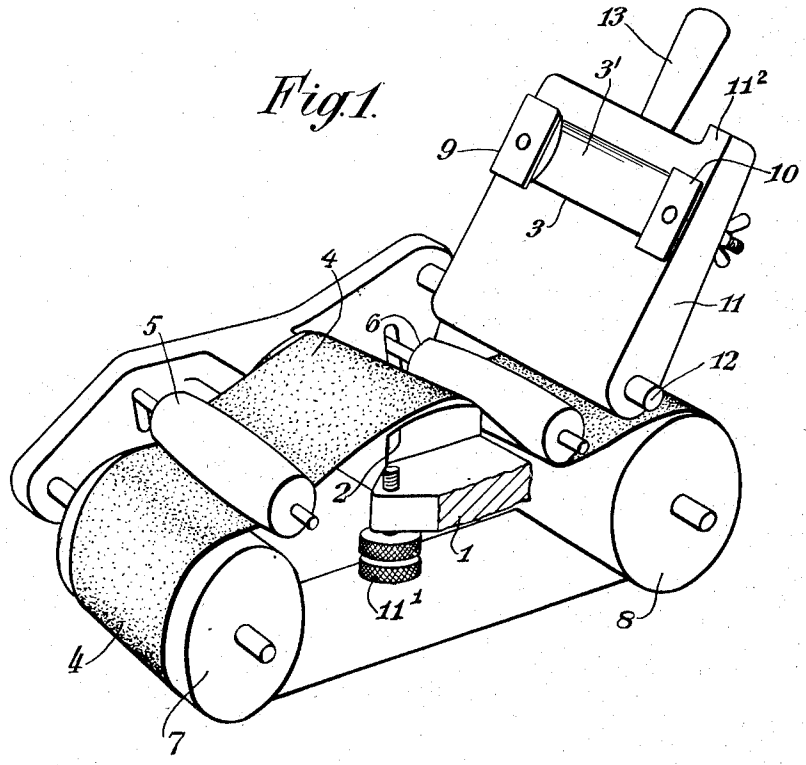
Sept. 4, 1956 J. L. JAMESON 2,761,254

APPARATUS FOR FINISHING SURFACES HAVING SHAPES WHICH VARY ALONG THEIR LENGTHS

Filed Dec. 12, 1951 4 Sheets-Sheet 1

Fig. 1.




Inventor:
Joseph Lambert Jameson;
By his attorneys,
Baldwin & Wight

Sept. 4, 1956 J. L. JAMESON 2,761,254

APPARATUS FOR FINISHING SURFACES HAVING SHAPES WHICH VARY ALONG THEIR LENGTHS

Filed Dec. 12, 1951 4 Sheets-Sheet 2

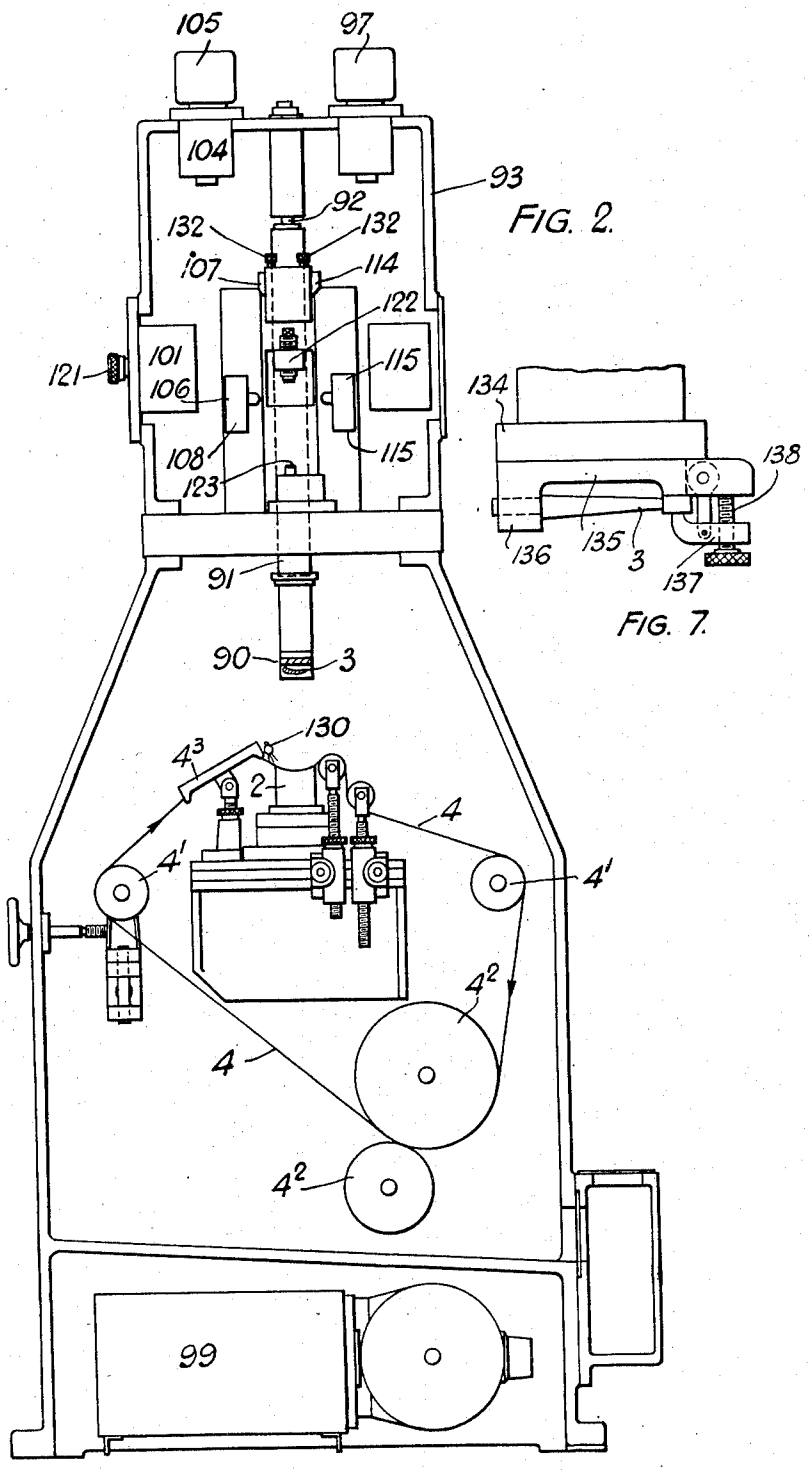



FIG. 2.




FIG. 7.

Inventor: Joseph Lambert Jameson;
By his attorneys, Baldwin & Wight

Sept. 4, 1956 J. L. JAMESON 2,761,254

APPARATUS FOR FINISHING SURFACES HAVING SHAPES WHICH VARY ALONG THEIR LENGTHS

Filed Dec. 12, 1951 4 Sheets-Sheet 3

FIG. 6.

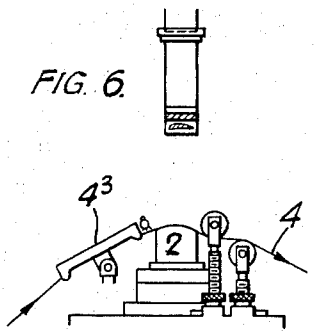



FIG. 4.

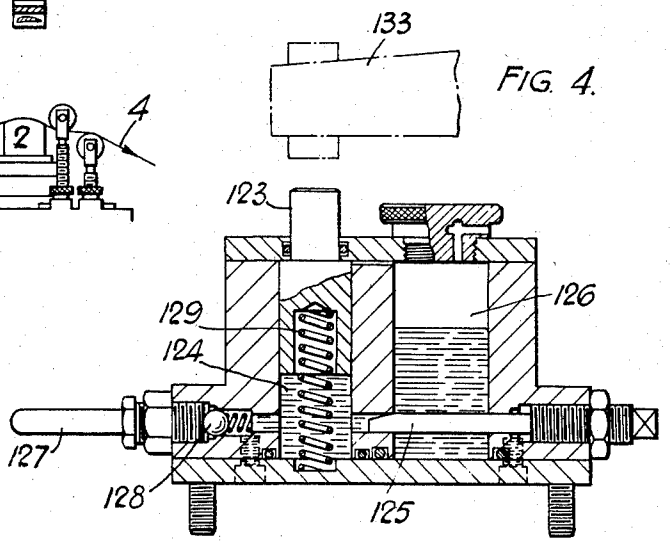
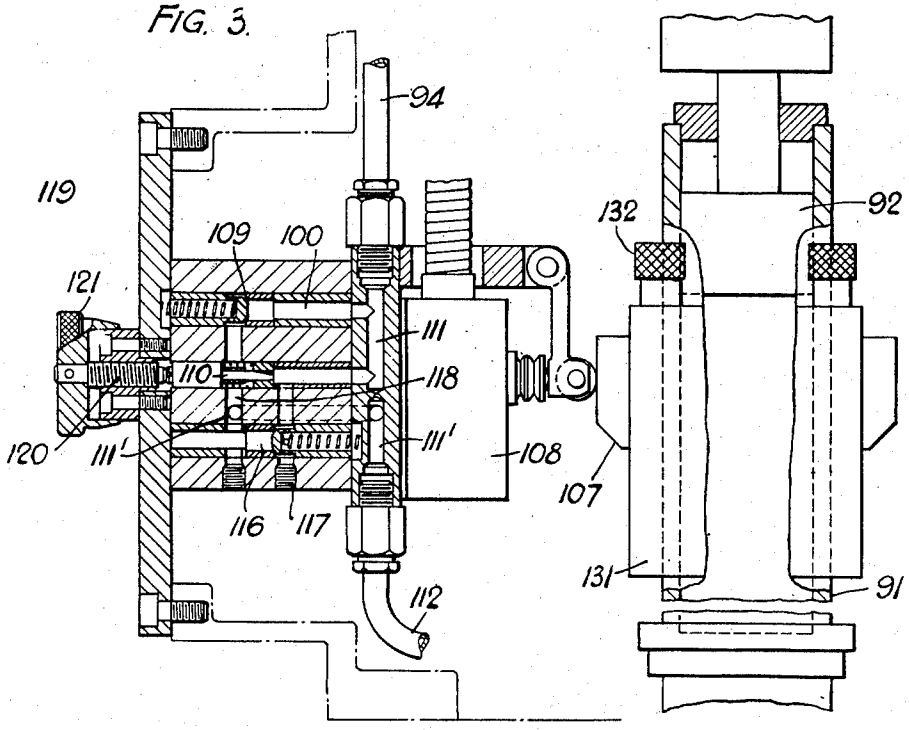



FIG. 3.




Inventor: Joseph Lambert Jameson;
By his attorneys, Baldwin & Wright

Sept. 4, 1956 J. L. JAMESON 2,761,254

APPARATUS FOR FINISHING SURFACES HAVING SHAPES WHICH VARY ALONG THEIR LENGTHS

Filed Dec. 12, 1951 4 Sheets-Sheet 4

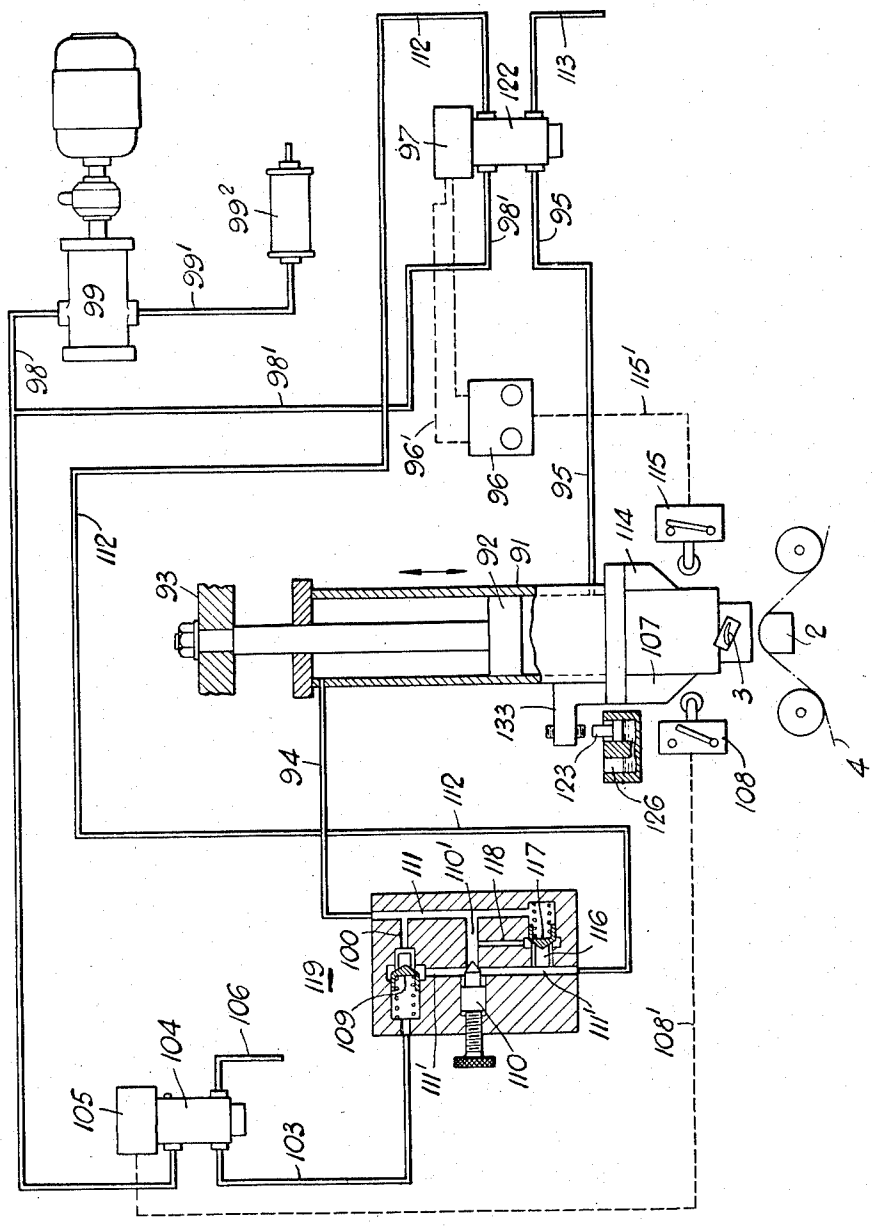



FIG. 5.

Inventor:
Joseph Lambert Jameson;
By his attorneys,
Baldwin & Wight

United States Patent Office 2,761,254 Patented Sept. 4, 1956



2,761,254

# APPARATUS FOR FINISHING SURFACES HAVING SHAPES WHICH VARY ALONG THEIR LENGTHS

Joseph Lambert Jameson, Brockhamhurst, Betchworth, England

Application December 12, 1951, Serial No. 261,178

Claims priority, application Great Britain May 17, 1945

5 Claims. (Cl. 51—141)

This invention relates to an apparatus for finishing the surfaces of turbine blades and the like which in most cases are of unsymmetrical curvature, varying in shape along their lengths. Such articles, particularly turbine blades, must be produced with a high degree of accuracy and surface finish and must conform to each other very closely. The present application is a continuation-in-part of my application "Method of and apparatus for forming surfaces," Serial No. 669,676, filed May 14, 1946, now abandoned.

Such blades have commonly in the past been finished by hand, an operation which requires much skill and considerable time, so that turbine blades were difficult to produce, and were expensive. An object of my invention accordingly is the provision of an apparatus which will enable such blades to be finished with a high degree of accuracy, rapidly and cheaply, without requiring the exercise of any particular skill by the operator.

My invention employs a die or former element having a surface formed to duplicate, in reverse, the shape and extent of the surface to which the workpiece is to be finished. According to the invention, novel means moves the workpiece surface which is to be finished, and the die or former surface, relatively, towards each other, a moving flexible carrier, such as an endless band, being interposed between them, this having an abrasive surface opposed to the workpiece and a nonabrasive surface opposed to the die surface.

The novel apparatus utilizes the die and workholder and abrasive carrier as referred to, means for progressing or otherwise moving the carrier, with its opposite faces engaging the die and workpiece surfaces as described, and means for causing the relative movement, and positioning, of the die and workpiece, to bring about the required aligned engagement of the parts, as well as the opposite movement, when the finishing operation is completed. The said relative movement may well be produced by holding either the die or the workpiece, in its holder, stationary, while moving the other by a guided straight line movement, or by holding one of the same stationary while moving the other through a path which is curved until the abrasive carrier is nearly approached, the last increment of the movement, into contact with the carrier, being substantially straight line, as is also the continued movement of the parts towards each other during the finishing operation, as material is removed from the workpiece.

In order that the invention may be understood more clearly, reference will now be made to the accompanying drawings, forming part of this application.

In the drawings:

Figure 1 is a perspective view, somewhat diagrammatic, of a machine in which the work holder is swung through a curved path, which approximates a straight line, as the workpiece engages the abrasive band.

The remaining views are of a construction, in which



the workholder is moved upwardly and downwardly by fluid pressure, and of which figures, more specifically,

Figure 2 is a diagrammatic elevation of the machine;

Figure 3 is a detail vertical sectional view, showing means for controlling the rise and fall of the cylinder which carries the workholder;

Figure 4 is a detail vertical sectional view, showing means for cushioning the final part of the descent of the said cylinder;

Figure 5 is a diagrammatic view of the machine with its control devices and connections, partly shown in section;

Figure 6 is a diagrammatic view of the workholder, die, and related parts, set to produce a blade of different form from that shown in Figure 2; and

Figure 7 is a local elevation showing one means of clamping the blades in position in the holder.

Reference will now first be made to the simple form of machine shown in Figure 1, in which the reference number **1** indicates a rigid stationary former block or die having what may be termed a die surface **2** which is preformed to a shape corresponding to the shape but in reverse or obverse to which the surface **3'** of a turbine blade blank **3**, is to be finished. The extent of the surface **2** of the die corresponds to the extent of the surface **3'** of the blade. Tracked over the surface **2** is an endless flexible band **4** which passes also over pulleys **5**, **6** and around return pulleys **7**, **8** one of which is driven. The endless band **4** has an abrasive on only its uppermost face, i. e. the face remote from the die surface **2**, where it passes over that surface.

The blade **3** is clamped by clamps **9**, **10** to a holder **11** which is pivoted at **12**: this enables the holder to be swung from a position (as shown) in which a blade to be treated can be loaded into the holder whereupon the holder is swung to bring the blade into the operating zone of the band **4**: thus the band **4** being backed on its non-abrasive side by the die surface **2**, the surface causes the abrasive on the other side of the band to reproduce the shape on the surface **3'** of the workpiece, the reproduction being effected with a high degree of precision and quality and without requiring the exercise of any particular skill by the operator.

It is to be noted that for the purpose of the invention it is necessary to cause the blade **3** to be held, during the operation, in register with the die surface **2** and with the surface **3'** of the blade and the surface **2** of the die in juxtaposition and it is also necessary that in and immediately prior to the actual finishing operation the blade **3** shall move towards the die along approximately a straight line which is normal to the average level of the surface of the die and hence of the blade surface to be finished. These considerations are achieved for all practical purposes by the arrangement shown in Figure 1 for the holder pivot **12** is so arranged that when the holder is swung the blade **3** engages the abrasive face of the band in the final part of the movement. In this final part the blade is juxtaposed to the die surface **2** and the pivot **12** is at the level of the die so that the curvilinear movement of the blade over the small movement towards the die in the operating zone of the machine can be regarded as movement in a straight line normal to the surface of the die. The truth of this will be appreciated when it is realised that the amount of movement of the blade **3** while it is being operated on by the band will amount to only a few thousandths of an inch this being sufficient to remove the metal from the blade **3** while the die surface **2** is being reproduced on it. Pressure is, of course, exerted continuously on the workholder during the finishing operation to maintain pressure between the workpiece, abrasive band, and die, sufficient to cause the moving band to remove metal from the workpiece as desired. This is

accomplished in the Figure 1 form of construction by downward pressure on handle 13 of the pivoted work-holder.

In order to limit the movement of the blade 3 towards the die, an adjustable screw indicated at 11' would be provided to engage an abutment $11^2$ on the holder 11.

As shown in Figures 2, 3, 5, and 6, the die 2 is stationary and the blade holder, indicated at 90, is carried by the lower end of an hydraulic cylinder 91 which is slidable on a ram 92, the rod 92' of which is secured to the frame 93 of the machine: fluid, usually oil, is admitted to the cylinder 91 at one side of the ram 92 to cause the cylinder and with it the holder 90 to move down to present a blade to the band 4 and then, the band having effected the finishing operation, fluid is admitted to the cylinder 91 at the other side of the ram to raise the holder 90 to return it to its original position to enable the finished blade 3 to be removed and replaced. In this case also the blade 3 is presented in juxtaposition to the fixed die 2 and is moved in a straight line normal to the average of the surface of the die.

The band 4 passes over rollers 4' and between rollers $4^2$ of which one is driven and the band is guided as it approaches the die by a guide plate $4^3$.

The fact that the blade 3 is urged towards the die 2 by liquid pressure ensures that the blade is fed evenly during the finishing operation and this results in an exceptionally high degree of finish with of course the accuracy which is ensured by this invention.

To expedite the rapid production of finished blades, provision is made to cause the cylinder 91 to move down quickly from its upper loading position to a position in which the blade 3 is near the die 2 whereupon the rate of movement is reduced to advance the blade 3 at the required feed rate during the finishing operation carried out by the band 4.

This is effected by providing in the liquid feed to the cylinder a control valve arrangement which is actuated by the descent of the cylinder to reduce the rate of liquid feed at the required time; the valve arrangement then being actuated when the required depth of feed has been effected to reverse the supply of liquid to the cylinder 91 to raise it quickly to re-loading position.

Particular reference will now be made to Figure 5 which is a diagram of the control valve arrangement, the parts being indicated generally in Figure 2. In this diagram, fluid pipe lines are indicated by full lines and electrical lines by dotted lines: the electrical and other control components are of any usual form and it is therefore believed to be unnecessary to show the details of the components which will be familiar to those skilled in the art of control apparatus.

The part of the cylinder 91 above the ram 92 is fitted with a supply and discharge pipe 94: the part of the cylinder below the ram 92 is similarly fitted with a supply and discharge pipe 95.

The cycle of operations is started by a push-button switch 96 which through a line 96' closes an electric circuit to a solenoid 97 energisation of which operates a valve 122 to connect the pipe 95 connected to the lower end of the cylinder 91 through a pipe 98' to a liquid pressure supply pipe 98 supplied with liquid under pressure by a motor driven pump 99 drawing its supply through a pipe 99' and a filter $99^2$. At this time the pipe 94 connected to the upper end of the cylinder 91 is connected to a regulating unit 119 having a passage 100 which connects the pipe 94. At this time the valve 109 on unit 119 is open so that the passage 100 and hence the pipe 94 is in communication with a passage 111' which is connected by a pipe 112 to the valve 122 which at this time connects the pipe 112 and hence, through the passage 111', valve 109, passage 100 and pipe 94, the upper end of the cylinder 91, to a discharge pipe 113.

The lower part of the cylinder 91 being now supplied with liquid under pressure through the pipe 95 and the upper part connected to discharge through the pipe 94 the cylinder 91 is caused to move down quickly.



During this time of quick descent the valve 109 is free to be held open by the pressure of liquid discharged from the upper end of the cylinder through the pipe 94 and the passage 100: this quick action continues until a block 107 moving with the cylinder 91 operates a micro-switch 108 which is normally open: this switch energises through a line 108' a solenoid 105 which operates the valve 104: the energisation of the solenoid 105 causes the valve 104 to connect the liquid-pressure pipe 98 through a pipe 103 to the valve 109: the valve is now closed by liquid pressure acting on it so that the passage 100 is closed and free discharge of liquid from the upper end of the cylinder 91 is prevented. However from the passage 100 is branched a passage 111 which is connected via a branch 110' to an adjustable needle valve 110 to the passage 111' and hence to the pipe 112; the setting of the valve 110 now controls the rate at which liquid can be discharged from the upper end of the cylinder 91 through the pipe 94, passage 111, branch 110', valve 110, passage 111', and thence through pipe 112 to exhaust.

Thus, the valve 109 is closed by the energisation of the solenoid 105 effected by the operation of the switch 108 when the cylinder 91 (and hence the blade 3) have been moved quickly to a position in which the blade 3 is close to the die 2: at this point the liquid from the upper end of the cylinder can be discharged only past the needle valve 110 and this is set to reduce the rate of discharge to a value such as to produce the required low rate of further movement of the cylinder 91 during the actual feed in the period while the blade 3 is being acted on by the abrasive band.

This regulated feed action continues until a second cam block 114 operates to open a second micro-switch 115 which is normally closed: when the switch is opened, it operates through a line 115' to de-energise the solenoid 97: this operates the valve 122 to connect the pipe 95 to the pipe 113 so that the lower end of the cylinder 91 is connected to discharge. At the same time the valve 122 connects the pipe 112 to the pressure pipe 98 through the pipe 98'. The passage 111' has a branch 116 which is normally closed by a spring-pressed valve 117: this valve is now opened by the application of pressure through the passages 111' and 116 and so the pressure liquid is now supplied through a passage 118 and the passages 110' and 111 to the pipe 94 and so to the upper end of the cylinder 91.

Thus, the upper end of the cylinder 91 is now supplied with liquid under pressure and the lower end is opened to discharge and as the result the cylinder is moved quickly up to its original position in readiness for a following cycle of operation initiated by re-operation of the switch 96.

Figure 3 shows the regulating unit which is indicated as a whole by the reference 119 in Figure 5, the parts shown in Figure 3 being given the same reference numerals as those in Figure 5.

As is shown in Figure 3 the setting of the needle valve 110 is controlled by an adjusting screw 120 having an operating knob 121 which can be calibrated in terms of feed rate.

The operating blocks 107, 114 for the micro-switches 108 and 115 as shown, are adjustable to come into operation at points which are best suited for any particular case: this can be effected by mounting the blocks to slide on a support 131 and by providing for each block an adjusting screw 132 as indicated in Figures 2 and 3.

In order to cushion the final part of the rapid downward movement of the cylinder 91, a hydraulic damper may be employed as is indicated in Figures 4 and 5. The cylinder is provided with a lug 133 which moves into engagement with the head of a plunger 123 in a cylinder 124 the escape of liquid from which is regulated by an adjustable needle valve 125: the liquid discharged passes

into a chamber **126** which is connected by a transfer pipe **127** and a non-return valve **128** to the cylinder **124**. The plunger **123** is urged outwardly by a spring **129** so that when the lug **122** rises clear of the plunger **123** the spring moves it out and liquid is drawn back into the cylinder **124** through the pipe **127**, and past the valve **128** from the chamber **126** so that the device forms a self-recuperating unit.

In Figure 2 is shown a jet **130** to deliver oil to the band **4** as it passes to the die **2**. In this figure also the die is shown as required to finish the convex surface of a turbine blade, i. e. the lower surface of the blade **3** shown in the holder **90**. In Figure 6 the same machine is shown with a die **2** formed to finish the concave surface of a blade such as is shown in the holder **90** in that figure.

The holder **90** can be arranged in any convenient manner to receive a blade, as is indicated in Figure 7, the lower end of the cylinder **91** is formed with a pad **134** carrying a fixture **135** having at one end a locating socket **136** into which the one end of a blade **3** is located, the other end being held by a familiar releasable swinging clamp **137** which can be locked by a screw **138** reacting against the fixture **135**.

What I claim is:

1. In apparatus for finishing the surfaces of turbine blades and the like having shapes which vary along their lengths, the combination of a former element having a surface varying in shape along its length and in extent to duplicate in reverse the shape and extent of the surface to which a workpiece is to be finished, a workpiece holder, said holder with its workpiece and former element constituting relatively movable elements, a reciprocable member carrying one of said elements, a flexible band having opposite abrasive and non-abrasive surfaces positioned between said elements with its abrasive surface opposed to a workpiece in said holder, means for driving said band longitudinally, means for guiding the operative movement of said reciprocable member to cause the workpiece in said holder and said former surface to come into surface contact with the opposite faces of said band in alignment with each other, and power means for moving said member towards and away from said band, at one rate of travel while the element carried thereby is relatively distant from said band, and at a reduced rate of travel, on its movement towards said band, during the period within which said element is close to and in surface contact with said band.

2. In apparatus for finishing the surfaces of turbine blades and the like having shapes which vary along their lengths, the combination of a former element having a surface varying in shape along its length and in extent to duplicate in reverse the shape and extent of the surface to which a workpiece is to be finished, a workpiece holder, said holder with its workpiece and former element constituting relatively movable elements, a reciprocable member carrying one of said elements, a flexible band having opposite abrasive and non-abrasive surfaces positioned between said elements with its abrasive surface opposed to a workpiece in said holder, means for driving said band longitudinally, means for guiding the operative movement of said reciprocable member to cause the workpiece in said holder and said former surface to come into surface contact with the opposite faces of said band in alignment with each other, and means for applying fluid pressure to said reciprocable member at a constant regulated rate during the period of contact of the element carried thereby with said band to cause an even operative movement of said member.

3. In apparatus for finishing the surfaces of turbine blades and the like having shapes which vary along their lengths, the combination of a former element having a surface varying in shape along its length and in extent to duplicate in reverse the shape and extent of the surface to which a workpiece is to be finished, a workpiece



holder, said holder with its workpiece and former element constituting relatively movable elements, a reciprocable member carrying one of said elements, a flexible band having opposite abrasive and non-abrasive surfaces positioned between said elements with its abrasive surface opposed to a workpiece in said holder, means for driving said band longitudinally, means for guiding the operative movement of said reciprocable member to cause the workpiece in said holder and said former surface to come into surface contact with the opposite faces of said band in alignment with each other, and power-operated means for moving said member towards said band at one rate of travel until the element carried thereby nearly approaches said band, then at a reduced rate of travel during the period of contact of said element with said band, and for then moving said member away from said band at a rate of travel greater than said last named rate.

4. In apparatus for finishing the surfaces of turbine blades and the like having shapes which vary along their lengths, the combination of a former element having a surface varying in shape along its length and in extent to duplicate in reverse the shape and extent of the surface to which a workpiece is to be finished, a workpiece holder, said holder with its workpiece and former element constituting relatively movable elements, a reciprocable member carrying one of said elements, a flexible band having opposite abrasive and non-abrasive surfaces positioned between said elements with its abrasive surface opposed to a workpiece in said holder, means for driving said band longitudinally, means for guiding the operative movement of said reciprocable member to cause the workpiece in said holder and said former surface to come into surface contact with the opposite faces of said band in alignment with each other, fluid pressure operated means for moving said member towards said band at one rate of travel until the element carried thereby nearly approaches said band, means for reducing the rate of effective applicaiton of motive fluid to said member during the period of contact of said element with said band to produce a reduced rate of movement thereof, and means for regulating such reduced rate of effective application of motive fluid.

5. In apparatus for finishing the surfaces of turbine blades and the like having shapes which vary along their lengths, the combination of a former element having a surface varying in shape along its length and in extent to duplicate in reverse the shape and extent of the surface to which a workpiece is to be finished, a fixed support for said former element, a reciprocable member aligned with said former element on said support, a workpiece holder carried by said member, a flexible band positioned between said former element and holder arranged to travel over the surface of said former element, said band having an abrasive surface opposed to a workpiece in said holder and a non-abrasive surface opposed to said former element, means for driving said band longitudinally, means for moving said member towards and away from said band, and means automatically operated upon the near approach of the workpiece in said workholder to said band for reducing the rate of travel of said member during the period of contact of the workpiece with said band.

**References Cited** in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 230,663 | Savage | Aug. 3, 1880 |
| 236,475 | Ambler et al. | Jan. 11, 1881 |
| 552,066 | Leach | Dec. 24, 1895 |
| 880,663 | Herrmann | Mar. 3, 1908 |
| 900,249 | Wysong | Oct. 6, 1908 |
| 1,019,287 | Watkins | Mar. 5, 1912 |
| 1,082,670 | Wysong | Dec. 30, 1913 |

**(Other references on following page)**

7

UNITED STATES PATENTS

| | | |
|---|---|---|
| 1,144,347 | Butcher et al. | June 29, 1915 |
| 1,150,155 | Sumner | Aug. 17, 1915 |
| 1,841,411 | Kux | Jan. 19, 1932 |
| 1,954,035 | Ashworth | Apr. 10, 1934 |
| 2,123,269 | Ball et al. | July 12, 1938 |
| 2,312,028 | Clausing | Feb. 23, 1943 |

8

| | | |
|---|---|---|
| 2,359,488 | Ponder | Oct. 3, 1944 |
| 2,376,847 | Glike | May 22, 1945 |
| 2,453,972 | Clave et al. | Nov. 16, 1948 |
| 2,575,656 | Coe et al. | Nov. 20, 1951 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 591,890 | Great Britain | Sept. 1, 1947 |