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Cowdrick

[11] **3,863,399**

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[54] APPARATUS FOR FINISHING A FOIL

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[52] **U.S. Cl.** **51/151**, 51/157
[51] **Int. Cl.** **B24b 69/00**
[58] **Field of Search** 51/149, 150, 151, 159, 51/156, 157

[56] **References Cited**

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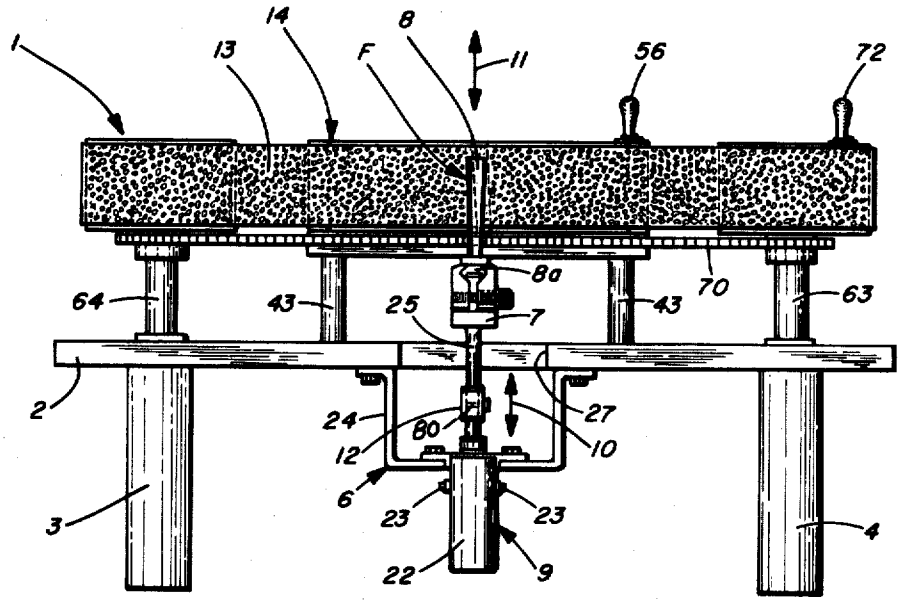
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Primary Examiner—Harold D. Whitehead
Attorney, Agent, or Firm—Teare, Teare & Sammon

[57] **ABSTRACT**

An apparatus and method for finishing the lengthwise extending edge of a foil including a finishing material mounting assembly for supporting a finishing material and a reciprocating jig assembly for holding the foil so as to position its one edge toward the finishing material and reciprocating the blade in its lengthwise direction simultaneously over one travel distance at one rate and a shorter travel distance at a more rapid rate. The finishing material mounting assembly includes a yieldable pressure means for urging the finishing material into tangential engagement with the edge of the blade. The jig assembly includes a rotatable jig head to enable the foil to rotate about its lengthwise axis, and the pressure means includes a relief means for imparting an oscillation rotating motion to the foil as it is reciprocated and to conform the finishing material to the contour of the foil edge, resulting in a rounded finished edge on the foil.

13 Claims, 6 Drawing Figures



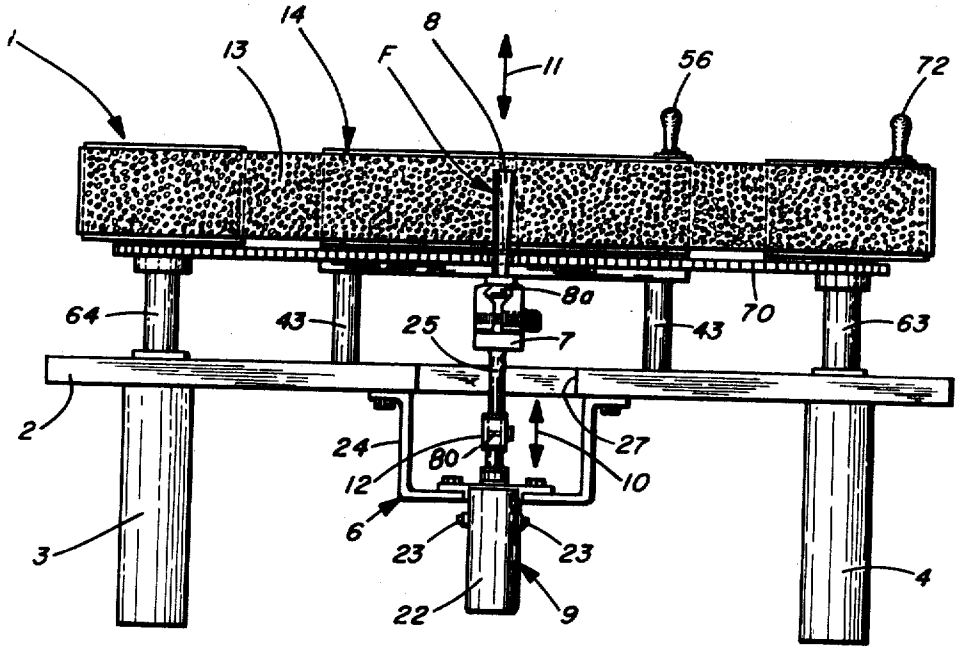

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FIG. 1

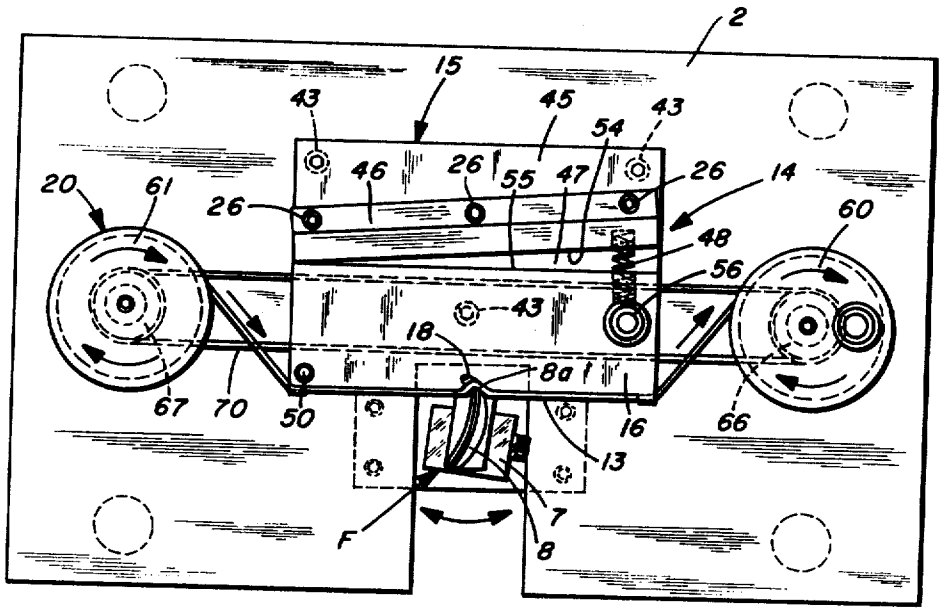

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FIG. 2

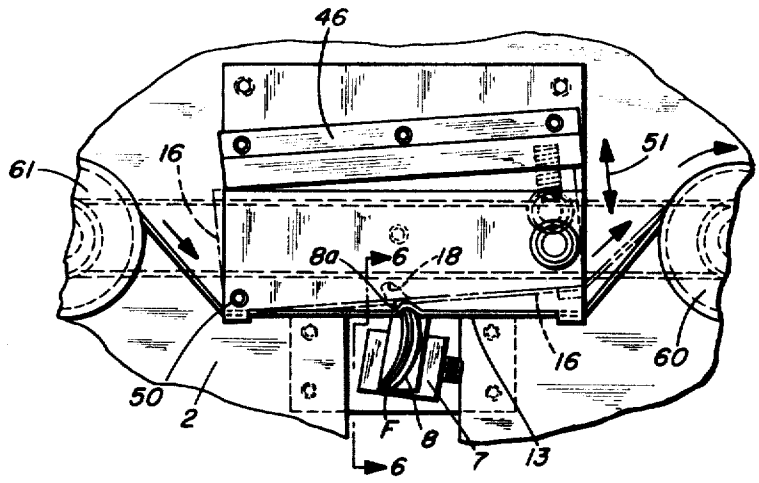

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FIG. 3

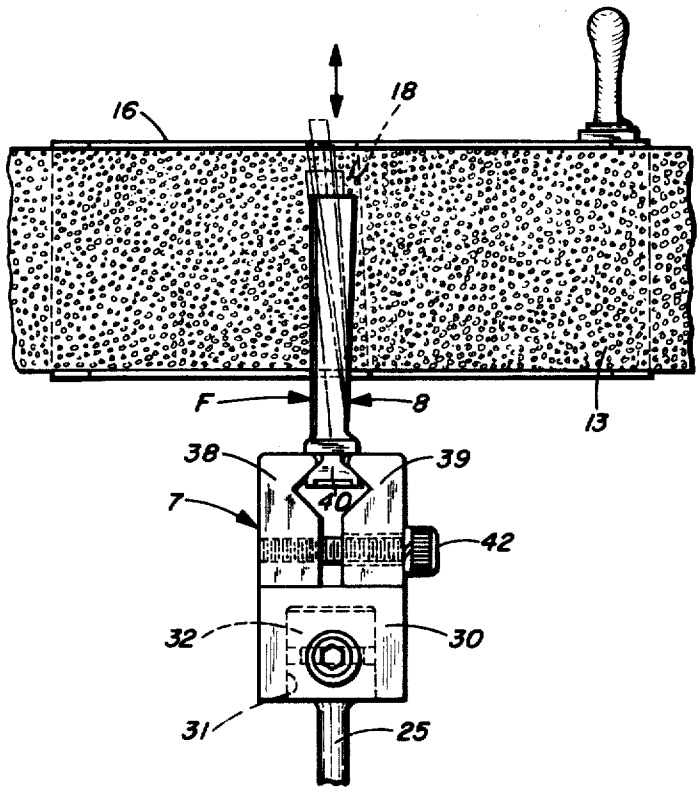

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FIG. 4

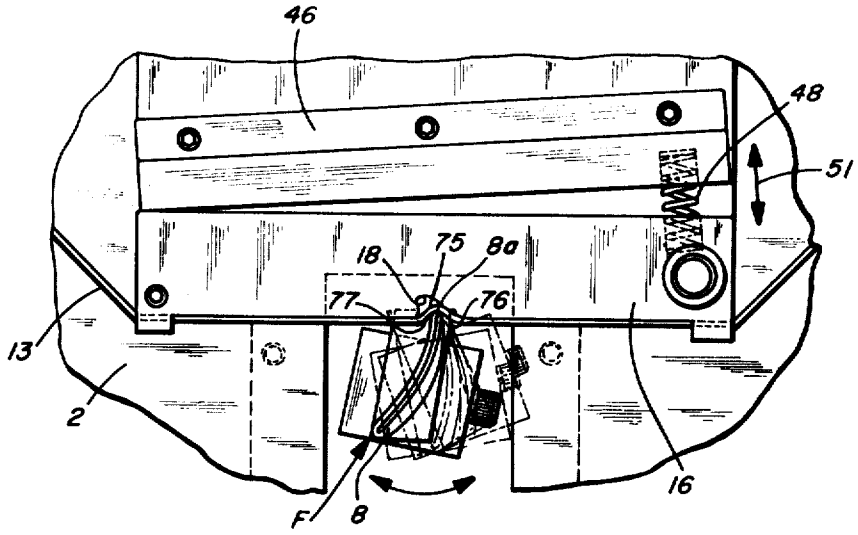

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FIG. 5

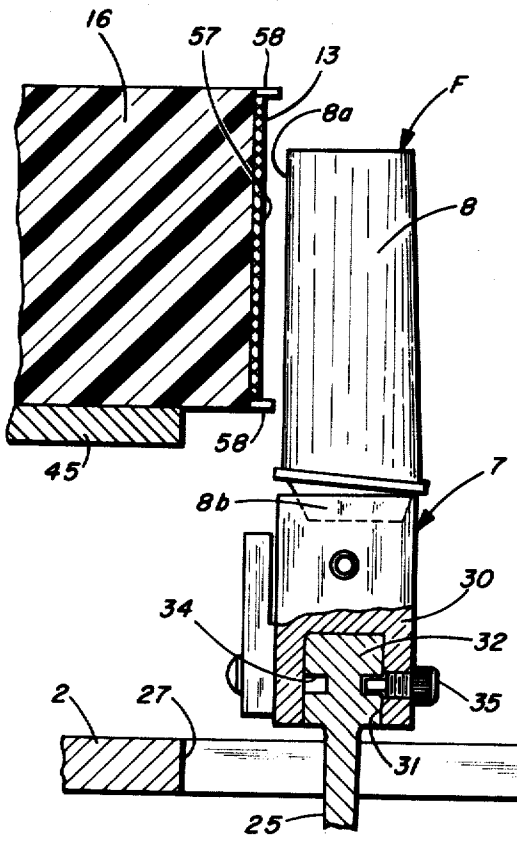

16
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8b
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FIG. 6

APPARATUS FOR FINISHING A FOIL

BACKGROUND OF THE INVENTION

The present invention relates to finishing of a foil, and more particularly, to an apparatus and method for finishing the rounded lengthwise edge of the foil blade.

There are numerous forms of foils to which this invention is applicable, which are provided in various sizes and shapes for use in different machinery, such as engines, compressors, turbines, or the like and which operate in confunction with different fluid mediums, such as water, steam, air or the like. In the manufacture of such foils, they are cast, forged, or otherwise preformed to a predetermined shape in accordance with NACA specifications. In this preformed state, the surface of the blades is rough and must be further finished to provide a precise, smooth exterior surface. More particularly, the blades are preformed so as to have rounded lengthwise extending edges. It is extremely important that, in the finished form, these lengthwise edges have an extremely smooth contour so as to be substantially free of any flat spots or corners. Still further, it has also been found desirable to provide an arrangement whereby numerous blades may be finished simultaneously and in a substantially automatic manner while maintaining the high precision that is necessary.

SUMMARY OF THE INVENTION

The present invention contemplates providing an improved apparatus for finishing the lengthwise extending edge of a foil blade. The apparatus includes a support structure on which is supported a finishing material mounting assembly for supporting a finishing material, such as a strip of abrasive material, and a reciprocating jig assembly for supporting a turbine blade in confronting relation to the finishing material, and reciprocating the blade in its lengthwise direction. The jig assembly includes a rotatable jig head for holding the blade edge toward the finishing material and enable the blade to rotate about its lengthwise axis. The jig assembly includes a main reciprocating mechanism for reciprocatingly moving the blade in its lengthwise direction transversely of the finishing material, and includes a supplementary vibrating means which imparts a rapid vibratory motion to the blade in its lengthwise direction simultaneously as it is moved by the main reciprocating mechanism 9. The finishing material mounting assembly includes a yieldable pressure means in the form of a pressure block which urges the finishing material into tangential engagement with the edge of the blade. A cam relief means is provided in the form of an elongated, relief cavity formed in the pressure block which enables the finishing material to conform to the contour of the blade edge defining an elongated pocket for receiving the blade edge therein. The cavity is contoured to yieldably support the finishing material in camming engagement with the blade edge to impart an oscillating rotational movement thereto when it is reciprocated. The finishing material mounting assembly further includes a material supply assembly in the form of a pair of reels between which the strip of finishing material extends, and which is adapted for moving the strip from one reel to the other in a direction transverse to the direction of reciprocating movement of the jig head. The pressure block is resiliently biased toward the blade and includes actuation means to enable the pressure block to be moved away from the engine blades to release the pressure on the strip so that the strip can be moved transversely to the lengthwise direction of the blade edge to expose an unused portion of the strip for completing the finishing of one blade or to commence the finishing of a new blade.

This arrangement provides for the efficient and precise finishing of the edge of a blade. In addition, there is provided a substantially automatic arrangement whereby the pressure of the finishing material on the blade and the contact area of the finishing material with the blade is controlled to produce a smoothly contoured edge. Further, this arrangement is highly applicable to mass production requirements so that one operation may finish numerous blades simultaneous in a highly efficient and precise manner.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front elevation view of the apparatus of the present invention;

FIG. 2 is a top plan view of the apparatus shown in FIG. 1;

FIG. 3 is a fragmentary portion of FIG. 2 indicating the movement of the pressure block 16 between the pressure applying position and the release position;

FIG. 4 is an enlarged, fragmentary front elevation view of a portion of FIG. 1 indicating the sequential reciprocating movement of a foil;

FIG. 5 is an enlarged, fragmentary top plan view of a portion of FIG. 2 indicating the sequential rotational movement of the foil; and

FIG. 6 is an enlarged, fragmentary, transverse sectional view taken along line 6—6 of FIG. 3 with the pressure block in the released position.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now again to FIG. 1, the apparatus of the present invention is shown, generally at 1, as including a support table 2 having legs 3 and 4. A jig assembly 6 is supported on the table 2 for supporting the blade 8 of a foil F so as to expose at least one lengthwise extending edge, as at 8*a* which may have a length in a range from ¾ to 24 inches. The jig assembly 6 includes a jig head 7 mounted for rotation in a generally horizontal plane and for clampingly engaging the foil base 8*b* to support the blade 8 in a generally vertically-oriented position for rotation about its lengthwise axis. The jig head 7 is mounted on a main reciprocating mechanism 9 being adapted to reciprocate the jig head 7 in a generally vertical direction, as indicated by the arrow heads at 11, to reciprocate the blade 8 in its lengthwise direction, as indicated by the arrow heads 10. The reciprocating mechanism 9 includes a supplementary vibrating mechanism 12 which is operably connected to the jig head 7 to impart a rapid vibrating motion to the jig head 7, and thus, vibrate the blade 8 in its lengthwise direction as it is being reciprocated by the main reciprocating mechanism 9.

Referring now also to FIG. 2, a finishing material mounting assembly 14 supports a strip 13 of finishing material for engagement with the edge 8*a* when the foil 8 is in the mounted position. The finishing material assembly 14 includes a pressure applicator assembly 15 having a resiliently-based pressure block 16 for urging the strip 13 against the edge 8*a*. The pressure block 16 is formed with a relief cavity 18 which is adapted for alignment with the edge 8*a* of the blade 8, such that

when the pressure block **16** is urged toward the blade **8**, the edge **8***a* will be disposed within the cavity **18** and deform the strip **13** to the contour of the edge **8***a* defining a yieldable pocket for receiving the blade **8**. In addition, the cavity **18** is disposed at a predetermined angular relationship with respect to the vertical direction and the lengthwise dimension of the blade **8** so that the strip **13** will yieldably cammingly engage the blade edge **8***a* to cause oscillating rotating movement of the blade **8** as the jig head **7** is reciprocated. By this arrangement, the strip **13** will be rubbed longitudinally across the entire edge **8***a* of the blade **8** while held in conforming engagement therewith.

Referring again to FIG. **1**, the reciprocating mechanism **9** comprises a fluid-actuated cylinder **22** of the reciprocating stroke type, as well known in the art, which is adapted for connection such as at **23**, to a suitable source of pressurized fluid. The cylinder **22** is secured to the underside of the table **2** by a bracket **24** and includes an upwardly extending piston rod **25** adapted for reciprocating movement in a generally vertical direction, as indicated by the arrow heads **10**. As shown, the table **2** includes an opening defined by a marginal edge **27** through which the rod **25** extends for supporting the jig head **7** above the table **2**. The cylinder **22** is preferably of the adjustable stroke type or well known in the art, being capable of adjustment for large strokes over distances in a range from ½ to 3 inches and at a rate of approximately 60 strokes per minute.

Referring now to FIGS. **4** and **6**, the jig head **7** includes a base **30** which is swivelly-connected to the upper end of the rod **25**. More particularly, the base **30** includes a downwardly opening circular bore **31** for slidably receiving the complementary-shaped upper end **32** of the rod **25**. The upper end of the rod **25** is provided with an annular recess **34** and a pin **35** is threaded through the adjacent wall which projects into the bore **31** so as to be disposed in sliding relation within the recess **34**. By this arrangement the base **30** is freely rotatable about the upper end of the rod **25** for a reason which will be more fully understood hereinafter. The jig head **7** further includes a pair of oppositely-disposed grip members **38** and **39** which are mounted on the base **30** for movement toward and away from one another, being adapted for clamping engagement with the base **8***b* at one end of the blade **8**. As shown, the grip members **38** and **39** are interconnected by an adjustable screw **42** for moving one grip member, such as **39**, toward the other grip member **38** for clampingly engaging the base **8***b*. In this regard, it should be pointed out that, when the foil F is mounted in the jig head **7**, the edge **8***a* to be finished should be disposed in a substantially vertical orientation, as shown in FIG. **6**, so as to extend generally parallel to the general plane of the strip **13**, as will be more fully understood hereinafter.

The pressure applicator assembly **15** includes a base **45** which is supported above the table **2** posts, such as at **43**. A bar **46** is rigidly mounted on the base **45**, being secured thereto by screw, such as at **26**. The pressure block **16** is mounted forwardly of the bar **46** and is pivotally connected to the base **45** by a pivot pin **50** to enable pivotal movement of the block **16** back and forth in a generally horizontal plane, as indicated by arrow-heads **51** in FIG. **3**. In this regard, the bar **46** has its forward surface **54** disposed in spaced relation from the rear surface **55** of the block **16** to provide a clearance space **47** therebetween to enable pivotal movement of the block **16** toward the bar **46**. In the form shown, the surface **54** extends in angular relation with respect to the surface **55** and provides an abutment for limiting rearward movement of the block **16**. A resilient member in the form of a helical spring **48** is supported between the bar **46** and the end of the block **16** remote from the pivot pin **50** for urging the block **16** forwardly toward the blade **8**. An actuating knob **56** is mounted on and projects upwardly from the block **16**, being adapted to be grasped by an operator for moving the block **16** against the pressure of the spring **48** to a rearward clearance position, such as indicated by the dotted lines at **16** in FIG. **3**, and which, upon release thereof, will enable the spring **48** to move the block **16** forwardly to the normal pressure applying position, as indicated by the solid lines at **16** in FIGS. **2** and **3**. The spring **48** may be of relatively light weight capable of applying a tension force of 2 to 4 psi on the finishing material.

Referring now to FIGS. **2** and **6**, the block **16** is of a generally oblong-shape having a substantially flat front surface **57** for supporting the strip **13** thereon. As shown, projections **58** extend outwardly from the front surface **57** and provide guide elements for guiding the strip **13** along the front surface **57** of the block **16** as will be described more fully hereinafter.

Referring now to FIGS. **1** and **2**, strip **13** is supported by a reel assembly **20** which includes a drive reel **60** and a driven reel **61** which are mounted for rotation on posts **63** and **64**, respectively, for supporting a strip **13** of finishing material, such as backed carborundum having a 240 grit size. As shown, each of the reels **60** and **61** include a sprocket **66** and **67** adjacent their underside for connecting each in driving relation to a flexible drive element, such as a chain **70**, or the like. An actuating knob **72** is mounted on and projects upwardly from the reel **60**, being offset with respect to the rotational axis thereof for cranking the drive reel **60**. By this arrangement, the reel **60** may initially have a strip of finishing material disposed thereon, and then the material may be threaded between the projections **58** of the block **16** and then around the reel **60**. By this arrangement, when the material becomes worn over the area contacting the blade **8**, the reel **60** is cranked so as to place an unused area of the strip over the cavity **18** for engagement with the blade **8**. Each time the material becomes worn, the reel **60** is indexed to place an unused portion of the strip for engagement with the blade **8** until the entire strip is used. In the indexing operation, the block **16** is moved rearwardly to its release position, as indicated by the dotted lines **16** in FIG. **3**, which enables the strip to be easily moved transversely of the blade. Subsequent release of the block **16** will again force the strip against the blade **8** in the manner previously described. Although the indexing mechanism is shown in only a manual mode, it is to be understood that automatic means could be provided to achieve this function. More particularly, such automatic means could be operably connected to the reciprocating mechanism **9** to index the strip after a predetermined number of strokes of the rod **25**.

Referring now particularly to FIGS. **4** and **5**, the cavity **18** is provided in the form of an elongated slot formed in the face **57** of the block **16**. As shown in FIG. **4**, the slot **18** extends in a slightly angular relationship with respect to the vertical direction, which will depend

upon the particular shape of the foil being finished, and being adapted to be aligned with the confronting edge **8***a* of the blade **8** so that the blade **8** can move up and down within the cavity **18** as it is reciprocated. As best shown in FIG. **5**, the cavity **18** is defined by an irregularly curved interior surface **75** being deeper toward one side than at the other. The cavity is defined on the shallow side by an interior wall portion **76** which is disposed at an acute angle with respect to the surface **57** and on the deep side by an interior wall portion **77** which is disposed at an obtuse angle with respect to the surface **57**. The strip **13** is tensioned so that it will be supported away from the interior wall of the cavity to enable it to yieldably conform to the curvature of the edge **8***a*. By this arrangement, the strip **13** will also cammingly engage the edge **8***a* to rotate the blade **8** as it is reciprocated. In addition, the strip **13** will cover the entire transverse width of the edge **8***a* being disposed tangentially to the curved back side of the blade **8** at the completion of the rotation in one direction, such as in a counterclockwise direction, and in subtantially parallel to adjacent portion of the front side of the blade **8** at the completion of rotation of the blade **8** in the opposite or clockwise direction as best shown in FIG. **5**. It is to be understood that the block **16** could be provided with more than one cavity **18**, and the jig assembly could be arranged for supporting more than one foil F for alignment with each cavity to enable finishing of more than one blade **8** at a time.

The supplementary vibrating mechanism **12** of the reciprocating mechanism **9** may be provided in the form of any well known vibrating mechanism for imparting a short vibrating or reciprocating axial movement to the rod **25** as is it reciprocated by the cylinder **22**. In the form shown, the rod **25** is of a split-construction, as at **80**, having its upper section and lower section connected by the vibratory mechanism **12**. The vibratory mechanism **12** may be of the type manufactured by the Shopmate Company, Model No. 4,000 which has a 3/16 inch travel and vibrates at a rate of 4,000 strokes per minute. In this arrangement, the upper rod sections are maintained in axial alignment with one another and separated a predetermined distance. The mechanism **12** includes interiorly mounted vibrating members which, when the mechanism is actuated, such as from a suitable power source, will cause the upper rod section to vibrate in an axial direction with respect to the lower rod section at the aforemention 4,000 strokes per minute and cause an axial movement therebetween of approximately 3/16 of an inch.

It is to be understood that the apparatus may be arranged so that any number of tapes of finishing material **13** may be stacked in superposed relation. In this regard, the jig assembly **6** would be arranged to have a corresponding number of jig heads **7** to support the same number of foils F for engagement with the finishing material **13** for finishing, as aforedescribed.

In regard to all of the above embodiments, a suitable control assembly as well known in the art may be provided for actuating and deactuating the apparatus. Such control assembly may be arranged for separately or simultaneously actuating the fluid cylinder **22** and the vibrating mechanism **12**.

The method of the present invention will be fully understood from the following descriptions of the operation of the apparatus **1** of the present invention. Initially, a reel **61**, having a strip **13** of unused finishing material wrapped thereon, is mounted on the post **64** and threaded past the block **16** onto the reel **60**. The block **16** is then moved to the released position against the pressure of the spring **48** as indicated by the dotted lines at **16** in FIG. **3**, and foil F is inserted in the jig head **7**. The foil F is rotated to position the blade **8***a* toward the block **16** in aligned relation to the cavity **18**. The block **16** is then released to position the edge **8***a* in the cavity **18** forcing the strip **13** to deform into the cavity **18** forming a yieldable pocket for the edge **8***a*. The blade edge **8***a* is initially positioned so that it engages the strip **13** in a generally perpendicular relation at the bottom of its stroke, as seen in FIGS. **5** and **6**, and the base **8***b* is sufficiently below the strips **13** so as not to engage the bottom edge of the strip **13** at the completion of the upward stroke. The reciprocating mechanism **9** is then actuated, causing the foil F to be reciprocated in a generally upward vertical direction, over a one travel distance at one rate by rod **25** of the fluid cylinder **22** and simultaneously reciprocated back and forth in the axial direction of the rod **25** over a considerably shorter travel distance at a considerably faster rate by the vibrating mechanism **12**. The edge **8***a* of the foil F will be cammed in a generally counterclockwise direction, following the angular direction of the cavity **18**. At the completion of the upward stroke, the strip **13** will be disposed in substantially tangential relationship with respect to the curved back side of the blade **8** due to the acute angular relationship of the adjacent interior wall portion **76**. Upon the reverse downward stroke of the piston rod **25**, the foil **8** will be rotated about its lengthwise axis in a clockwise direction, as seen in FIG. **5**, and at the completion of its downward movement, the strip **13** will be disposed in substantially parallel relation to the portion of the front side of the blade **8** adjacent the edge **8***a* due to the obtuse angular relationship of the adjacent interior wall portion **77** of the cavity **18** to the front surface **57**. This combined reciprocating and vibrating motion is continued until the edge **8***a* has been completely finished to the required tolerances. Should the strip **13** become too used to be effective, the operation may be temporarily terminated, and the block **16** moved to the release position. The driving reel **60** is then rotated so as to draw the strip **13** from the driven reel **61** past the cavity **18** to position an unused portion for engagement with the blade edge **8***a*. The finishing operation may then be completed, as required. On the other hand, should the finishing operation of each blade edge **8***a* be finished before the area of strip **13** being used becomes worn, then the indexing operation, as aforesaid, may be carried out each time a new foil F is positioned in the jig head **7** for finishing. In this manner finishing of the entire edge **8***a* from top to bottom and front to back is achieved in a highly precise and uniform manner.

As previously stated, the apparatus and method of the present invention can be utilized with many different sizes and shapes of foils, and therefore, the various rates and dimensions specified for the components of the apparatus will vary, depending upon the type of foil being finished. Accordingly, any dimensions or rates referred to herein are provided for purposes of clarity of explanation and are not intended to limit the scope of the invention.

I claim:

1. An apparatus for finishing the edge of a foil comprising,

a support structure,

a finishing material mounting means on said support structure having a finishing material mounted thereon,

a reciprocating jig means mounted on said support structure for holding said foil with said edge in exposed, confronting relation to said finishing material,

said jig means including a rotatable jig head to enable said foil to rotate about its lengthwise axis when in the mounted position, and

cam relief means yieldably supporting said finishing material in camming coacting engagement with said edge to impart an oscillatory rotating movement to said foil upon reciprocating movement of said jig means for providing a smooth finish for said edge of said foil.

2. An apparatus in accordance with claim **1**, wherein

said reciprocating means comprises a reciprocating mechanism for reciprocating said foil over one travel distance at one rate and a vibrating mechanism for simultaneously reciprocating said foil over a shorter travel distance at a more rapid rate.

3. An apparatus in accordance with claim **1**, wherein

said mounting means includes a yieldable applicator means for supporting said finishing material in engagement with said edge of said foil.

4. An apparatus in accordance with claim **1**, wherein

said finishing material comprises an elongated strip, and

said finishing material mounting means includes indexing means for supporting said strip for movement in a direction transverse to the direction of reciprocating movement of said jig head.

5. An apparatus in accordance with claim **1**, wherein

said jig means comprises a fluid-actuated cylinder and a reciprocating piston rod operably connected to said cylinder for reciprocating movement in the lengthwise direction of said foil when said foil is in the mounted position, and

said jig head is mounted at the end of said piston rod for reciprocating movement therewith for moving said foil in its lengthwise direction.

6. An apparatus in accordance with claim **5**, including

a vibrating mechanism,

said piston rod is of a split-construction having a lower section operably connected to said cylinder and an upper section connected to said jig head, and said vibrating mechanism interconnects said rod sections for reciprocating movement relative to each other in their axial direction for vibrating said foil over one travel distance as it is reciprocated by said cylinder over a greater travel distance.

7. An apparatus in accordance with claim **5**, wherein said jig head is rotatably mounted on said piston rod, and said rotatable mounting comprises a swivel connection.

8. An apparatus in accordance with claim **3**, wherein

said applicator means includes a base and a movable pressure member pivotally mounted on said base for supporting said finishing material for engagement with said foil, and

resilient means coacting between said base and said pressure member for urging said finishing material into pressured engagement with said foil.

9. An apparatus in accordance with claim **8**, wherein

said cam relief means comprises a cam slot in said pressure member to enable said finishing material to be deformed therein defining a yieldable pocket for receiving the edge of said foil and to enable said finishing material to conform to said edge as said foil is reciprocated.

10. An apparatus in accordance with claim **9**, wherein

said cam slot extends in angular relation to the direction of said reciprocating movement of said foil for supporting said finishing material for camming coacting engagement with said foil as it is reciprocated for rotating said foil in one direction as it is moved in one lengthwise direction and for rotating said foil in the opposite direction as it is moved in the opposite lengthwise direction.

11. An apparatus in accordance with claim **4**, wherein

said indexing means comprises reel means mounted on said support member, and

said reel means comprises a set of reels rotatably mounted on said support member to enable said strip to be moved transversely to the direction of reciprocating movement of said foil to position an unused portion of said strip in confronting relation with said foil.

12. An apparatus in accordance with claim **4**, wherein

said finishing material mounting means including a pressure member pivotally supported on said support structure for supporting said finishing material for engagement with said foil, and

actuation means operably connected to said pressure member, pivoting said pressure member away from said finishing material for relieving the pressure on said finishing material to enable said finishing material to be moved relative to the direction of movement of said jig head.

13. An apparatus in accordance with claim **4**, wherein

said finishing material comprises at least two strips supported in superposed relation, and

said jig assembly includes at least two jig heads for supporting a corresponding number of foils in engagement with a respective one of said strips.

* * * * *