown in FIG. **5**. In a similar fashion a projection can be produced on an aerofoil blade such as a snubber or a tip shroud.

Fluid flow blades require shapes which include spanwise twist and the required twist can be imparted to the aerofoil section by arranging that the jaws **15** are rotatable around an axis parallel to the movement of saddle **16** and coincident with the twist axis required in the blank. In operation, the jaws **15** rotate as elongation occurs and twist is automatically imparted to the blade which is formed.

The work-piece is locally heated for elongation to a temperature above a lower limit which is the temperature below which the material of the blank will neck and fracture, or simply fracture, rather than elongate.

At temperatures above this limit the material is sufficiently ductile to enable it to be elongated uniformly under tensile load without necking when there is relative movement between the work-piece and the source of heating to enable the position of local heating to remain at the transition area between the large and small cross-section. This defines the "lower limit" of working temperature.

The upper limit of temperature is defined as that at which undesirable metallurgical changes occur e.g. grain growth or phase transformation. Factors which affect the level of this temperature are the time during

which the material is maintained at the temperature and the amount of work performed on the material whilst it is at the temperature. Generally, the shorter the time and the lower the amount of work the higher this temperature can be before metallurgical changes occur. An additional restriction on this temperature may be the incidence of oxidation but this restraint may be overcome by the use of shrouding around the work-piece to reduce oxidation by substantial air exclusion or by complete enclosure to enable it to be maintained in a non-oxidizing atmosphere or in vacuo.

In carrying out the process it has been established that the strain rate must lie between upper and lower limits. For each material the working temperature and tensile load used determine the strain rate; the strain rate must be below the rate at which the material necks and fractures, or simply fractures, and above the rate at which the slow working of the material causes undesired metallurgical changes to occur.

The process of this invention is in some respects similar to the known elongation processes which use superplastic properties possessed by certain materials. However, the present invention is not restricted in its application to superplastic materials and, indeed, it operates at temperatures below those required to produce superplastic behavior.

In one particular example using a titanium alloy consisting of 6 percent aluminum, 4 percent vanadium with the remainder titanium, the lower temperature limit was found to be about 850°C and the upper temperature limit to be about 980°C.

Operating with this material pre-formed into the shape of a fluid flow blade blank as shown in FIG. 2 and with a local operating temperature of 900°C the following results were found:

Two successive passes of the heating arrangement were made and the following changes in physical dimensions were noted:

| | First Pass | Second Pass |
|---|---|---|
| Percentage change on chord dimension | 11% | 9% |
| Percentage change on thickness | 40% | 39% |
| Percentage elongation | 53% | 50% |

In another example using a nickel alloy comprising chromium 15.0 percent, carbon 0.12 percent to 0.2 percent with the remainder nickel, the working temperature was 1020°C.

Referring now to FIGS. 6 and 7 there is shown apparatus for producing arcuate elongated articles. A work-piece **30** is elongated in an arc using the method of this invention to produce an arcuate portion **31**. The work-piece is held between jaws **32** and **33** and during elongation is heated by a heating coil **34** which may be an induction coil. As elongation proceeds the jaw **33** is moved in the direction of arrow **35** in an arc about center **36** and the work-piece material immediately after elongation is given mechanical support by a roller **37** to enable it to retain its shape whilst cooling. The movement is performed by means of a worm wheel **38** and worm drive **39** driven from an electric motor and gear box **40**. The jaw **33** is mounted at one end of an arm **41** which is adjustable in length by means of a screw and locknut arrangement **42** to enable the radius of movement of jaw **33** to be varied. As the jaw **33** is moved so the jaw **32** moves in the direction of arrow **43** so as to keep the transition area between the original cross-section and the cross-section achieved during elongation, beneath the heat source **34**. The movement of jaw **32** is achieved by means of a lead screw **44** driven by an electric motor and gear box **45**.

A solid article in the shape shown in FIG. 7 is suitable for incorporation in a gas turbine engine as "wire lacing" to damp fluid flow blade vibrations.

It has been found in performing the method described that considerable elongation of a work-piece which is radially symmetrical about its longitudinal axis of elongation, does not affect its cross-sectional proportions. An example of such a work-piece is a tube. However, work-pieces which are not symmetrical in cross-section, such as the work-pieces illustrated in this specification, do suffer changes in proportions, and portions which are relatively thicker in the cross-section before elongation tend to remain relatively thicker during elongation. This effect can be allowed for in the design of the original blank or by final machining of the elongated article.

The work-piece shown in cross-section in FIG. 8 was provided with an aerofoil cross-section which was both longer and wider than the required cross-section of the finished aerofoil. Circular holes **50** were made which extended longitudinally through the work-piece and then the work-piece was drawn on the apparatus described with reference to FIG. 4, until the length and width of the cross-section were reduced to the required finished size. The cross-section of the holes was changed from circular to the oval shape **51** shown in FIG. 9. This was due to the fact that during the drawing operation the ratio of the width of the section of the work-piece to the length of that section was reduced, and it was found that the length of the elongate section of the holes remained substantially that of the diameter of the original circular holes in the work-piece.

This provides a simple and effective means of producing holes of elongate cross-section in a work-piece. It also enables the production of holes in long work-pieces to leave thin-walled hollow bodies.

This can be done by producing a billet the cross-section of which is shorter and fatter than that of the required finished article, producing in the billet holes **52** of a pre-determined shape and size and drawing the billet, as described above, down to the required finished size.

FIG. **10** shows the cross-section of a stator vane approximately 18 inches long which was produced by the method of the present invention by drawing a billet to three times its original length.

The final thickness of the walls **53** of the article in FIG. **10** can be much smaller than can be produced by conventional forming techniques.

What we claim is:

**1.** A method of drawing a metal workpiece to form in it a hole of non-circular cross-section, the workpiece having an elongate cross-section, the length and width of the cross-section being greater than those required in the cross-section of the finished article, the method comprising the steps of forming in the workpiece a hole which extends longitudinally of the workpiece, applying a tensile load over at least a length of the workpiece including said hole in the direction of the longitudinal

axis of the hole, heating the workpiece locally to a temperature lying between upper and lower limits, the lower limit of said temperature being just above the temperature below which the material of the workpiece will neck and fracture or simply fracture rather than elongate, the upper limit of temperature being just below the temperature at which undesirable metallurgical changes such as grain growth or phase transformation occur in the material of the workpiece, said local heating being carried out at a portion of said length of the workpiece to cause local elongation of the workpiece, the temperature and tensile load together being such as to cause said local elongation of the workpiece to take place at a strain rate lying between upper and lower limits, the lower limit of said strain rate being above the strain rate at which the slow working of the material of the workpiece causes undesirable metallurgical changes to occur and the upper limit of the strain rate being below the strain rate at which the material of the workpiece will neck and fracture or simply fracture rather than elongate and causing relative longitudinal movement between the heating means and the workpiece so as to maintain the position of said heating means relative to said workpiece in such manner that the workpiece is deformed into a desired shape of smaller cross-section and said hole is reduced in size and of different cross-section.

2. A method according to claim 1, wherein the strain rate is varied so as to produce an elongation of varying cross-section.

3. A method according to claim 1 wherein the workpiece has an end piece which is not subjected to elongation and which is adapted to be formed into an integral end fitting.

4. A method according to claim 1 for producing an aerofoil blade wherein twist is imparted during elongation.

* * * * *