United States Patent

Palmenberg

[15] **3,685,219**

[45] **Aug. 22, 1972**

[54] **CONTOUR-ABRASION MEANS AND METHOD**

[72] Inventor: **Edward C. Palmenberg,** Nanuet, N.Y.

[73] Assignee: **Chromalloy American Corporation,** Orangeburg, N.Y.

[22] Filed: **Dec. 4, 1970**

[21] Appl. No.: **95,067**

[52] **U.S. Cl.** **51/328,** 51/141, 51/143

[51] **Int. Cl.**.....**B24b 1/00,** B24b 21/10, B24b 21/16

[58] **Field of Search**.....51/135 R, 141, 143, 148, 217 R, 51/217 S, 328, 216 R, 216 A

[56] **References Cited**

UNITED STATES PATENTS

3,170,272	2/1965	Burnham	51/141
1,434,334	10/1922	Freeman	51/141
2,699,019	1/1955	Dackor	51/141 X
2,453,972	11/1948	Clave	51/141 UX
2,755,604	7/1956	Jameson	51/141

FOREIGN PATENTS OR APPLICATIONS

494,890	6/1954	Italy	51/141

Primary Examiner—Donald G. Kelly

Attorney—Sandoe, Hopgood & Calimafde

[57] **ABSTRACT**

The invention comprises abrading a work surface to desired contour by using a continuously driven endless abrasive belt in the region of passage over a thin air-film or cushion by which the belt is locally supported and shaped at a suitably contoured platen. The platen is air-permeable and is supplied with a continuous flow of pressurized air from within, being directed at the inner surface of the belt, and over the entire region of belt support by the platen. The platen is contoured for the particular finished work contour to be achieved. Various features of work-support and work-feeding are described.

21 Claims, 6 Drawing Figures

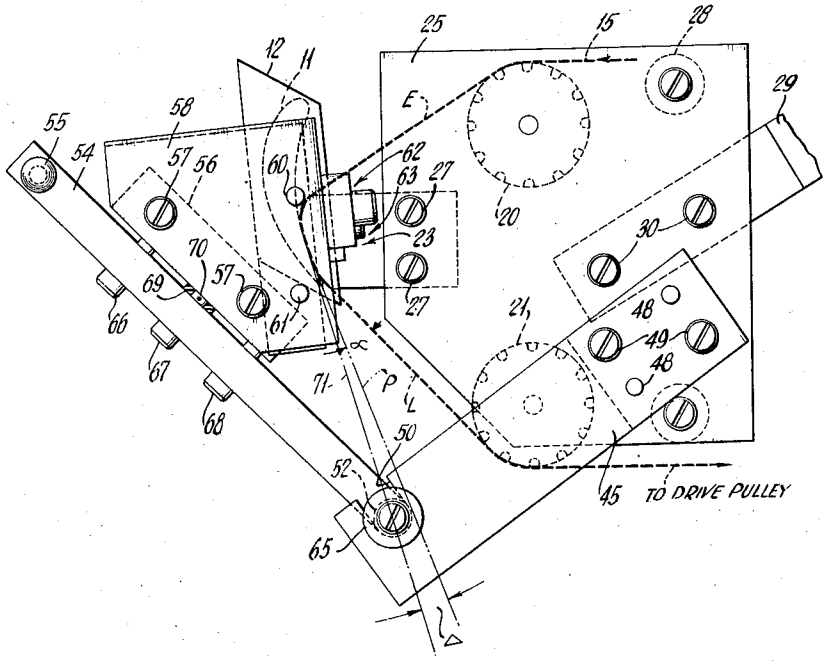


Fig. 1.

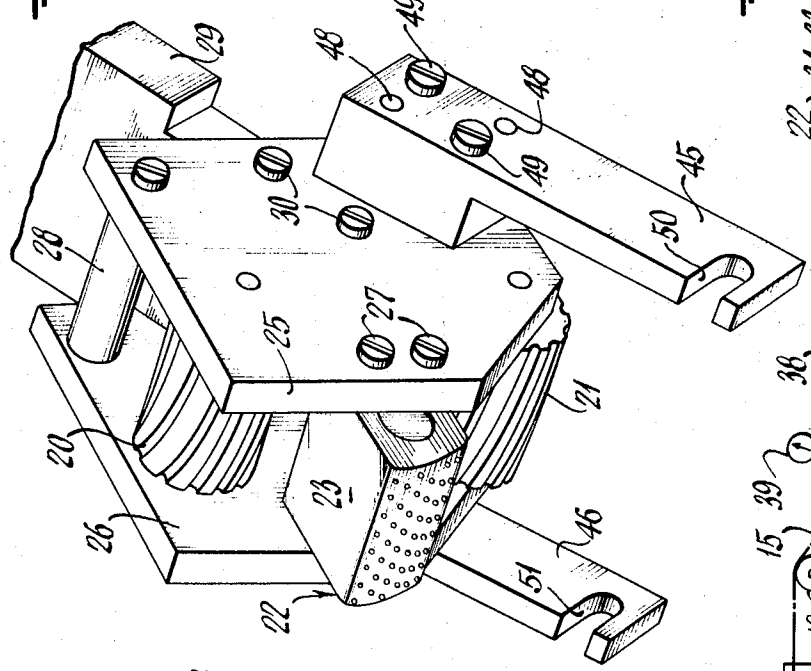


Fig. 2.

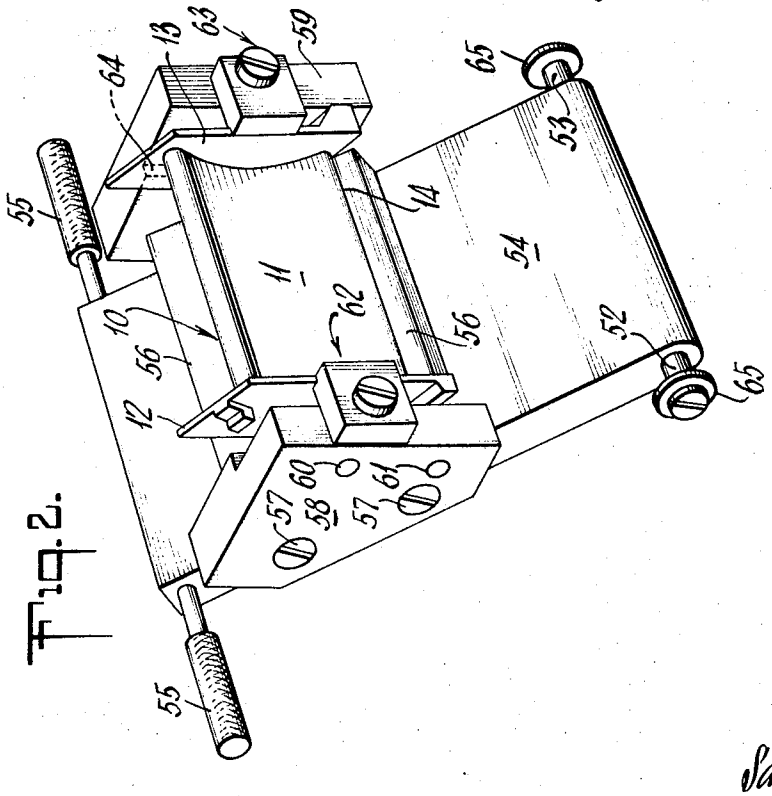


Fig. 5.

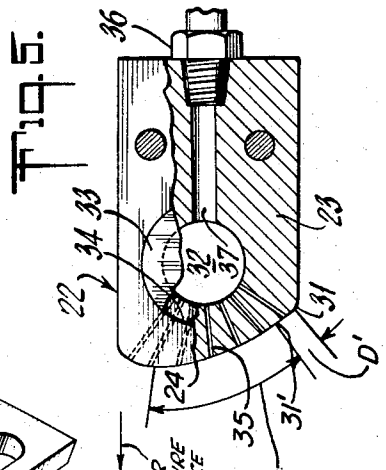
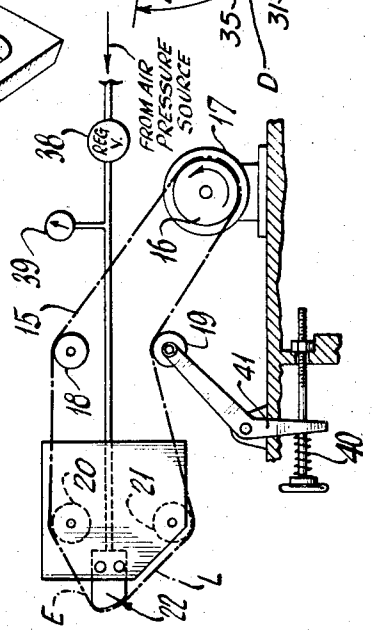


Fig. 6.



INVENTOR
EDWARD C. PALMENBERG
BY
Sandoe, Hopgood & Calimafde
ATTORNEYS

Fig. 3.

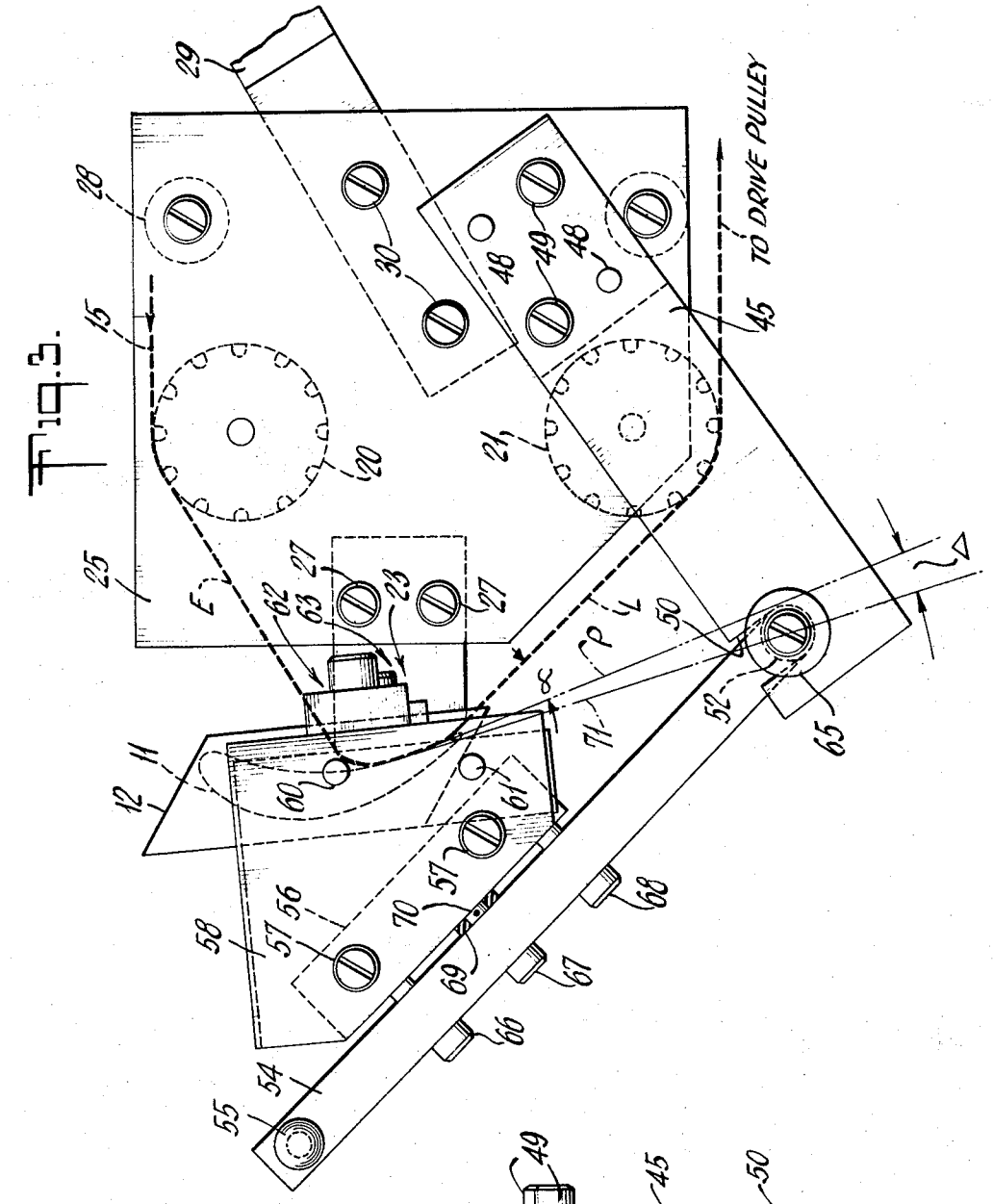
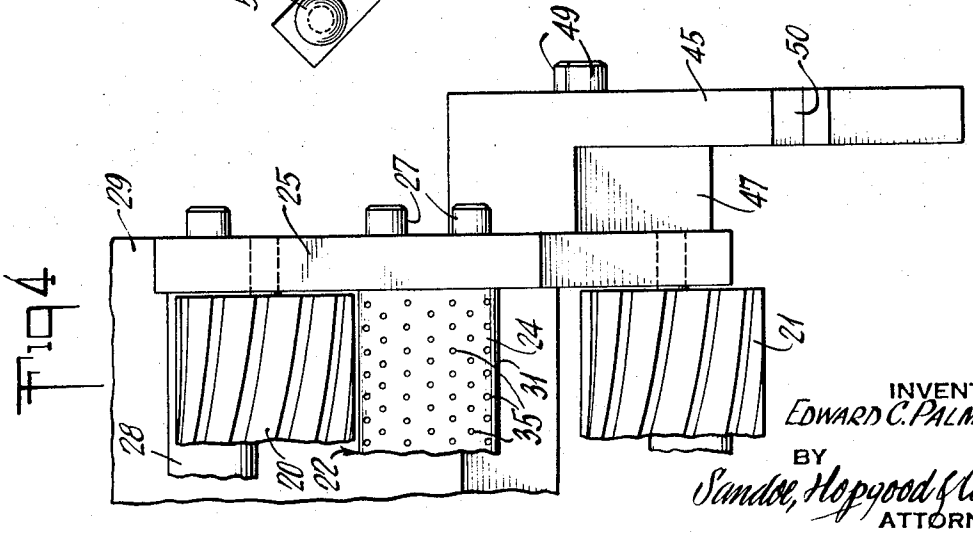


Fig. 4



INVENTOR
EDWARD C. PALMENBERG
BY
Sandoe, Hopgood & Calimafde
ATTORNEYS

CONTOUR-ABRASION MEANS AND METHOD

This invention relates to contour abrasion and in particular to the finishing of concave work surfaces, such as the concave surfaces of jet-engine turbine blades, in the region of and in substantial approach to the trailing-edge gage line.

The finishing of turbine vanes, particularly such vanes as are used in multiple to define a particular stage of a jet engine, is extremely critical, especially in the so-called gage-line regions which are determinative of the "class" of each particular vane. Correct "class" of all vanes in a particular stage is just as important for reconditioned vanes as it is for the original product, but the amounts to be abraded in reconditioned vanes can vary tremendously, depending upon the nature of the inlay, fillet, bead or other technique by which new metal replaces old metal in the blade-reconditioning process. The vane-reconditioning industry has been confronted with major problems in achieving correct blade contour on the concave surface, in the region of approach to the desired trailing-edge gage line. These problems have caused needless expense and time to achieve the desired contour, to a reasonably correct approach to intended vane "class". These problems have been aggravated by the unavailability of an adequate contour-abrasion method and machine.

It is, accordingly, an object of the invention to provide an improved method and machine for precision abrasion of surfaces to desired contour.

Another object is to meet the above object with an abrasion tool which can safely and accurately remove metal at hitherto-unprecedented rates.

A further object is to inherently avoid undue heat generation in achieving the above objects.

A specific object, in the case of turbine-vane finishing, is to provide a method and means whereby the convex blade surface in approach to the trailing-edge gage line region can be accurately contoured.

Another specific object is to meet the foregoing specific object with a tool in which simple adjustment enables vanes of a given initial "class" to be simply abraded to the contour applicable to a different "class," thereby enabling a reconditioned vane to serve a different "class" stage in a jet engine.

A general object is to meet the above objects with apparatus that is efficiently usable by relatively unskilled personnel, to produce superior products, including products which are superior in that blade-contour fidelity and particular vane "class" are achieved in spite of the fact that the new metal of the reconditioning is tougher and more durable than that of the originally manufactured vane.

Other objects and various further features of novelty and invention will be pointed out or will occur to those skilled in the art from a reading of the following specification in conjunction with the accompanying drawings. In said drawings which show, for illustrative purposes only, a preferred form of the invention:

FIG. 1 is a view in perspective of belt-supporting means, in the region of the work station of a machine of the invention;

FIG. 2 is a perspective view of work-holding means for use at the station of FIG. 1;

FIG. 3 is a side elevation of the means of FIGS. 1 and 2, in assembled relation;

FIG. 4 is a fragmentary front elevation of the means of FIG. 1;

FIG. 5 is a side elevation of the platen at the work station of FIG. 1; and

FIG. 6 is a simplified diagram of drive and other connections to the work station of FIG. 1.

Briefly stated, the invention contemplates continuous drive of an endless abrasive belt over a defined path of movement which includes a work station at which the belt is supported by a thin air cushion, in close conformance with the contour of a platen wall or surface. The wall is air-permeable and provides the means of supplying and distributing pressurized air to generate the cushion.

Referring to the drawings, the invention is shown in application to the contour abrasion of the critical trailing-edge region of a jet-engine turbine vane **10**, comprising a blade or airfoil portion **11**, rigidly united to end buttresses **12–13**, by which it is assembled in multiple in the building of a turbine stage. The blade region to be abraded in my machine is that substantial area of the concave surface which is visible in FIG. 2, extending the full span of the blade and running, from a point just aft of the mid-chord location, to the trailing edge **14** and with substantially perfect fidelity of the trailing-edge gage line for the particular "class" to which the vane **10** is to be finished.

The means for contour-abrading the indicated critical region of blade **11** is best seen at the work station depicted in FIGS. **1**, **3** and **4**. This work station is part of the supporting system for driving and guiding an endless abrasive belt **15**, deriving continuous motion from the pulley output **16** of an electric motor **17**, and supported and guided by various idler and tension pulleys **18–19** (FIG. **6**). Two idler pulleys **20–21** are shown at the work station, where specially configurated platen means **22** of the invention serves to complete the definition of the path of movement of belt **15**. Platen means **22** comprises a generally prismatic body **23** having an air-permeable outer wall **24** over which the belt **15** runs on a cushion of air. A major portion of the wall **24** is exactly contoured to mate with the desired ultimate abraded contour of the blade **11**; as shown in FIG. **5**, this major portion is identified over the distance D, and the remaining external contour of wall **24** is smoothly continuous with that over the distance D, to allow for smooth and continuous belt flexing, without degrading the definition of the desired contour. Thus, a more steeply rounded curve at the upper end of wall **24** smoothly accommodates belt **15** as it enters the platen region, from the upper pulley **20**; and a short lower extension D′ of wall **24** (beyond the distance D) smoothly carries the belt beyond the trailing edge **14** of the work piece, to the free stretch which extends to the lower pulley **21**.

The work-station pulleys **20–21** and platen means **22** may be of substantially the width of belt **15**, which also preferably matches the span (between buttresses **13–13**) of the blade **11**; actually means **22** is slightly longer than the pulleys, to perform a spacer function, between spaced upstanding frame members **25–26** of the work station. Pulleys **20–21** may be journaled for idle rotation between these frame members, and the platen body **23** may be removably fixed, as by bolts **27**, to these frame members. Further spacer means **28**,

bolted between frame members **25–26**, assures integrity of the work-station frame, and the rugged arm **29** (bolted at **30** to members **25–26**) suggests the bracket by which the work station is referenced to a bench or other part of the machine frame.

As best seen in FIGS. **3** and **6**, the belt stretches E and L which respectively enter and leave the platen region (from pulley **20**, and to pulley **21**) represent substantially different directions in the path of belt motion; as shown, the change of direction through the region of platen support is substantially **90** degrees, and the working or abrading region D of the platen wall **24** embraces a limited region of changing belt direction, located generally mid-way between the directional limits represented by stretches E and L. Preferably, the relieving angular offset α by which the stretch L leaves the lower edge **31'** of wall-backed contact with the work is in the order of 10 to 20 degrees, as shown (see FIG. **3**): this angle α is measured as an offset from the trailing-edge tangent plane P, i.e., the plane which is substantially tangent to the concave airfoil surface of the blade **11**, at the trailing edge **14**.

FIG. **5** provides a simple showing of the basic construction of the platen means **22**. The block or body **23** is basically rectangularly prismatic, except for the end-wall curvature at **24**, already described. The body **23** carries fluid-communicating means to supply the air-permeable end wall **24** with continuous inward-to-outward flow that may be substantially uniform over the entire surface area of wall **24**. As shown, a large transverse bore **32** runs through body **23** but is closed by plugs or caps (**33**), which may be welded at locating counterbores (**34**). Plural spaced small holes **35** are drilled inward from various points distributed over the surface **24**; and the bore **32** serves as a manifold, supplied via an inlet fitting **36** and passage **37**, for distribution of pressurized air through the platen wall **24**.

To place the abrasive belt in motion, pressurized air is first applied to the platen at **36**, as from a selectively controlled regulating valve **38**, monitored at an indicator **39**. The motor **17** is then started, to drive belt **15** counterclockwise, in the sense of FIG. **6**. The tension idler **19** is adjusted, as necessary, by manually setting the load of a spring **40** on the other arm of bellcrank means **41** which carries idler **19**. Generally, I have found that common industrial-grade abrasive belt material, e.g., fabric-backed and with an aluminum-oxide abrasive surface, performs very satisfactorily, when driven at a speed in the order of 6,000 feet per minute and supported by sufficient air pressure and flow through wall **24** to maintain a uniform air cushion that is 1 to 5 mils thick, between wall **24** and belt **15**. The combined area of holes or perforations **35** may be in the order of 5 to 15 percent (and, preferably, about 10 percent) of the total external surface area of wall **24**, to achieve this result, with fairly tight belt-tensioning at **40**.

A further feature of the invention resides in novel work-holding means and in the manner of selectively supporting and guiding the same in the course of making an abrasive cut. Specifically, the work station further includes side arms or brackets **45–46** having rugged offsets or bases (**47**) by which they are secured to the respective side members **25–26**. As shown, two diagonally positioned dowel pins **48** and two diagonally positioned bolts **49** provide unambiguous location of the downwardly projecting orientation of arms **45–46**, each provided with upwardly open aligned slots **50–51** for accurate location of the corresponding projecting ends **52–53** of a pivot shaft forming part of the work-holding means.

In FIG. **2**, the work-holding means is seen as having a flat rugged body or base plate **54** which carries the pivot means **52–53** at its lower end, and manual grasping means **55** similarly mounted at its upper end. The base plate **54** includes means for centrally supporting a clamp jig for the work piece **10**. As shown, the latter comprises a heavy plate **56** secured by bolts **57** to spaced side members **58–59**. A hardened pin insert **60** in side member **58** projects inwardly to provide an axially positioning stop or reference for the central region of the adjacent buttress **12**, and similar provision of a spring-loaded pin (not shown) at side member **59** provides opposed stabilizing loading of vane **10** via the other buttress **13**, and against the reference at the inner end of pin **60**. Appropriately located further pin means, as at **61** (in plate **58**), provide vertical location, and bolted clamp lugs **62–63** engage the outer exposed buttress edges, to firmly clamp each buttress against a seat or shoulder (as at **64**) in the adjacent side member or plate **58–59**. Of course, such shoulders (**64**), pins (**60–61**) and clamps **62–63** are cut and positioned appropriate to the particular vane design to be finished, the proportions and arrangement being such that correct posture is assured for the trailing-edge region to be abraded, when pivotally manipulated with shaft means **52–53** located in slots **50–51**. Preferably, the width of base plate **54** is slightly less than the spacing between arms **45–46**, and reliance is placed on locating flanges or washers **65** (bolted to the outer end of each shaft projection **52–53**) to laterally stabilize the work-holding means at the work station.

In accordance with a feature of the invention, the bolt means **66–67–68** by which the work-holding jig plate **56** is held to base plate **54** incorporates provision for small angular adjustment about a transverse axis. This is shown to be achieved about one or more spacer washers **69** on the transverse-axis alignment established by the central bolt means **67**, the axis being designated by a heavy dot **70** in FIG. **3**. By taking up the bolt means **66** and backing off the bolt means **68**, the plate **56** (and, with it, the work **10**) is tilted further back; and by backing off the bolt means **66** and taking up the bolt means **68**, the work **10** is positioned forward. The net result of such adjustments, after all bolt means **66–67–68** have been firmly set, is to establish the correct "class"-determining orientation for abrading the work to the correct trailing-edge gage-line profile, as will be understood.

A further feature of the invention resides in the particular relation between the tangent plane P and the work-support pivotal axis (**52–53**). Preferably, this relation is one of slight offset Δ from coincidence with the pivotal axis (**52–53**); the direction of the offset is toward the pulley **21**, and the magnitude of the offset depends upon the gravity vector operative on the work-holding means, for its belt-contacting orientation. As shown, the belt-contacting orientation of plate **54** is about **45** degrees back from the vertical, the tangent plane P is about 23 degrees back from the vertical, and

the pivot means **52–53** establishes an alignment **71** (between the pivot axis and the trailing edge) that is about 20 degrees back from the vertical. Under these conditions, I find a gentle self-energizing action to characterize the abrasive contact of the work with the belt. The primary vector of this action is generally along the tangent plane P and is therefore in the direction to produce significant torque that is clockwise about the pivot axis **52–53**. This torque in part offsets the normal static counterclockwise gravity moment of the work-holding means about the same axis, so that manual feeding forces, applied at **55**, can be applied with sensitivity and with relatively great precision and ease of control.

In use, the described abrasive tool and method are found to meet all the stated objects. The cut proceeds rapidly and accurately, to precisely the desired contour. This is no doubt largely attributable to the inherently cool nature of the operation, since the windage of abrasive-belt motion rapidly conducts all hot metal fragments and particles away from the abrasive zone. The cushion of air beneath the belt assures uniform distribution or abrasive-loading, normal to the abraded surface, and the most asymmetrical and bulbous inlays, fillets, beads and the like (of even the hardest repair and reconditioning materials) are quickly abraded to contour continuity at the design profile and at the correct "class-defining" incidence. Abrading to a different "class" is quickly adjusted by resetting the bolt means **66–68** for a slightly different tilt about axis **70**; in fact, I have found important utility for the machine in converting vanes of one "class" to similar vanes of the adjacent "class," merely by regrinding the vanes after making appropriate adjustment of this nature.

While the invention has been described in detail for the preferred forms shown, it will be understood that modifications may be made without departing from the scope of the invention.

I claim:

1. A contour-abrading machine, comprising means for supporting an endless abrasive belt along a path of movement and for continuously driving the same along said path, said means including a stationary working platen having an external air-permeable convex wall contiguous to a part of said path and over which said belt is run in conformance with the external surface of said wall, pressure-fluid communicating means within said platen and communicating with the inner surface of said wall, whereby said belt is spaced from said wall by pressure fluid delivered through said wall, and pivotally mounted work-holding means for positioning work against said belt in the region of wall and fluid support thereof, the pivot axis being offset from a plane tangent to the belt as it leaves abrading contact with the work, and such offset being in the direction to develop a self-energizing work-feeding force component by reason of abrasive belt contact with the work.

2. A machine according to claim **1**, in which said supporting means includes a pulley near to but spaced from the trailing edge of said wall, the belt course between said trailing edge and said pulley being sloped away from substantially the tangent to said wall at said trailing edge.

3. A machine according to claim **1**, in which said platen has an interior bore forming part of said fluid-communicating means, and in which said wall is perforated with passages to said bore, the total perforation area at the external surface of said wall being in the order of 10 percent of the overall external surface area.

4. A contour-abrading machine, comprising means for supporting an endless abrasive belt along a path of movement and for continuously driving the same along said path, said means including a stationary working platen having an external air-permeable convex wall contiguous to a part of said path and over which said belt is run in conformance with the external surface of said wall, and pressure-fluid communicating means within said platen and communicating with the inner surface of said wall, said supporting means including a frame to which said platen is fixedly mounted, an idler pulley supported by said frame beyond the trailing edge of said wall to define the course of said belt as it leaves said platen, work-holding means having a pivotal reference connection to said frame on a fixed axis substantially parallel to the pulley axis and offset from the tangent plane of said belt at said trailing edge, the offset being in the direction such that, in the course of abrading a concave surface of work carried by said work-holding means, through belt contact in the region of said trailing edge, the pivotal approach of the work to said belt includes a self-energizing work-feeding force component.

5. A machine according to claim **4**, in which the work surface to be abraded has a trailing edge and in which said work-holding means includes means positioning the work such that the trailing edge contacts said belt at a location preceding belt passage over the trailing edge of said platen wall.

6. A machine according to claim **4**, in which said supporting means includes a frame to which said platen is fixedly mounted, said work-holding means including a body and a work clamp, and means including a selectively adjustable pivotal connection between said body and said work clamp about an axis substantially parallel to the transverse dimension of said belt, whereby the angle of incidence of the abraded convex surface of the work may be selectively varied.

7. A contour-abrading machine, comprising a frame, an endless abrasive belt, means including spaced drive and idler pulleys for supporting and continuously driving said belt along a given path of movement, said support means including a frame-mounted working platen having an external convex wall contiguous to a part of said path and over which said belt is run in conformance with the external surface of said wall, fluid-pressure operated means directed for discharge at the concave surface of said belt as it passes over the external surface of said wall, whereby said pressure fluid relieves belt contact in the region of said platen, and pivotally mounted work-holding means for positioning work against said belt in the region of pressure-fluid support thereof, the pivot axis being offset from a plane tangent to the belt as it leaves abrading contact with the work, and such offset being in the direction to develop a self-energizing work-feeding force component by reason of abrasive belt contact with the work.

8. A machine according to claim **7**, in which one of said pulleys is part of belt-tensioning means.

9. A machine according to claim 7, in which said convex wall is perforated and in which said fluid-pressure operated means directs pressure fluid through said wall.

10. A machine according to claim 9, in which said fluid-pressure operated means includes means for selectively varying the fluid delivery pressure at said wall.

11. The method of abrading a work surface to a desired contour, which comprises selecting an endless abrasive belt, supporting and continuously driving the belt along a predetermined path of movement which includes a work station, selecting and mounting at said work station an air-permeable platen member having a working surface characterized by the inverse of the desired contour, supplying air under pressure to the region between the belt and the working surface via the air-permeable platen member, and feeding the work surface to the belt in the region of air-pressure support thereof, said feeding being effected by supporting the work to pivot about an axis which is offset from a plane tangent to the belt at its trailing contact with the work, such offset being in the direction to develop a self-energizing force component by reason of abrasive belt contact with the work.

12. The method of claim 11, in which the desired work contour is concave and in which the working platen surface is convex.

13. The method of claim 12, in which the air pressure is controlled to position the driven belt at a spacing in the order of 1 to 5 mils from the platen working surface.

14. The method of claim 12, in which the belt drive along said path is at a speed in the order of 6,000 feet per minute.

15. An abrasive machine for finishing the trailing-edge contour of a jet-engine vane having a given span between opposed buttresses, comprising rigid work-supporting means including a frame and spaced clamps for simultaneously clamping both buttresses in an orientation to expose the concave blade surface in a generally horizontal direction and with the trailing edge projecting downward, an endless abrasive belt and fixedly oriented means for supporting and continuously driving the same, said support means including a convex contoured air-permeable surface projecting generally horizontally, means forcing air through said surface to define an air cushion between said belt and said surface, the belt-drive direction being downward over said surface, and a fixed horizontal pivot support for said work-supporting frame, said pivot support being located below said air-permeable surface sufficient to position work in said supporting means in face-to-face relation with said belt as it traverses said air-permeable surface, and said pivot support being offset from the center of gravity of said work-supporting means to the extent that due to gravity action said work-supporting means tends to rotate in a first direction about said pivot support, said frame and clamps so orienting the work that the tangent plane which includes the trailing edge of the work piece is offset from the axis of said pivot support whereby a torque reaction to abrasion is developed substantially in said tangent plane, the direction of said last-mentioned offset being such as to place said reaction torque in offsetting relation with the torque due to gravity action on said work-supporting means about said pivot axis.

16. The machine of claim 15, wherein the pivot support is so located with respect to the region of contact that the center of gravity of said work-supporting means, when in working position, is operative about the pivot axis to develop a gravity torque urging said work-supporting means in the direction away from abrasive contact.

17. The machine of claim 15, wherein said tangent plane is so offset from said pivot axis that said torque reaction to abrasion is in the direction of self-energized work engagement with said belt.

18. An abrasive machine for finishing the trailing-edge contour of a jet-engine vane having a given span between opposed buttresses, comprising rigid work-supporting means including a frame and spaced clamps for simultaneously clamping both buttresses in an orientation to expose the concave blade surface in a generally horizontal direction and with the trailing edge projecting downward, an endless abrasive belt and fixedly oriented means for supporting and continuously driving the same, said support means including a convex contoured air-permeable surface projecting generally horizontally, means forcing air through said surface to define an air cushion between said belt and said surface, the belt-drive direction being downward over said surface, and a fixed horizontal pivot support for said work-supporting frame, said pivot support being offset from said air-permeable surface sufficient to position work in said supporting means in face-to-face relation with said belt as it traverses said air-permeable surface, said frame and clamps so orienting the work that the tangent plane which includes the trailing edge of the work piece is offset from the axis of said pivot support whereby a torque reaction to abrasion is developed substantially in said tangent plane and about the pivot axis, the direction of said last-mentioned offset being such as to develop said reaction torque in the direction of self-energized work engagement with said belt.

19. The machine of claim 4, in which the course of belt movement over said convex wall is generally downward, in which said pivotal connection is below the elevation of work contact, and in which said offset is in the direction away from the pulley axis.

20. The machine of claim 4, in which the center of gravity of said work-holding means is offset from the axis of the pivotal connection, the latter offset being in the direction such that gravity produces a natural moment about said connection, said moment being in the direction opposite to that produced by said self-energizing force component.

21. An abrasive machine for finishing the trailing-edge contour of a jet-engine vane having a given span between opposed buttresses, comprising rigid work-supporting means including a frame and spaced clamps for simultaneously clamping both buttresses in an orientation to expose the concave blade surface in a generally horizontal direction and with the trailing edge projecting downward, an endless abrasive belt and fixedly oriented means for supporting and continuously driving the same, said support means including a convex contoured air-permeable surface projecting

generally horizontally, means forcing air through said surface to define an air cushion between said belt and said surface, the belt-drive direction being downward over said surface, and a fixed horizontal pivot support for said work-supporting frame, said pivot support being located below said air-permeable surface sufficient to position work in said supporting means in face-to-face relation with said belt as it traverses said air-permeable surface, and said pivot support being offset from the center of gravity of said work-supporting means to the extent that due to gravity action said work-supporting means tends to rotate in the direction about said pivot support and away from work engagement with said belt.

* * * * *