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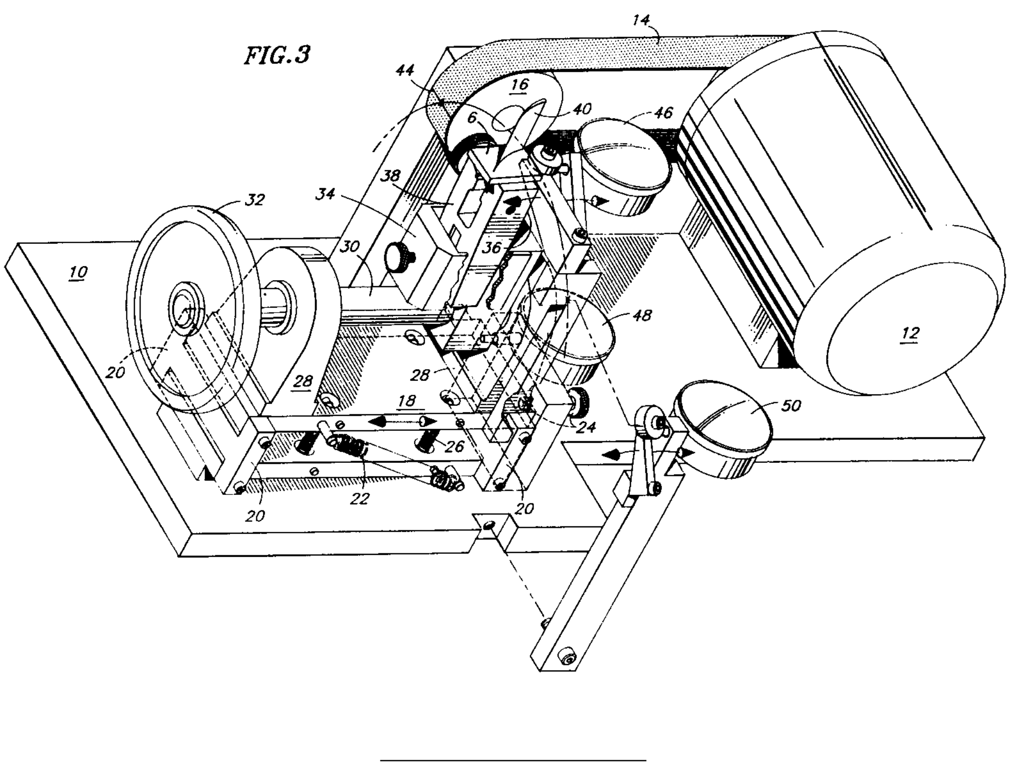
(54) Gas turbine engine blade platform trimmer.

(57) An apparatus for precision machining of metal articles to precise dimension as described. A moving cylindrical surface causes metal removal. The surface to be machined moves in an arc which lies in a plane tangent to the moving cylindrical surface.

FIG.3



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Technical Field

This invention relates to the abrasive machining of metal articles and more specifically to the precision abrasive machining required on gas turbine engine blade platforms during the final assembly process.

Background Of The Invention

The present invention relates to the machining of gas turbine engine blade platforms. As is well known, gas turbine engines are widely used for aircraft propulsion and power generation. Gas turbine engines include a compressor section, a combustor section, and a turbine section. The compressor section of the engine compresses air to conditions of moderate temperature and pressure. Compressed air is mixed with fuel and burned in the combustor system and the products of combustion (hot high pressure gases) are expanded through the turbine section which extracts energy. A portion of the extracted energy is used to drive the compressor section.

The present invention is pertinent to certain compressor designs. The typical compressor in a large gas turbine engine is an axial flow compressor. Such a compressor includes multiple stages, each of which comprises a rotatable disk having radially extending airfoils mounted on its outer periphery. The rotating disk/blade assembly is adapted to rotate between circular structures (stators) which include stationary airfoils which project radially inwardly, usually referred to as compressor vanes. The interaction of the blades and vanes, as the discs rotate, causes the compression of the air which is required for engine operation.

This invention relates generally to compressor blades and specifically to compressor blades which are mounted using what is termed a circumferential attachment scheme. The older convention in the gas turbine engine field is to use individual slots in the disk periphery, one for each blade. The newer circumferential attachment scheme employs a circumferential groove in the disk periphery. This is illustrated in Figure 1 wherein the periphery of the disk 1 is seen to have a shaped groove 2 with lips 3 which enclose a portion of the groove 2. One blade 4 is shown in the groove. Blade 4 includes airfoil portion 5 and platform portion 6. Figure 2 shows how a plurality of compressor blades is mounted on a disc in accordance with Fig. 1

The present invention solves a problem associated with the assembly of circumferentially mounted compressor blade assemblies. A typical compressor section will contain fifty to eighty compressor blades and problems arise related to the tolerances associated with the blades and the disk. It can be appreciated that it is desired to have a minimal gap or free play between the blades so as to prevent blade rubbing and interaction during engine operation. It will also be appreciated that a certain gap will usually be required in order to accommodate thermal growth which occurs during engine operation (the compressors are assembled at room temperature but may see operating temperatures of up to about 300 °F). More specifically, the differential thermal expansion between the disk which may be a steel or nickel assembly and the compressor blades which are nickel or titanium must be accommodated.

When assembling a new compressor, even minor dimensional variances in the blades can add up to a significant amount. Thus, for example, if there were sixty blades in the stage and each blade was .001 inch undersize, the net result would be a .060 inch gap when the last blade was inserted. In order to permit the accurate fitting of the blades in the disk, it is conventional to make the blade platforms slightly oversized. So, for example, in the assembly of sixty blades into a compressor disk, if each blade was only .001 inch oversize, it would be necessary to remove approximately .060 total inch from one or more of the turbine blades in order to fit the necessary number of blades into the disk (assuming no gap was desired at the assembly temperature).

It is impractical to remove all material from a single blade because this will cause too much variance in airfoil spacing. It is also not practical to remove a small amount from each blade platform because of time and accuracy constraints. The compromise is to remove the required material from 8-12 blades distributed more or less uniformly about the disc circumference. These selected blades may be made deliberately oversize for this reason.

Figure 2 illustrates how adjacent blades 7 fit together and interact, and it can be seen that the blade platforms each form a small section of an arc and that when all the blades are assembled, a complete circle is formed. It is required that adjacent blades touch over a surface rather than on a line. contact. This requires that the abutting surfaces of adjacent blades be parallel. It will be appreciated that the surfaces 8 of adjacent blades (when parallel) are radially disposed with respect to the center of rotation and that the angle (α) to which the abutting blade surfaces must be machined can be calculated based on the formula

$$\alpha = \frac{360}{N_b \times 2}$$

where N_b is the number of blades and where the factor 2 originates because each blade has two surfaces between which the necessary angularity is divided.

While it is not a particular problem to machine new blades with the necessary angular relationships, it is difficult to accurately maintain these angular relationships when removing material from blades in order to provide the requisite interblade spacing.

It will be appreciated that this problem exists during initial assembly and also after overhaul and repair operations. During an overhaul and repair operation, some if not all of the compressor blades will likely be replaced, and it is also likely that blades from different engines may become intermingled. This means that upon assembly of overhauled compressor sections, it is also necessary to perform a precision machining operation to adjust the blade platform widths while maintaining the requisite angular relationships.

Summary of the Invention

The present invention includes a compact simple low-cost tool for precision machining compressor blade platforms. Machining of blade platforms is accomplished using a rotating cylindrical abrasive surface which may be, for example, an abrasive belt passing over a cylindrical wheel. The turbine blade to be machined is held in space in required relationship and is passed over the cylindrical abrasive surface during which time the appropriate amounts of material are removed.

The compressor blade is held so that the platform surface to be machined lies in a plane which is tangent (or parallel to a tangent plane) to the cylindrical abrasive surface and the turbine blade is moved in this plane in such a fashion that it passes through the point of tangency between the plane and the cylindrical abrasive surface to cause material removal. Means are provided to advance the turbine blade into this imaginary tangent surface in such a fashion that layers of material can be controllably removed from the blade platform edge.

Brief Description of the Drawings

Figure 1 is a cutaway schematic of a gas turbine engine compressor disk which employs the circumferential attachment scheme.

Figure 2 illustrates the geometric relationship between adjacent compressor blades.

Figure 3 is a detailed drawing of a machine according to the present invention.

Figure 4 shows how a blade is mounted in a shuttle.

Detailed Description

The present invention permits the precise removal of thin layers of material from the platform edges of gas turbine blades. Metal removal is accomplished by interaction of the blade platform edge with a moving abrasive surface.

The abrasive surface is at least partially cylindrical and preferably a right circular cylinder. The cylindrical surface rotates about an axis. It will be appreciated that a plane which contains a line which is parallel to the axis of rotation can be caused to touch the cylindrical surface in a tangent fashion so that only a line on the cylindrical surface touches the plane.

According to the present invention, the blade is mounted in such a fashion that the blade is angled with respect to the previously described plane of tangency, and the blade platform edge to be machined lies essentially in the plane of tangency. The blade platform edge is moved in the plane of tangency so that it intersects the previously described tangent line. It is at this time that the metal removal occurs. The present invention includes means for moving the blade platform edge in planes parallel to the plane of tangency so as to produce a controlled amount of interaction and controlled amount of metal removal. The metal removal will usually be parallel layers since the compression blade platform was presumably initially produced with the desired angular relationship.

An apparatus which illustrates one embodiment of the present invention is shown in Figure 3. According to Figure 3, the entire apparatus is mounted on Base Plate 10 and the essential parts of the apparatus include electric motor 12 which moves abrasive belt 14 over rotatable wheel 16. Also mounted on base plate 10 is a movable plate 18 which is held parallel to base plate 10 and arranged to move parallel thereto by a parallelogram linkage which includes links 20. Coil spring 22 urges movable plate 20 to move towards the abrasive belt but the movable plate 18 is restrained in its motion by adjustable stop screw 24. Coil springs 26 extend between the base plate and the movable plate and serve to take free play out of the apparatus. Attached to movable plate 18 are pillow blocks 28 through which passes rotatable shaft 30. Rotatable shaft 30 is connected at one end to handwheel 32 and at the other end to shuttle holder 34. The assembly, comprising the handwheel 32, the rotatable shaft 30, and the shuttle holder 34, is freely rotatable, and upon rotation, the face 36 of the shuttle defines a plane which is tangent with the abrasive belt 14, along line 44, as it passes around wheel 16. This means that a plane perpendicular to shaft 30 can contain the axis of rotation of the moving wheel 16.

The compressor blade 40 to be machined or trimmed is clamped in shuttle 38 and shuttle 38 includes positive location features so that the blade 40 can be accurately located. It can be seen that the plane 42 defined by the rotation of the shuttle holder 34 can move axially along the axis of the shaft 30 as the movable plate 18 is translated with respect to the base plate. As the plane 42 is translated axially it will intersect the abrasive sanding belt at the tangent line 44, permitting the platform edge to be abraded as handwheel 32 and shaft 30 and attached shuttle holder 34 are rotated causing the blade to move through an arc in plane 42.

The dial gages 46, 48 and 50 are provided to guide the operator in the removal of the appropriate amount of material from the blade platform edge. Dial gage 46 is activated by direct contact with the blade platform edge which is being trimmed as handwheel 30 and shaft 32 are rotated. Dial gage 46 measures the position of the blade platform edge being trimmed relative to the movable plate. Dial gage 50 is also actuated by contact with the blade platform edge being trimmed but dial gage 50 is mounted on the fixed plate thereby giving of the relative position of the blade platform edge to the fixed plate. Dial gage 48 measures the relative position between the fixed plate and the movable plate. The dial gages provide information about the position of the blade platform edge and can be used to determine the amount of material removed. The dial gages provide redundant information and not all dial gages are necessary but provide flexibility in the machine operation.

Figure 4 shows how a blade whose platform 6 is to be trimmed is mounted in a holder or shuttle 38 prior to being mounted in the apparatus of Fig. 3. Portion 52 of surface 36 is tapered so as to generate the desired blade platform angle. Shuttle surface 52 will fall in the tangent plane in which abrasive interaction occurs.

Although the invention has been shown and described with respect to detailed embodiments thereof, it should be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and the scope of the claimed invention.

Claims

1. Apparatus for removing metal from a workpiece, at a controlled depth of removal and a controlled angle of removal, which comprises:
   a. an abrasive surface, said surface extending around at least a portion of a cylinder, said surface having an axis of rotation;
   b. means for locating the workpiece surface from which metal is to be removed in a plane tangent to said abrasive surface;
   c. means to advance said workpiece surface into said tangent plane so as to remove material as said workpiece surface is moved through said arc; and
   d. means for moving said workpiece surface through an arc in said tangent plane, said arc passing though said line of tangency.

2. An apparatus to selectively remove material from compressor blade platform edges which comprises:
   a. a rotating wheel having an axis of rotation;
   b. an abrasive belt passing over said wheel
   c. a shaft whose axis is aligned so that a plane perpendicular thereto can contain the axis of rotation of said wheel, said shaft being adapted to rotate about its axis and to advance generally along said shaft axis;
   d. a shuttle holder mounted on said shaft, said holder being adapted to hold said compressor blade so that the blade platform edge from which material is to be removed lies in said plane which is both perpendicular to the shaft axis of rotation and tangent to the moving abrasive belt; and
   e. a tapered shuttle which holds said workpiece at a predetermined angle.

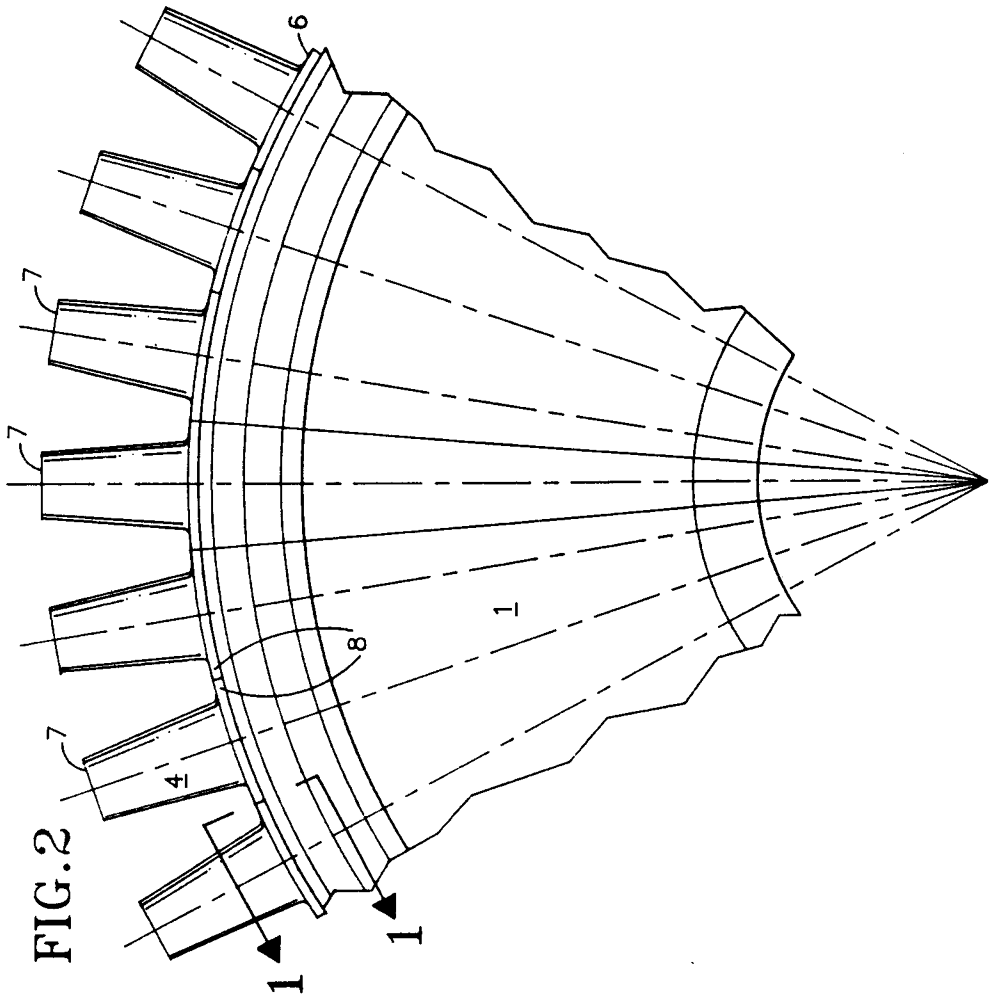

FIG.2

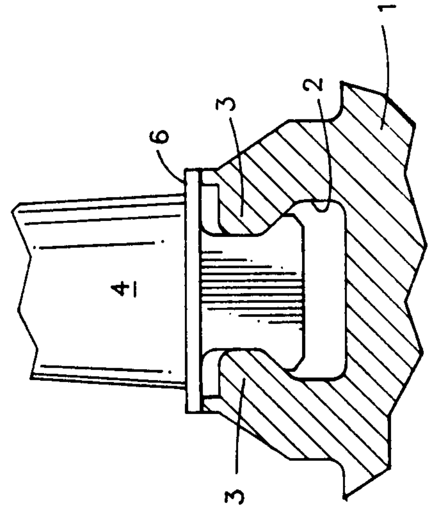

FIG.1

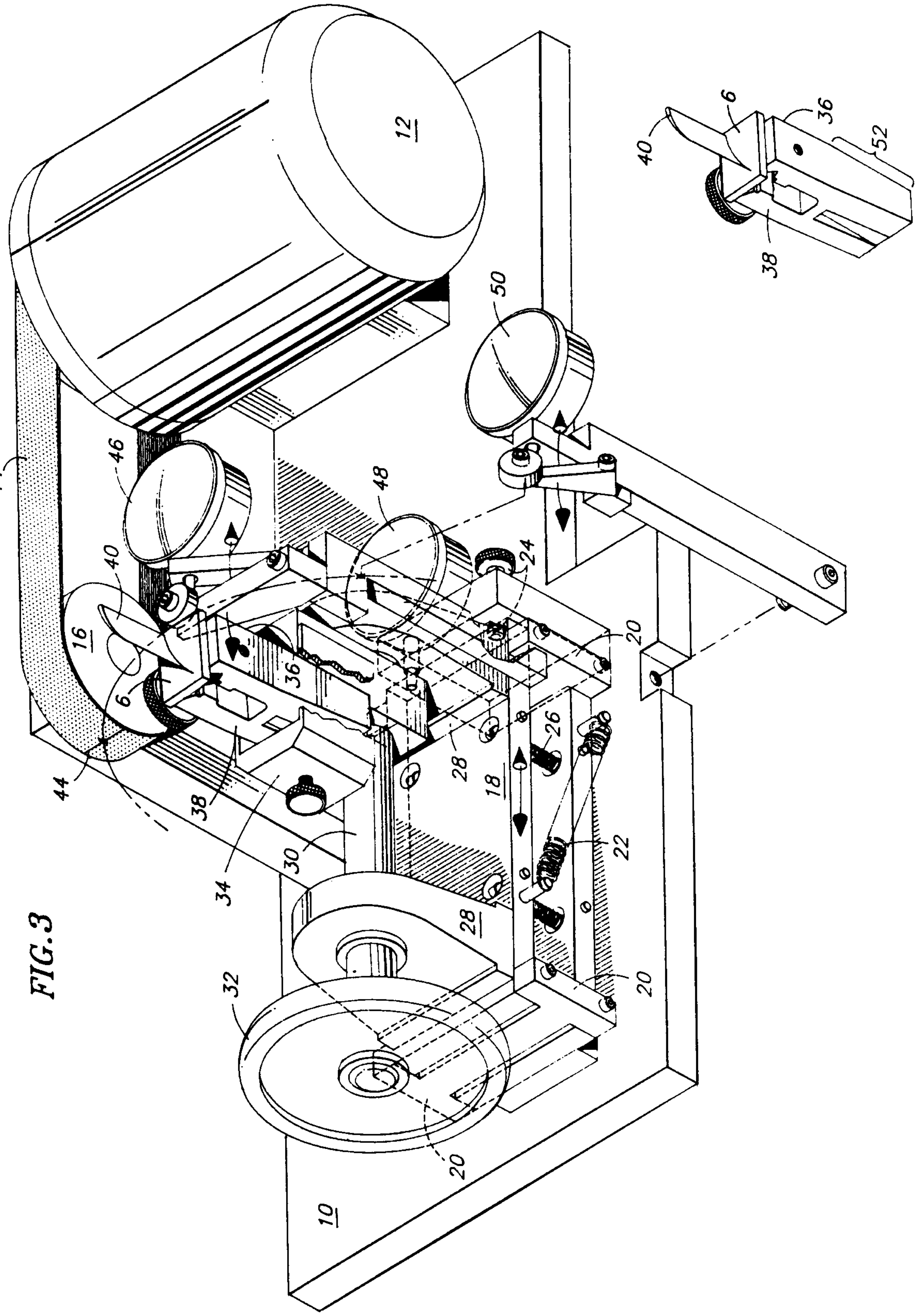

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FIG.3

FIG.4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number EP 91115198.3

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	FR - A - 2 488 541 (KOENNEMANN) * Fig. 2 * --	1,2	B 24 B 5/313
X	US - A - 4 860 499 (DINGER) * Fig. 1 * --	1,2	
A	US - A - 2 754 636 (CREEK) * Reference numerals 36B,36C * --	1,2	
A	EP - A - 0 128 110 (UNITED) * Fig. 1,3 * ----	1,2	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B 24 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	28-11-1991	GLAUNACH

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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