

[54] **METHOD FOR CONTROLLING FINISHED THICKNESS OF PLANETARY-LAPPED PARTS**

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51/281 R

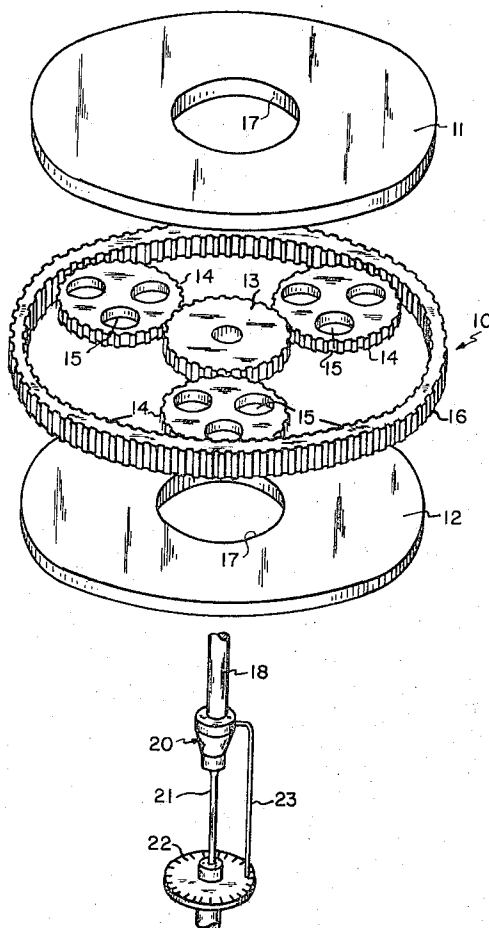
[57] **ABSTRACT**

A method for controlling the thickness of a planetary-lapped part prepared by a lapping apparatus having planetary carriers for containing the part which is in gear train with a sun and ring gear and in abrasive engagement with a pair of lapping plates. The method comprises measuring the forces of at least one of the gears during lapping and detecting any increases in those forces and stopping the apparatus upon the detection of said increase.

[56] **References Cited**
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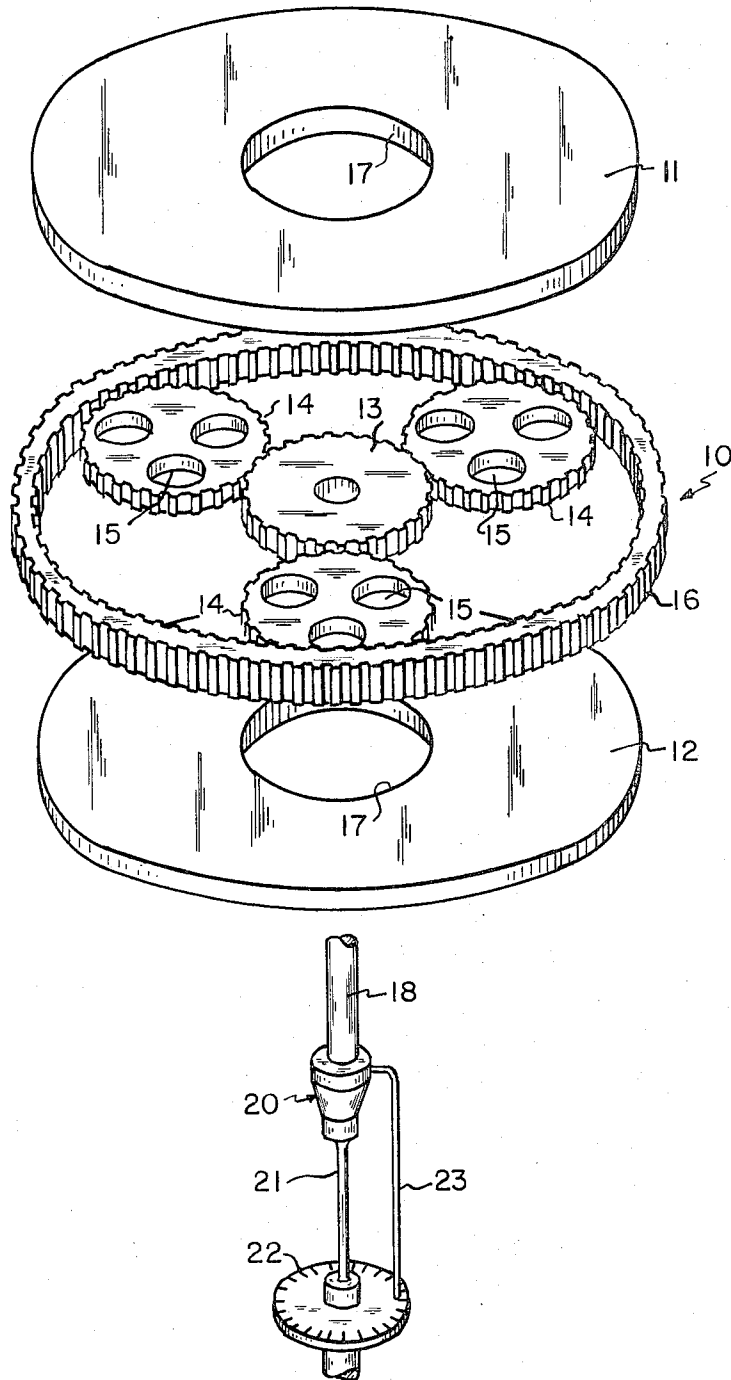
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4 Claims, 1 Drawing Figure



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METHOD FOR CONTROLLING FINISHED THICKNESS OF PLANETARY-LAPPED PARTS

FIELD OF THE INVENTION

The present invention relates to a method for controlling the finished thickness of planetary-lapped parts.

BACKGROUND OF THE INVENTION

Planetary lapping is a well known process for achieving uniformly thick plates having planar parallel faces by free-abrasive machining. Planetary lapping is generally carried out on a lapping machine comprising top and bottom lapping plates, which are positioned within the annular space between a ring and sun gear. Between the plates and in gear train with the ring and sun are a plurality of planetary carrier members each of which has at least one eccentric opening therethrough to carry the part or material to be lapped. The thickness of the carrier is designed to be approximately equal to but necessarily slightly less than the desired thickness of part to be lapped. A slurry comprising a suspension of fine abrasive particles in a suitable liquid vehicle, which also serves as a lubricant, is introduced into the system between the top and bottom lapping plates. The abrasive particles are carried across the sample faces by the relative motion between the parts and the plates and abrades the respective surfaces removing material from both the parts carried by the carriers and the plates. The rate of surface removal depends upon such things as pressure on the part and lapping plates, the relative speeds of rotation, the slurry composition, plate and part hardness, and slurry feed rate.

In order to obtain the relative motion between the lapping plates and the carriers, a number of different methods have been devised and used: For example, both lapping plates are held stationary and the ring and sun gears are driven so as to rotate in the same direction at different angular velocities; both plates are driven so as to rotate at equal rates, but in opposite directions, and the ring and sun gears are made to counter-rotate at generally much lower rates; and the bottom plate is fixed and the top plate driven to rotate as well as rotating the sun and ring gears so that the angular velocity of revolution of the carriers around the system axis is approximately one-half of that of the top plate. Generally, the motion of the carriers and, thus, the parts is determined by the motion of the sun and ring gears. In order to distribute wear equally over the lapping plates, it is preferable to have the carriers rotate around their own centers as well as around the system's center and to have the part holes in the carriers eccentrically spaced within the carrier so that the parts to be lapped partially extend over the outer and inner edges of the lapping plates, alternately, as the carriers rotate and revolve, thus sweeping the samples radially across the entire plate face as well as azimuthally around the plates. Carrier rotation about its own center is insured if the sun and ring gear angular velocities are unequal.

When lapping parts to a preselected thickness, it is desirable to achieve uniformity of thickness successively throughout numerous lapping operations. Several methods have been proposed for controlling the desired thickness and/or for stopping the lapping oper-

ation when the desired thickness has been achieved. These approaches include the actual measurements during lapping of the amount of material removed or remaining, or predictions of this amount based on initial part thickness and experimentally established removal rates. The predictive method has not proved to be accurate, because the rate of removal of the part material depends on factors which are not readily controlled and usually vary significantly during operation.

For accurate control of the thickness, methods have been devised which measure the thickness during lapping. For example, the thickness can be determined by the internal work space between the lapping plates during operations or the distance between the outer faces of the lapping plates. A typical method for making such measurements employs a transducer, rigidly mounted on one of the plates, to measure distance. This method senses the position of internal references fixed with respect to each of the plates. Transducers employed include air gauges, differential transformers, mechanical dial indicators, and capacitive and inductive proximity detectors. Also, the distance between external references on the lapping plates can be measured and is equivalent to the aforementioned method. Both of these methods have several disadvantages which will cause measurement error: The mechanical path between top and bottom plates is relatively long and contains many elements subject to variation, such as play in the bearings and rotating joints, as well as thermal expansion; the lap working space includes not only the part, but also the thickness of the slurry films between the part and plate surfaces; and the plates as well as the parts are lapped at a significant rate. Thus, the measurements between plate reference points cannot distinguish between plate loss and part loss and, therefore, the amount of plate loss must be anticipated for each run by previous experiment.

To overcome these disadvantages, it has been suggested to measure the interior work space between the lapping surfaces. One technique is to use quartz crystals in place of a part in the carrier. Quartz crystals are used which produce voltages between the lapping plates by the rubbing action on the piezoelectric quartz samples. The rubbing causes the quartz to vibrate in shear and the crystal thus generates between the spaces a voltage the frequency of which depends on its thickness. Although the clamping and rubbing action of the plates makes the vibrations small and nonsinusoidal, the voltage is large enough to be readily detected on a radio receiver and well enough defined in frequency to indicate crystal thickness to within about 0.0001 inches. This system overcomes the disadvantages found to be inherent in the aforementioned methods, but requires relatively expensive equipment with a continuing supply of quartz samples which are consumed in use. Accordingly, none of the methods presently available provide a completely satisfactory way for controlling finished thickness of planetary-lapped parts.

SUMMARY OF THE INVENTION

The present invention provides a method for stopping a lapping operation when the part to be lapped has reached a desired thickness. The present invention provides a method which overcomes the disadvantages inherent in the methods previously used and available.

Generally, the method of the present invention comprises measuring the torque of at least one of the drive

means for the sun, planetary carrier, ring, or drive plates. In the method of the present invention, preferably, the forces exerted on the carrier teeth by the sun and ring gears are measured during operation. In the initial state; i.e., when the part thickness considerably exceeds the carrier thickness, the gear-tooth forces are required to balance only the force exerted on the carrier by the part edges, since the lapping faces do not bear against the carrier. When the part thickness is reduced to approximately that of the carrier, the gear-tooth forces will change because the lapping plate surfaces will begin to exert significant frictional forces on the carrier surfaces. These changes in gear-tooth forces, measurable in terms of the torques on the ring and sun gears, signify the approach of the sample thickness to the carrier thickness and it is used to stop the operation.

Since the method of the present invention uses the carrier as a reference thickness standard, there is no need for precision measuring apparatus of the part in the lapping machine. The carrier tooth forces, particularly those components of the forces associated with rotation of the carrier about their own centers, change quite abruptly as the lapping plates come into contact with the carrier faces. Moreover, the change in force required is independent of plate wear and, thus, overcomes the inherent disadvantages of the methods utilizing the reference distance between the plates to measure finished thickness.

BRIEF DESCRIPTION OF THE DRAWING

The drawing is an exploded view of a lapping apparatus comprising a pair of lapping plates, sun gear, planetary part carriers, and ring gear, and including a means for measuring the torque of the sun gear.

PRESENTLY PREFERRED EMBODIMENT

Referring to the drawing, a planetary-lapping apparatus 10 comprises a top lapping plate 11 and a bottom lapping plate 12. Apparatus 10 also includes a sun gear 13 in gear train with a number of planetary carriers 14 having openings 15 therein for captively engaging the part to be lapped. Planetary carriers 15 are in gear train relation to ring gear 16. Top and bottom plates 11 and 12, respectively, include openings 17 therein designed to fit over sun gear 13 when the plates are positioned within ring gear 16 to engage the parts held in carrier openings 15. Lapping plates 11 and 12 engage parts to be lapped after the admission or introduction of an abrasive slurry.

In the method of the present invention, the machine is designed to permit the ring and sun gear drive torques and/or the plate torques to be individually measured and a suitable combination of these torques is determined. The most satisfactory combination of forces is that producing a movement on carriers 15 about their centers, since this turning movement is most subject to increases as the lapping plates 11 and 12 meet carrier 15. However, other force combinations may also serve, including the torques on the plates. In this respect, an easy torque to measure is that which is required to hold stationary the top plate in a fixed plate lapping machine. However, this particular torque is not significantly changed as the samples are lapped to the carrier thickness and, thus, not preferred, since the torque would not provide a particularly satisfactory indication of carrier and part thickness equality.

In the determination of the torque required when the plate engages the carrier, the loss of the carrier thickness by lapping also must be considered. Thus, in order for the forces to accurately reflect the thickness of the part it must be assumed that the abrasive-impregnated plate surface comes into contact with the carrier and removes some material from the carrier. The amount lost before the increased torque effects shut-off of the machine is determinative of how often the carrier can be reused before it no longer accurately reflects the desired part thickness. The amount of loss is determined by experimentation with respect to the nature of the parts to be lapped, the nature of the slurry used, and the materials from which the carrier is made.

Methods for measuring the torque on rotating elements are well known to those skilled in the art and do not comprise a part of the invention. Since these methods are well known, only a few illustrative examples are described which are suitable for use with the present invention.

Preferably, for each driven member for which the driving torque is to be measured, a shaft is provided which is unique to that element. The torque on the element can be obtained by measuring the torque on the drive shaft and multiplying by the appropriate gear ratio. In general, this does not require any modification to the machine, since at least one commercially available machine has all four elements independently driven by separate shafts. The torque is then measured from the driven rotating shaft. For example, a section of the drive shaft may be replaced by a differential gear arrangement having two axle members. If drive torque is applied to one axle and a third shaft normal to the gear-axle arrangement is restrained from rotating, the second axle will rotate at the same speed and in an opposite direction. The torque required to restrain the third shaft from rotating will be proportional to the torque transmitted from axle to axle. Since the third shaft is stationary the torque therein can be measured by how much it deflects a calibrated compliant restraint. Alternatively, a section of shaft 18 used to drive the sun gear 13 may be replaced by a compliant coupling 20; the amount of twist or torque in coupling member 21 is then proportional to the shaft torque. Such twist may be observed, for example, by having a circular plate 22 attached to one end of the coupling and a pointer 23 to the other end. Since the entire assembly rotates, a convenient way to observe the deflection is by stroboscopic illumination synchronized to the shaft speed. It may be preferable in some cases to utilize a second compliant coupling 20 on the shaft used to drive ring gear 16. By measuring the gear-tooth forces of the sun and ring gears, divided by the respective radii of the gears, and calculating from these either the sum or differences of torques produced, depending upon rotational directions the changes in torque of the carrier can be found. Another way of measuring torque, is where the shafts are driven by separate motors, for example, an electric DC shunt motor. The torque is then proportional to the product of the armature current and magnetic flux which can be conveniently indicated by measurement of the armature current.

While presently preferred embodiments of the invention have been described in particularity, it may otherwise be embodied within the scope of the appended claims.

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What is claimed is:

1. A method for controlling the thickness of planetary-lapped parts wherein said parts are contained in a planetary carrier of the desired final part thickness which is in gear train with a ring and sun gear and said parts are in abrasive engagement with a pair of lapping plates, the method comprising measuring the forces of at least one of said gears during lapping, detecting any change in those forces, and stopping said gears upon

detection of said change.

2. A method as set forth in claim 1 wherein the forces measured are those of the sun gear.

3. A method as set forth in claim 1 wherein the forces measured are those of the sun and ring gears.

4. A method as set forth in claim 1 wherein the measured forces comprise the torque produced by the planetary carriers.

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