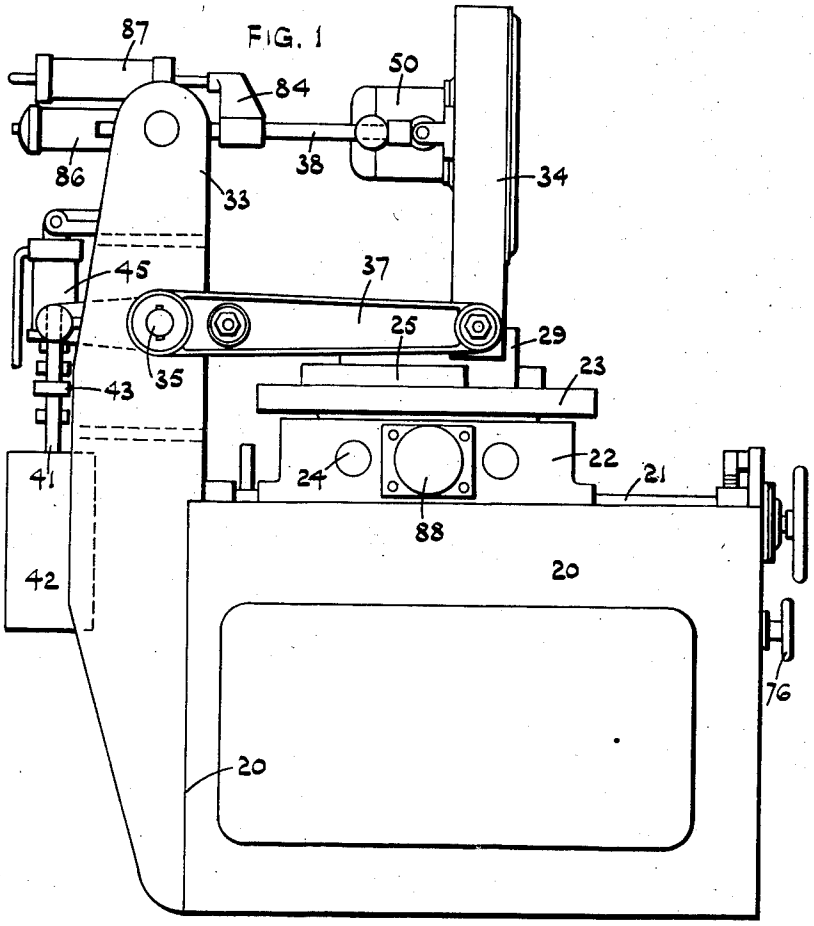
July 9, 1957 J. C. SHARMAN 2,798,341

MACHINES FOR USE IN PERFORMING FINISHING AND SIMILAR SURFACING OPERATIONS ON WORKPIECES

Filed Oct. 11, 1955 5 Sheets-Sheet 1

FIG. 1



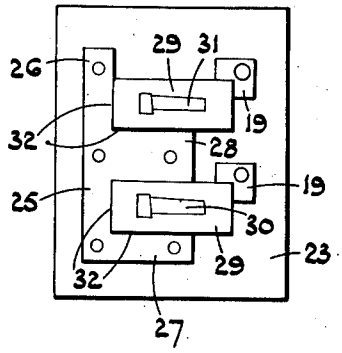


FIG. 2

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FIG. 3

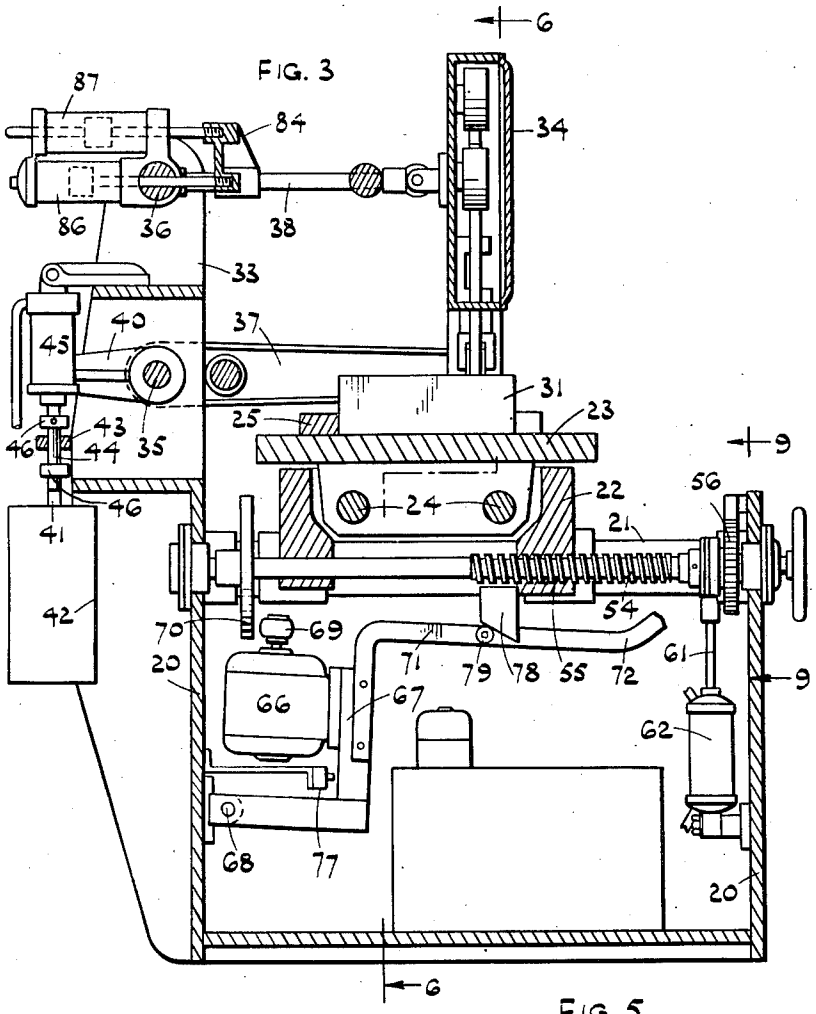

FIG. 4

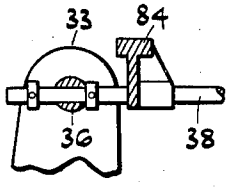

FIG. 5

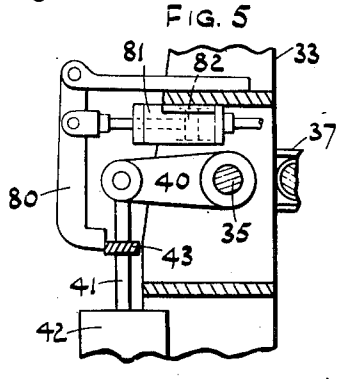

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FIG. 6

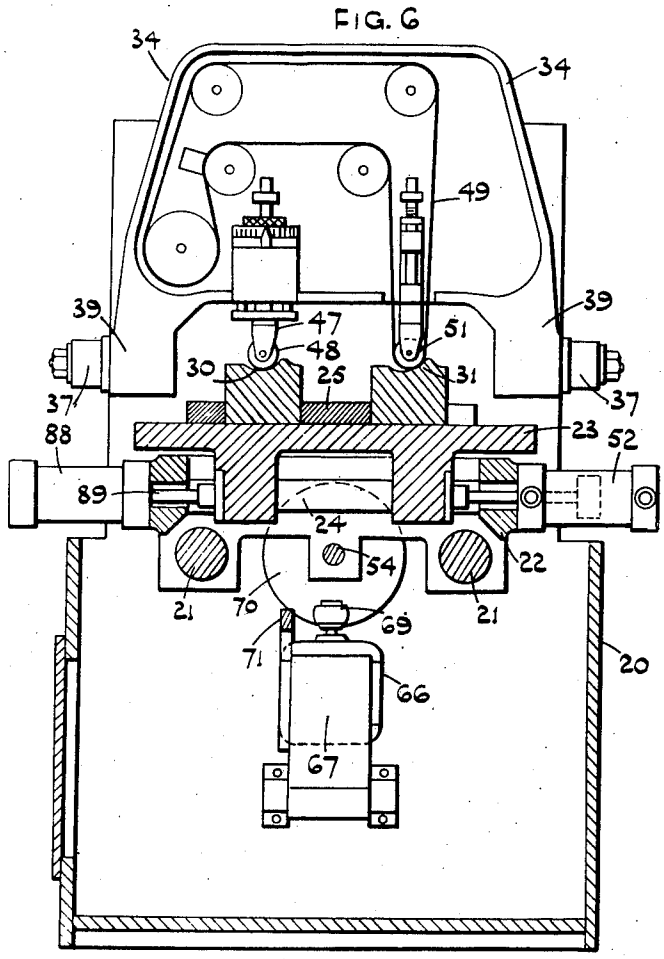


FIG. 7

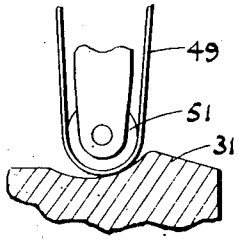
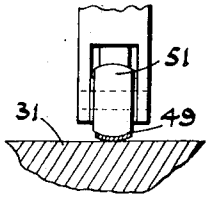


FIG. 8



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MACHINES FOR USE IN PERFORMING FINISHING AND SIMILAR SURFACING OPERATIONS ON WORKPIECES

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FIG. 9

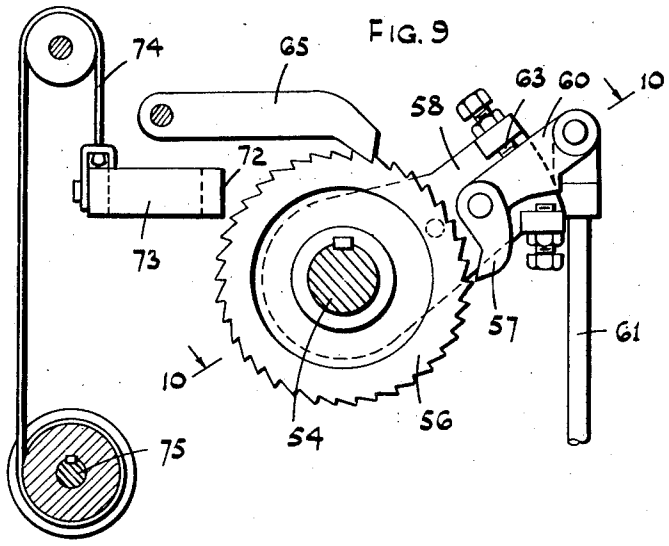

FIG. 10

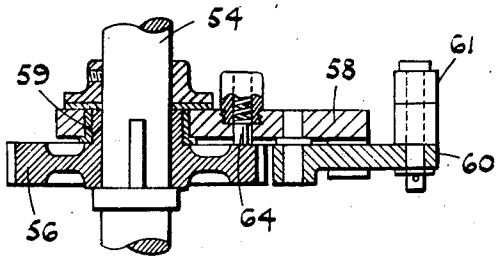

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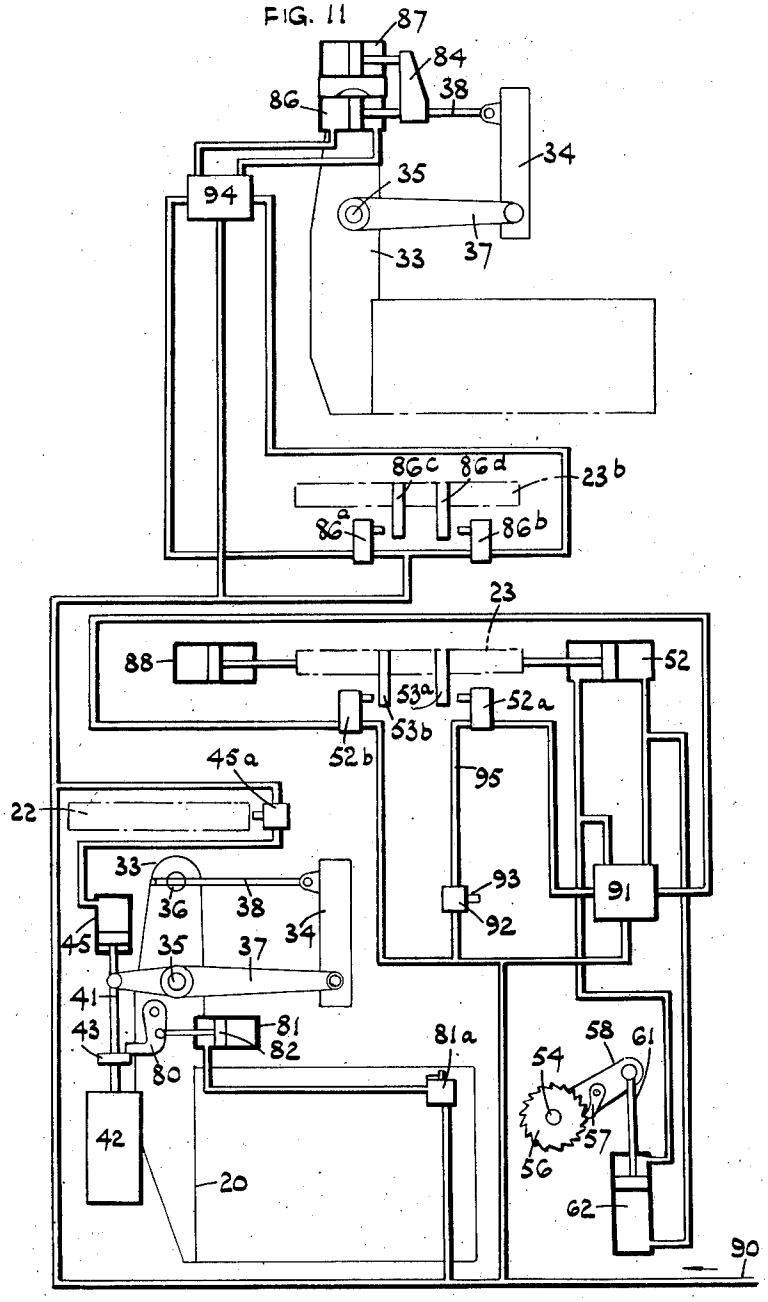
FIG. 11



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United States Patent Office 2,798,341 Patented July 9, 1957

2,798,341

MACHINES FOR USE IN PERFORMING FINISHING AND SIMILAR SURFACING OPERATIONS ON WORKPIECES

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Application October 11, 1955, Serial No. 539,813

11 Claims. (Cl. 51—143)

This invention relates to machines for use in performing polishing and similar surfacing operations on workpieces, herein referred to and included in the generic expression "surfacing operation."

The invention has been specifically developed for use in the formation of forging dies for the production of forgings to highly accurate configuration, for example forging dies for use in the production of gas turbine blades, but the invention is capable of general application to the surfacing of the work-pieces of various kinds, including for example gas turbine blades themselves.

At present in the formation of highly accurate forging dies such as those used in the forging of gas turbine blades, it is at present the practice to finish the operative surface of each forging die by a hand-filing or other hand-polishing or hand-abrasive operation, a procedure which is extremely time consuming as well as being most costly by reason not only of the time taken in completing the finishing of each forging die, but also by reason of the highly skilled nature of the work involved.

The present invention has for its object the provision of a machine of a new or improved form which enables such surfacing operation as applied to forging dies as well as to other work-pieces to be performed mechanically instead of manually, with consequent enormous saving in both time and labour costs.

The object of the invention may be realised by the means or process described in detail in the following specification.

The invention will appear more clearly from the following detailed description when taken in connection with the accompanying drawings, showing by way of example, a preferred embodiment of the inventive idea.

Figure 1 is a side elevation of one form of machine in accordance with the present invention.

Figure 2 is a plan view of part of the machine depicted in Figure 1 showing the manner of mounting the master former and work-piece to be surfaced.

Figure 3 is a cross sectional side view of the machine depicted in Figure 1.

Figures 4 and 5 are detailed views of certain parts associated with the tool carrying head of this machine.

Figure 6 is a sectional view on the line 6—6 of Figure 3.

Figures 7 and 8 are two detailed views of the abrasive carrying band and its associated supporting roller depicting the manner in which the band operates on the surface of the work-piece in this machine.

Figure 9 is a sectional view on an enlarged scale on the line 9—9 of Figure 3.

Figure 10 is a sectional view on the line 10—10 of Figure 9.

Figure 11 is a diagrammatic view illustrating the lay-out of the pneumatic circuit employed for controlling the operation of the various moving parts of this machine.

In the drawings the invention is depicted as applied to a machine for finishing the operative surface of forging dies for use in the forging of gas turbine blades. Such machine comprises a base in the form of a hollow body 20

of generally rectangular configuration open on its upper side, the body being provided with a pair of main slide bars 21 extending in the direction of the length or major axis of the forging tool surface to be formed on which slide bars is mounted for horizontal sliding movement a main slide 22 on the upper surface of which is mounted a carriage 23 supported through further slide bars 24 so that the carriage 23 can reciprocate on the main slide 22 in a horizonal direction perpendicular to the direction of sliding of the main slide; i. e. in a direction transverse to the length of the forging surface to be formed; i. e. in a direction corresponding to the width of the gas turbine blade itself.

The carriage 23 takes the form of a flat horizontally extending table and as shown in Figure 2 its upper surface is provided with a locating member 25, which in plan has the configuration of a letter F disposed with its stem 26 extending parallel to the direction of reciprocation of the carriage and with its two arms 27, 28 extending parallel to the direction of sliding of the main slide.

Extending parallel to the length of the said two arms 27, 28 in engagement therewith are rectangular elongated blocks 29 one of which carries the master former 30 and the other of which carries the forging die 31 to be surfaced.

Two of the mutually adjacent vertical sides 32 of each block 29 are formed so as to be exactly perpendicular to one another and are adapted to engage with correspondingly relatively disposed sides of the stem 26 and arms 27, 28 of the F-shaped locating member 25; the arrangement providing an exact relative location of the master former 30 and forging die 31 on the said carriage 23.

The latter is provided with a pair of clamping means 19 adapted to secure the said blocks with their exact right angle corner fully within the corresponding exact right angle corners of the F-shaped locating member 25.

The body 20 at one end thereof, namely the rear end, is provided with a pair of upstanding pillars 33 spaced apart transversely of the machine; i. e. in the direction of reciprocation of the carriage 23, which pillars project substantially above the level of the carriage and serve to support the tool-carrying head or tool head 34.

For this purpose the pillars are joined by a pair of vertically spaced shafts 35, 36 each of which carry a pair of transversely spaced link arms; i. e. both a lower and an upper pair of link arms 37, 38 respectively, which link arms project above the surface of the carriage and at their projecting ends are connected pivotally to the tool head 34.

The tool head 34 is of a hollow form and of generally rectangular configuration disposed with its main plane of cross section vertical and parallel to the direction of reciprocation of the carriage 23, and the tool head is provided at each of its two lower corners with a dependent lug 39, each of which lugs has a bearing connection to the projecting end of one or the other of the lower link arms 37, while the upper pair of link arms at their projecting ends are connected pivotally to the rear side of this hollow tool head member.

The lower link arms are rigidly connected to the lower horizontal shaft 35 so as to pivot therewith, and this shaft centrally of its length carries as shown in Figure 5 two rearwardly extending arms 40 the rear ends of which are connected to the upper end of a corresponding dependent stem 41, the lower ends of the two stems being joined together by a counter weight 42 which serves partly but not completely to balance the weight of the tool head 34 itself, thereby limiting the downward force exerted by the weight of the tool head 34 in a direction towards the master former and forging surfaces.

The said two stems 41 intermediate their ends are joined by a horizontal cross bar 43, through the medial part of which cross bar extends freely the vertically ex-

tending piston rod 44 (see Figure 3) of a single acting tool head lifting pneumatic cylinder 45 arranged immediately above the cross bar 43 and carried from an adjacent part of the machine body, the piston rod being provided with a pair of abutments 46 spaced vertically apart by a distance substantially greater than the vertical thickness of the cross bar, the arrangement being such that on admitting air under pressure to the upper end of this single acting cylinder 45 the cross bar 43 is depressed and the tool head 34 raised well clear of the master former and work-piece the tool head 34 returning under gravity on release of the air pressure within the cylinder 45, while at the same time the tool head is itself free to move up and down to the limited extent necessary during the actual surfacing of the die surface by reason of the lost motion connection provided between the cross bar 43 and the piston rod 44 by the said spaced abutments 46.

The tool head 34 supports a tracer element 47 in the form of a roller and carried from the head by an adjustable support 48 of known form, this tracer element being adapted to engage with the surface of the master former 30. The head 34 further supports in the known manner an abrasive-carrying flexible band 49 power driven from electric motor 50, and supported adjacent to the surface of the forging die 31 which it is to form by means of a roller 51, the two rollers 47, 51 being of slightly different diameter so that the overall diameter of the band support roller 51 including that of the band corresponds to the diameter of the tracer element roller.

Both of these rollers 47, 51 are supported at their ends only on pintle type bearings with their axes of rotation parallel to one another and parallel to the direction of sliding of the main slide 22.

As shown in Figure 8, both the tracer element rollers and also the band support roller are each of slightly coned or barreled configuration, i. e. of convex configuration peripherally, the arrangement being such that the band 49 makes operative engagement with the surface to be finished or abraded over only a proportion of its entire width.

Reciprocation of the carriage 23 is effected by means of a carriage reciprocating double-acting pneumatic cylinder 52 mounted as shown in Figure 6 on the main slide 22 adjacent one of the lateral sides of the machine, the operation of which cylinder 52 is under the control of a pair of main control valves 52*a* and 52*b* (see Figure 11) the two valves being spaced apart in the direction of reciprocation of the carriage 23 and arranged to operate as hereinafter described.

For operating these two control valves the carriage 23 is provided at the front end thereof with a corresponding pair of transversely spaced valve actuating abutments 53*a*, 53*b* (see Figure 11) adapted to engage the operating members of one or the other of the two control valves 52*a*, 52*b* when the carriage reaches one or the other of its two extreme reciprocatory positions.

For effecting feeding and return movement of the main slide 22 the body 20 of the machine has rotatably mounted thereon, as shown in Figure 3, a longitudinally extending feeding screw 54 of conventional form, which works within a nut 55 carried by the main slide, this feeding screw adjacent the front end of the machine body carrying as shown in Figures 3, 9 and 10 a ratchet wheel 56 which is adapted to be engaged by a feeding pawl 57 mounted pivotally on a pawl carrier 58, which pawl carrier is itself pivoted to the hub 59 of the ratchet wheel 56 so as to turn about the axis of rotation of the feeding screw 54.

The feeding pawl 57 is connected to a pawl actuating arm 60 which extends substantially radially in relation to the ratchet wheel 56, the outer end of this arm 60 being connected pivotally to the piston rod 61 of a double-acting feeding pneumatic cylinder 62 (see Figures 3 and 11) the rod extending from the upper end of the cylinder 62, the lower end of which cylinder is pivoted to the

machine body 20 about an axis parallel to the axis of pivoting of the arm 60.

The feeding pawl 57 depends downwardly in relation to its associated arm 60, the arrangement being such that feeding movement is imparted to the feeding screw to turn this in a clockwise direction as viewed from the front of the machine when the piston of the feeding cylinder is displaced downwardly, the piston performing an idle stroke when displaced upwardly.

As shown in Figure 9, the pawl actuating arm 60 is adapted on its upper and lower sides to engage with adjustable screw stops 63 mounted on the pawl carrier 58, and the latter is provided with a spring loaded plunger 64 (in Figure 10) for engaging frictionally with a side face of the ratchet wheel, the arrangement being such that when the piston of the feeding cylinder 62 is first displaced in either direction the pawl is pivoted initially in one or the other direction relative to the pawl carrier before the pawl carrier is itself pivoted about the axis of the feed screw, thereby in practice ensuring:

(*a*) That the feeding pawl 57 is immediately disengaged from the ratchet wheel 56 on the commencement of the return or idle stroke of the piston of cylinder 62 and there is accordingly no possibility of any undesirable return movement being then imparted to the feed screw 54.

(*b*) That on the initiation of the feeding stroke by the cylinder 62, the feeding pawl 57 pivots into a position for immediately engaging with the ratchet wheel 56.

Return movement of the feeding screw is normally inhibited by a spring or gravity loaded non-return pawl 65 (see Figure 9) and pivoted to the machine body 20.

For effecting rapid return movement of the main slide 22 when this has been fully traversed in the one direction there is provided return feed mechanism comprising a normally inoperative electric motor 66 carried as shown in Figure 3 on upstanding arm 67 pivoted at 68 about a horizontally transverse axis to the interior of the hollow body 20.

This electric motor 66 is provided with an upstanding driving shaft, the upper end of which carries a friction driving wheel 69 which is adapted when the arm 67 is raised to be engaged with the forwardly directed side face of a driven friction disc 70 carried on the rear end of the feed screw 54 so as then to rotate this at high speed in the direction opposite to that of feeding.

The upstanding arm 67 is connected to the shorter dependent vertical arm of a substantially L-shaped lever 71, the longer arm 72 of which projects forwardly of the machine within the interior of the hollow body thereof and at its forward end is cranked in a transverse direction, the cranked portion 73 thereof (see Figure 9) being connected to one end of a cord or chain 74, the opposite end of which is connected to a shaft 75 carrying a rotatable hand-wheel 76 mounted on the front end of the machine, which when turned in the one direction raises the L-shaped lever 71 and associated arm 67 to engage the return feed motor driving wheel 69 with the driven disc 70.

The upstanding arm 67 is adapted to engage during such movement with a switch 77 for closing the normally open circuit to this motor 66.

Before the main slide can commence its return stroke it is necessary that the tool head 34 should be raised to bring the tracer element 47 and band 49 clear of the former 30 and die 31 respectively and this is done by providing the tool head lifting cylinder 45 (see Figure 11) with an operating valve 45*a* actuated by the main slide 22 when this reaches the end of its feeding stroke.

The arrangement is such that when the L-shaped lever 71 is raised in the manner above described at the conclusion of a feeding stroke of the main slide 22 the cranked portion 73 of the lever 71 engages with the non-return pawl 65 to disengage this from the ratchet wheel 56 and initially free the feed screw 54 for movement in the reverse direction.

As the L-shaped lever is further raised the switch controlling the return feed motor **66** is closed and thereafter, and before the motor driving wheel **69** engaged with the driven disc **70** the valve **45***a* for controlling the tool head lifting cylinder **45** will have been actuated so as to raise the tool head **34** with its associated tracer element and band well clear of the master former and forging die respectively.

Finally as the L-shaped lever completes its operative movement the motor driving wheel **69** engages with the driven disc **70** to effect the return movement of the slide **22**.

The weight of this electric motor **66** with associated parts tends to swing the L-shaped lever **71** towards its inoperative position and with the motor in the operative position, the operator must continue to grasp the handwheel **76** after he has turned this into the operative position.

Movement of these parts into their inoperative position when the return movement of the main slide has been completed is, however, effected automatically by providing the underside of the main slide **22** with an inclined or wedge-shaped abutment the operative face **78** of which engages with a nose portion **79** on the longer arm **72** of the L-shaped lever **71**, positively forcing this down to disengage the motor driving wheel **69** and switch off the motor as the slide **22** completes its return movement.

For safety purposes there is provided means for automatically retaining the tool head **34** in the raised position, such means comprising a loaded latch lever **80** (see Figure 5) over which the cross bar **43** joining the two stems **41** rides as these move downwardly with corresponding upward movement of the tool head, the latch lever **80** under its loading moving into engagement with the upper side of the cross bar as shown in Figure 11 when the tool head **34** is raised to retain the head positively in this position, disengagement of the latch lever being effected by means of a tool head release cylinder **81** (see Figures 5 and 11) the piston rod **82** of which is connected to the latch lever **80**. This cylinder **81** is controlled by manually operated valve **81***a* adapted when opened to effect disengagement of the latch lever **80** from the cross bar **43** and effect lowering of the tool head when a further feeding movement of the main slide is required after this has completed its return stroke with consequent release by the main slide of the valve **45***a* controlling the lifting cylinder **45** so that this is no longer operative. If desired to ensure a slow lowering movement of the tool head the tool head raising cylinder **45** may be provided with a manually operable release valve adapted to release the air pressure therein at a relatively slow controlled rate, irrespective of the operation by the main slide **22** of the valve **45***a* controlling such cylinder.

The pair of carriage reciprocating control valves **52***a*, **52***b* are so arranged in relation to their abutments **53***a*, **53***b* on the carriage that when the carriage **23** reaches one or the other extremity of its reciprocatory movement as determined by the transverse spacing of the control valve operating members and their associated actuating abutments on the carriage, the corresponding one or the other of these two control valves would be actuated so as to initiate opposite reciprocation of the double-acting carriage reciprocating cylinder **52**. Simultaneously as hereinafter explained one or another of these valves serves to effect at one extreme position of the carriage, feeding movement of the slide feeding cylinder **62** and at the other extreme position of the carriage, return movement of the slide feeding cylinder **62**, the arrangement being such that the main slide is fed through a predetermined distance by the turning of the feeding screw by means of the pawl and ratchet mechanism above described once for each complete amplitude of reciprocation of the carriage **23**, the actual feeding movement occurring only when the carriage is momentarily stationary at its one extreme transverse position.

The arrangement is such that the tracer element **47** and abrasive carrying band **49** are thereby caused to traverse twice in a direction perpendicular to the major axis of the die surface over every portion of the length thereof, while simultaneously the abrasive carrying band is driven continuously at high velocity and the engagement between the tracer element **47** and the master former **30** serves to raise the tool head and with it the abrasive band against the gravity loading provided by the unbalanced proportion of the weight of the tool head and its associated parts, the arrangement being such that the surface of the abrasive band partakes exactly of the movement of the tracer element and thereby forms in the forging die **31** an exact finished surface usually of concave configuration with the axis of curvature substantially parallel to the major axis of the forging die which surface is an exact copy of the surface of the master former.

It is possible with such a machine to remove at a single operation material to a depth of .0012" to .0015" and forming a final finishing surface in so doing for a single feeding movement of the main slide, and in the case of a forging die for a gas turbine blade having a length of approximately 5" it is possible to complete the finishing operation in an overall time of approximately twelve minutes which is enormously less than the time occupied by the existing hand-finishing operation.

Provision is made for continuously varying the inclination in both directions to the horizontal of the axis of rotation of the abrasive carrying band supporting roller **51**. This is desirable because having regard to the irregularity in the shape of the die surface to be formed it is important that as shown in Figures 7 and 8 there should only be a small area of contact between the band and the die surface for which purpose as earlier explained the band supporting roller **51** is of convex or barrelled configuration peripherally as clearly shown in Figure 8 so that only a very small portion of the entire width of the band **49** is at any one time in operative engagement with the die surface and in order that the entire width of the band should be utilised in operating on the die surface it is necessary that the axis of rotation of the band supporting roller **51** should be oscillated continuously in both directions from the mean position depicted in Figure 8 so as to bring both edge portions as well as the medial portion of the band **49** into engagement with the die surface.

For this purpose the upper pair of link arms **38** associated with the tool head **34** are mounted for sliding movement in a corresponding hole formed as shown in Figure 4 in the associated upper shaft **36** to which this pair of link arms is connected and this sliding movement is limited by abutments **83** on each link arm and controlled by connecting together these two link arms **38** adjacent to the shaft **36** through which they slide by cross member **84** carrying the piston rod **85** of a double acting tool head oscillating cylinder **86** which under the control of valves **86***a* and **86***b* (see Figure 11) serves as hereinafter explained to vary the effective length of the corresponding upper pair of link arms **38** relative to the lower pair **37** and thus displace the axis of rotation of the band supporting roller **51** into different positions of inclination to the horizontal; i. e. to the major axis of the forging die; simultaneous displacement of the axis of rotation of the tracer element roller **47** being necessarily effected since this is also mounted on the tool carrying head **34**, such displacement being essential to ensure that this tracer element roller **47** accurately controls the position of the band supporting roller **51** to which it corresponds in configuration as earlier explained.

The arrangement is such that the axis of the band supporting roller **51** moves through a single complete

amplitude of oscillation during a single complete reciprocatory movement of the carriage 23 and in order to ensure that this movement is performed at a rate corresponding to the rate of movement of the carriage 23 the cross member 84 associated with the upper pair of tool head link arms 38 is connected to a dash-pot 87.

A second dash-pot 88 is also provided having characteristics similar to that of the dash-pot 87 for the purpose of controlling the rate of movement of the carriage 23 in a transverse direction relative to the main slide 22, this dash-pot 88 being mounted on the side of the main slide 22 opposite to that on which is mounted the carriage reciprocating cylinder 52 and having its piston rod 89 connected to the carriage as clearly shown in Figure 6, further if desired a dash-pot or other form of shock absorber may be provided for controlling the downward or return movement of the tool carrying head 34 prior to the commencement of each feeding movement of the main slide 22.

The pneumatic circuit for controlling the operation of the pneumatic cylinders above referred to with their associated control valves and which is depicted in Figure 11 of the drawings will now be briefly described:

This comprises an air pressure supply line 90 which is connected in a manner which will be apparent from the drawing to the two main control valves 52*a* and 52*b* as well as to the tool head oscillating cylinder control valves 86*a* and 86*b*. This air line 90 is also connected in a manner which will be apparent from Figure 11 of the drawing to the control valve 45*a* which controls the operation of the tool head lifting cylinder 45 as well as to the manually operated valve 81*a* which controls the operation of the tool head release cylinder 81.

The two carriage reciprocating control valves 52*a* and 52*b* serve to control the operation of the carriage reciprocating cylinder 52 through the medium of a primary relay valve 91 the operation of which primary relay valve is itself controlled by a starting valve 92 provided with a manually displaceable operating member 93.

This primary relay valve 91 also serves to control the operation of the double acting feeding cylinder 62 for effecting the feeding movement of the main slide 22 which is depicted diagrammatically in Figure 11.

The two control valves 52*a* and 52*b* are mounted on the main slide so as to travel therewith and be capable of being actuated by the carriage 23 irrespective of the position of the main slide 22 and these two main control valves 52*a* and 52*b* are disposed adjacent the front end of the carriage as depicted at 23*a* in Figure 11, i. e. adjacent the right hand side of the machine when viewed in Figure 1.

The two valves 86*a* and 86*b* which control the operation of the tool head oscillating cylinder 86 are also mounted on the main slide at a position adjacent the rear of the carriage, which rear portion is indicated diagrammatically at 23*b* in Figure 11 and these two valves 86*a* and 86*b* which are actuated in manners similar to valves 52*a* and 52*b* by abutments 86*c* and 86*d* respectively and mounted on carriage 23 control the operation of cylinder 86 through the medium of secondary relay valve 94.

The mode of operation of the machine will be fairly apparent from the foregoing description of the various parts including the description of the pneumatic circuit and only a brief explanation of the sequence of events particularly with reference to the pneumatic circuit as depicted in Figure 11 will now be necessary.

At the commencement of the operation of surfacing a die surface for forming a gas turbine or other jet engine blade, the main slide 22 would be disposed in the extreme left hand position when viewing the machine in Figure 1, 3 and also Figure 11; in which position valve 45*a* would be closed so that the piston of tool head lifting cylinder 45 would be in its fully raised position, i. e. the tool head 34 would be in its operative position with the associated tracer element and abrasive carrying band in operative engagement with the former and die surface respectively, the band being in engagement with one end of the die surface which would be arranged with the major axis of the elongated blade forming die extending parallel to the direction of movement of the main slide 23.

The switch controlling the operation of the tool head driving motor 50 would now be closed to effect driving of the abrasive band 49 and the operating member 93 of the starting valve 92 would now be displaced into the operative position so as through line 95 to subject the associated port of primary relay valve 91 to air pressure and effect displacement of this relay valve in the known manner into a position for supplying air under pressure to one end of the carriage reciprocating cylinder 52 and also to supply air under pressure to the upper end of feeding cylinder 62 to effect downward movement of the associated piston and feeding rotation through pawl 57 of the ratchet wheel 56.

The amplitude of oscillation of the carriage 23 is quite small corresponding, as it does, merely to the overall width of a jet engine blade. The two carriage reciprocating control valves 52*a* and 52*b* are arranged with their associated operating members 52*c* and 52*d* respectively oppositely directed in such a manner that one or the other is engaged by the corresponding carriage abutment 53*a* and 53*b* to ensure that either one or the other of these two valves is always open, the arrangement being that as the carriage 23 moves from its medial position relatively to the slide 22 into its right hand position as depicted in Figure 11 the valve 52*a* is opened to so operate relay valve 91 as to admit fluid under pressure to the right hand end of cylinder 52 (as viewed in Figure 11) and effect displacement of the carriage on the completion of its right hand direction of movement in the opposite or left hand direction so as to now open valve 52*b* under the operation of the abutment 53*b* as the carriage approaches the extreme left hand end of its stroke so that relay valve 91 is now displaced to admit air under pressure to the left hand end of cylinder 52 and effect pressure release from the right hand end of that cylinder thus causing the carriage to move again in a right hand direction, the carriage accordingly being caused automatically to oscillate continuously in a transverse direction without any further intervention on the part of the operator.

Some form of loading for example from the dashpot 88 would be provided so that initially the carriage 23 is in a right hand position as viewed in Figure 11 in which valve 52*a* is open thereby ensuring immediate commencement of the reciprocation of the carriage when the starting valve 92 is initially actuated.

The carriage reciprocates relatively slowly by reason of the provision of dash-pot 88 whereas the piston of the feeding cylinder 62 is displaced in one or the other direction relatively quickly when the primary relay valve 91 is actuated under the control of one or the other of the two valves 52*a* and 52*b* as the carriage is at one or the other of its two extreme positions, i. e. each feeding movement of the ratchet wheel 56 and main slide 22 is effected when the carriage 23 is in one only of its two positions, return idle movement of the pawl 57 with its associated pawl carrier occurring as the piston of cylinder 62 moves upwardly when the carriage 23 is in the other of its two extreme positions relative to the main slide 22.

As soon as the carriage 23 commences to reciprocate in the manner above described it operates its abutments 86*c*, 86*d* operating in manner identical to the above described operation of valves 52*a* and 52*b* upon the tool head oscillating cylinder control valves 86*a*, 86*b* so as to open and close these alternately at one or the other of the two extreme positions of the carriage, and effect operation through secondary relay valve 94 of the tool head oscillating cylinder 86 in exactly the same way as the cylinder 52 is operated, thereby reciprocating the pis-

ton of cylinder 86 to reciprocate the upper pair of link arms 38 and effect oscillation of the tool head to bring each edge portion of the band 49 as well as the medial portion thereof into engagement with the die surface.

The aforesaid automatic reciprocation of the carriage 23 and oscillation of tool head 34 continues with simultaneous intermittent rearward movement of slide 22 until when the latter reaches its extreme rear position, i. e. the left hand position in Figure 11 it opens tool head lifting cylinder control valve 45*a* to depress the piston of the associated cylinder 45 and raise tool head with its associated band and tracer element clear of the die and former respectively the tool head being locked automatically as already described in the raised position under the operation latch lever 80.

The hand wheel 76 would now be turned by the operator to raise the L-shaped lever 71 and effect switching on of the return feed motor 66 as well as the engagement of its driving wheel 69 with disc 70 to cause the slide 22 to return to its initial position as already described in which under the engagement of abutment face 78 with the aforesaid nose portion 79 (see Figure 3) the L-shaped lever 71 is automatically depressed to render inoperative the motor 66. The position of the lever 71 when engaged by abutment face 78 during this movement is shown in Figure 3.

A further die to be surfaced may now be disposed on the carriage 23 and the hand operated valve 81*a* actuated to disengage latch lever 80 from the cross bar 43 under the operation of cylinder 81 whereupon the tool head 34 returns to its operative position and the cycle operations above described may then be repeated.

During the return movement of the slide 22 the starting valve 92 would be closed, and under the bias loading applied to the carriage 23 as above referred to, this would be in a position in which valve 52*b* was also closed so that reciprocation of the carriage relative to the main slide 22 during the return movement of the latch is then precluded.

The machine would be provided within the interior of the lower part of the hollow rectangular body aforesaid with an electric motor-driven pump for supplying a cooling lubricant to the surface of the abrasive band, and where as is customary such lubricant is of a paraffin base type so as to be readily volatile, a hood or shroud would be arranged in the neighbourhood of the forging die with which would be associated extractor means for removing the vapour generated under the high temperature at the cutting surface, such high temperature arising largely from the high linear velocity of the abrasive carrying band which may be of the order of 2,500 feet per minute.

The invention may similarly be applied to the polishing of the side faces of jet engine blades themselves, the operation being carried out in exactly the same manner as in the case of the forging die already described.

It will be understood that the scope of the invention is not limited by the above recited example but only by the appended claims.

What I claim is:

1. A machine for performing surface finishing operations on work-pieces comprising a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, a tool head, a pair of spaced parallel or substantially parallel links on which said tool head is mounted, an abrasive carrying band support roller of convex configuration peripherally also carried by said tool head, an abrasive carrying flexible band supported by said support roller so that said band makes substantially point contact with surface of said work-piece, power means for advancing said band around said support roller relative to said work-piece surface, means for oscillating said support roller so as to bring each edge portion as well as the medial portion of the band surface into engagement with the workpiece surface, fluid pressure operated means each provided for continuously varying the length of one of said links, said variation of length of said links causing oscillating of said support roller so as to bring each edge portion as well as the medial portion of the band surface into engagement with the work-piece surface, the tool head and carriage being relatively movable towards and away from one another in a direction transverse to the direction of movement of said abrasive carrying band across the surface of the work-piece, power means for imparting a reciprocating motion to said carriage with the master former and work-piece thereon along one given axis relative to said tool head, power means for imparting a feeding movement to said carriage with the master former and work-piece thereon and relative to the tool head along a second axis transverse to said axis of reciprocation, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of said carriage in timed relation with said reciprocating motion, and valve means controlling said fluid pressure operated means operated by the reciprocatory movement of said carriage.

2. A machine for use in the production of blades for jet engines comprising a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, a tool head, a tracer element carried by said tool head, an abrasive carrying band support roller of convex configuration peripherally also carried by said tool head, an abrasive carrying flexible band supported by said support roller so that said band makes substantially point contact with surface of said work-piece, power means for advancing said band around said support roller relative to said work-piece surface, means for oscillating said support roller so as to bring each edge portion as well as the medial portion of the band surface into engagement with the work-piece surface, the tool head and carriage being relatively movable towards and away from one another in a direction transverse to the direction of movement of said abrasive carrying band across the surface of the work-piece, power means for imparting a reciprocating motion to said carriage with the master former and work-piece thereon along one given axis relative to said tool head, power means for imparting a feeding movement to said carriage with the master former and work-piece thereon and relative to the tool head along a second axis transverse to said axis of reciprocation, and means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of said carriage in timed relation with said reciprocating motion.

3. A machine for performing surface finishing operations on work-pieces comprising, a fixed base, a main slide mounted for sliding movement in a single plane back and forth on said base, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion in a direction which is at right angles to the direction of movement of the slide in the same plane, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, and power means to advance said band about said support.

4. A machine for performing surface finishing operations on work-pieces comprising, a fixed base, a main slide mounted for sliding movement in a single plane

back and forth on said base, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion in a direction which is at right angles to the direction of movement of the slide in the same plane, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide, said feeding movement being imparted to the main slide when the carriage is in a position between two oppositely directed reciprocating strokes, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, and power means to advance said band about said support.

5. A machine for performing surface finishing operations on work-pieces of elongated configuration comprising a fixed base, a main slide mounted on said base for sliding movement back and forth along an axis parallel to the major axis of the work-piece, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion along an axis parallel to the minor axis of the work-piece, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, and power means to advance said band about said support.

6. A machine for performing surface finishing operations on work-pieces comprising a fixed base, a main slide mounted for sliding movement in a single plane back and forth on said base, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion in a direction which is at right angles to the direction of movement of the slide in the same plane, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, power means to advance said band about said support, and means for imparting a returning movement to said main slide in a direction opposite to the direction of feeding, said returning movement being at a higher rate than said feeding movement and said abrasive-carrying band and tracer element being out of contact with the work-piece and master former surfaces respectively during such returning movement.

7. A machine for performing surface finishing operations on work-pieces comprising, a fixed base, a main slide mounted for sliding movement in a single plane back and forth on said base, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion in a direction which is at right angles to the direction of movement of the slide in the same plane, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, a feed screw rotatably mounted on said base, a nut mounted on said main slide and threadably engaged by said feed screw, a ratchet and pawl mechanism adapted to rotate said feed screw and thereby impart a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, power means to advance said band about said support and means for imparting a returning movement to said main slide in a direction opposite to the direction of feeding, said returning movement being at a higher rate than said feeding movement and said abrasive-carrying band and tracer element being out of contact with the workpiece and master former surfaces respectively during such returning movement.

8. A machine for performing surface finishing operations on work-pieces comprising a fixed base, a main slide mounted for sliding movement in a single plane back and forth on said base, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion in a direction which is at right angles to the direction of movement of the slide in the same plane, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, a feed screw rotatably mounted on said base, a nut mounted on said main slide and threadably engaged by said feed screw, a ratchet and pawl mechanism adapted to rotate said feed screw and thereby impart a feeding movement to said main slide along its direction of movement, a pawl-carrying arm on which said pawl is pivotally mounted, a fluid pressure operated cylinder, a piston mounted in said cylinder, one end of said pawl-carrying arm being pivotally mounted about the axis of rotation of said feed screw and said ratchet wheel and the other end of said pawl-carrying arm being connected to said piston, valve control means adapted to control said cylinder, said valve control means being operated by said carriage in its reciprocating motion for automatically controlling said feeding movement of said main slide in timed relation with said reciprocating motion, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, power means to advance said band about said support and means for imparting a returning movement to said main slide in a direction opposite to the direction of feeding, said returning movement being at a higher rate than said feeding movement and said abrasive-carrying band and tracer element being out of contact with the work-piece and master former surfaces respectively during such returning movement.

9. A machine for performing surface finishing operations on work-pieces comprising, a fixed based, a main slide mounted for sliding movement in a horizontal direc-

tion back and forth on said base, a carriage supporting a work-piece with its operative surface presented upwardly, a master former also supported by said carriage in a predetermined relationship with said work-piece, and with its operative surface also presented upwardly, said carriage being mounted upon the main slide for reciprocating motion in a horizontal direction at right angles to the direction of movement of said slide, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head extending above said carriage, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, and power means to advance said band about said support.

10. A machine for performing surface finishing operations on work-pieces comprising, a fixed base, a main slide mounted for sliding movement in a horizontal direction back and forth on said base, a carriage supporting a work-piece with its operative surface presented upwardly, a master former also supported by said carriage in a predetermined relationship with said work-piece, and with its operative surface also presented upwardly, said carriage being mounted upon the main slide for reciprocating motion in a horizontal direction at right angles to the direction of movement of said slide, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head extending above said carriage, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying flexible band support also carried by said tool head, an abrasive-carrying flexible band, power means to advance said band about said support, means for automatically raising said tool head clear of said carriage and work-piece and master former thereon at the conclusion of each complete feeding movement of said main slide, and means for imparting a returning movement to said main slide in a direction opposite to the direction of feeding at the end of each complete feeding movement, said returning movement being at a higher rate than said feeding movement.

11. A machine for performing surface finishing operations on work-pieces comprising, a fixed base, a main slide mounted for sliding movement in a single plane back and forth on said base, a carriage supporting a work-piece, a master former also supported by said carriage in a predetermined relationship with said work-piece, said carriage being mounted upon the main slide for reciprocating motion in a direction which is at right angles to the direction of movement of the slide in the same plane, power means for imparting a reciprocating motion to the carriage with the master former and work-piece thereon, power means for imparting a feeding movement to said main slide along its direction of movement, means operated by the carriage in its reciprocating motion for automatically controlling the feeding movement of the main slide in timed relation with said reciprocating motion, a tool head, a tracer element carried by said tool head, said tool head being movable towards and away from the carriage in a direction at right angles to the plane of reciprocation of the carriage, an abrasive-carrying band support roller of convex configuration peripherally also carried by said tool head, an abrasive-carrying flexible band supported by said roller so that said band makes substantially point contact with the surface of the work-piece, power means for advancing said band around said support roller relative to said work-piece surface and means for oscillating said support roller so as to bring each edge portion as well as the medial portion of the band surface into engagement with the work-piece surface.

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