April 8, 1947. G. D. WILD 2,418,535

MACHINE FOR FINISHING METAL PARTS

Original Filed March 30, 1942 2 Sheets-Sheet 1

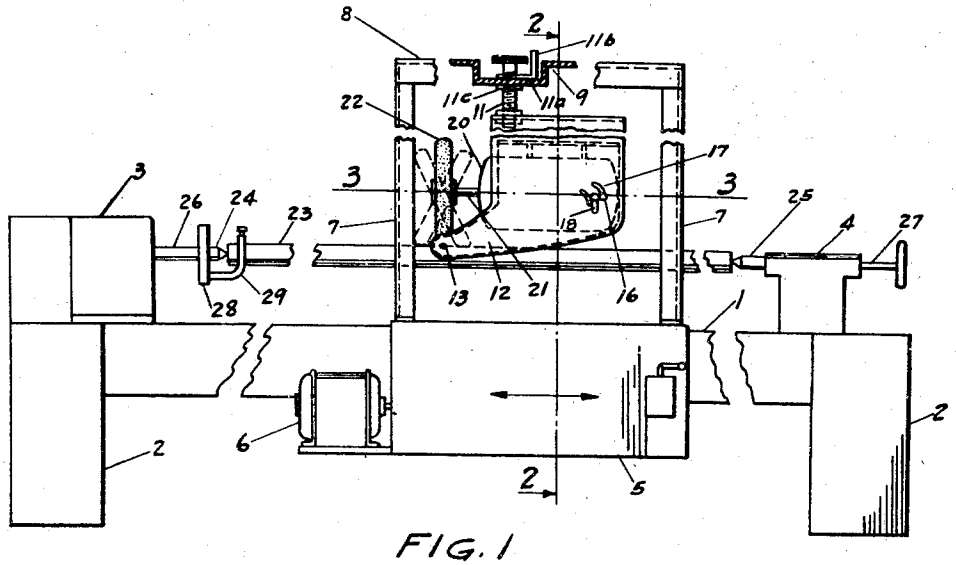


FIG. 1

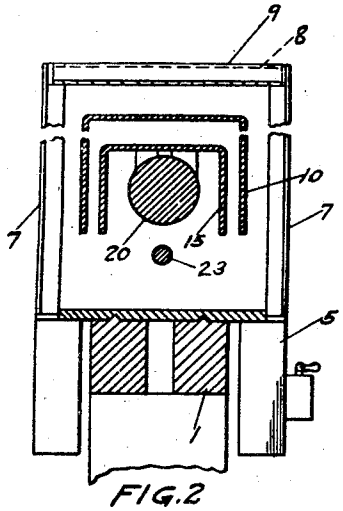


FIG. 2

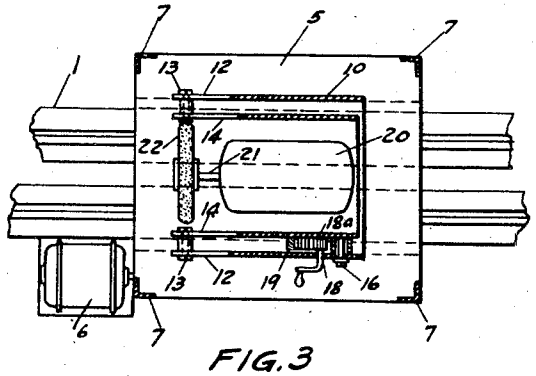


FIG. 3

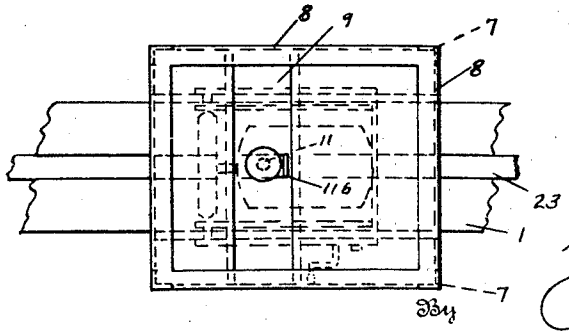


FIG. 4

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MACHINE FOR FINISHING METAL PARTS

Original Filed March 30, 1942 2 Sheets-Sheet 2

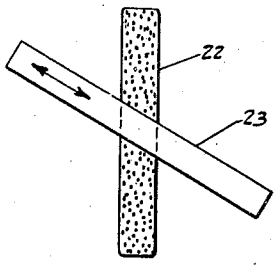


Fig. 5.

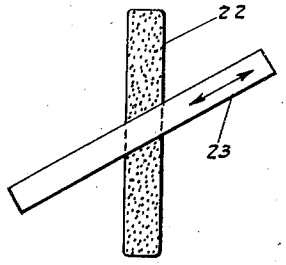


Fig. 6.

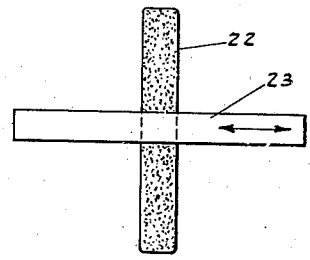


Fig. 7.

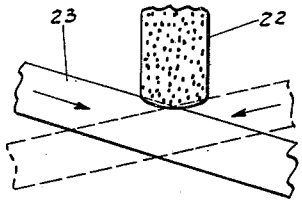


Fig. 8.

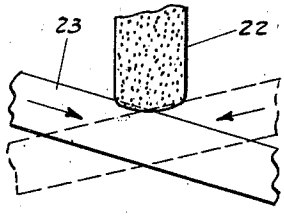


Fig. 9.

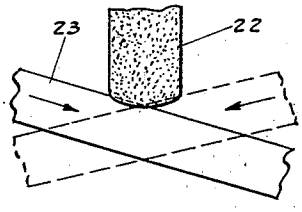


Fig. 10.

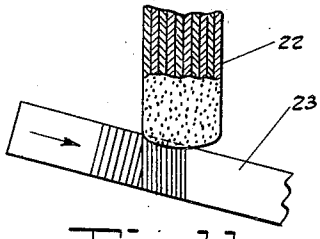


Fig. 11.

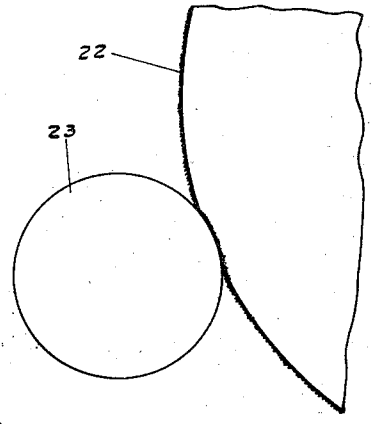


Fig. 13.

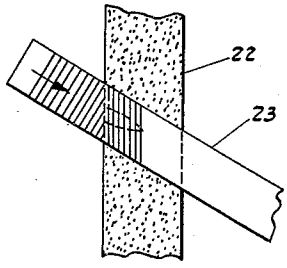


Fig. 12.

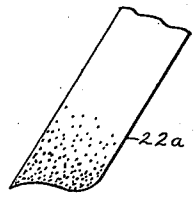


Fig. 14.

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Patented Apr. 8, 1947

2,418,535

UNITED STATES PATENT OFFICE

2,418,535

MACHINE FOR FINISHING METAL PARTS

Glenn D. Wild, Cleveland, Ohio, assignor of one-half to Michael Cisar, Cleveland Ohio

Original application March 30, 1942, Serial No. 436,890, now Patent No. 2,336,145, dated December 7, 1943. Divided and this application November 10, 1943, Serial No. 509,743

6 Claims. (Cl. 51—50)

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Th's application is a division of my copending application, Serial No. 436 890, filed March 30, 1942. now Patent No. 2,336,145, granted December 7, 1943.

My invention appertains to the art of finishing metal parts. It deals primarily with the provision of a novel method, and a novel machine for carrying out such method, for effecting a final grinding or finishing treatment of metal parts which have been pre-ground or pre-machined to certain fixed general tolerances.

While my invention as described herein is presented primarily with reference to final finishing operations on curved surface metal parts to bring them to the finest tolerances that are required for their use, the invention is equally adapted for use in conjunction with the finishing of metal parts with straight or combined flat and curved surfaces.

My invention has been evolved as a result of the requirements of today for increasing production of metal parts and has solved certain problems of great difficulty incurred by reason of the methods of finishing and mechanical instrumentalities heretofore available for finishing such parts to the finer tolerances that are being required at this time.

In reference to the problems referred to, it is notable that up to the time of my invention, the general manufacturing practices resorted to have been relatively crude, have retarded production because of the inability to employ such practises for expeditious production, and have been thoroughly unsatisfactory primarily for the last mentioned reason. Thus, in reference to metal parts, as for instance shaft units and the like, which have been pre-ground or pre-machine finished to general tolerances and required to be further finished to tolerances running to five thousandths, or in some instances hundred thousandths, it has heretofore been necessary to resort to crude and times-taking processing. The above finer tolerances are primarily important and essential in arriving at the final finished condition of metal parts, the surfaces of which are employed for bearings or bearing surfaces relatively movable with respect to one another. The manufacture of airplane engines and airplane parts, and other types of enginery, and analogous uses, has created the demand for finishing treatment of the method and machine as proposed in the present invention.

Heretofore the common methods employed for the purposes of this invention have been to utilize emery cloth manually held in contact with

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the metal parts for accomplishing the final finishing operation, requiring a high degree of skill and involving a tedious and slow method of production. In machine practise, recourse has likewise heretofore been had to the use of a moving belt surfaced with emery or equivalent abrasive, a likewise unsatisfactory and slow method of procedure and one which creates the liability of spoilage of the part operated on due to the inability to provide a homogeneous abrasive surface properly controlled to prevent the mutilation of areas of the surface of the final metal product.

Another method resorted to in machine practise is the employment of hones, a practise rendered slow and inefficient for high production purposes because of the continuous choking of the hone surfaces, as commonly recognized in this art. This choking of the hones may result in burning of the metal surface of the final product, requiring a further finishing or, in some cases, causing a complete spoilage of the product.

It is well known in the art to which my invention relates that the surface of metal parts produced by pre-grinding operation, bringing the part down to the closest tolerances that can be secured by using the generally known machines for the purpose desired, the actual finished surface referred to, viewed by the naked eye, can be seen to comprise fine feed lines creating projections encircling round metal parts or extending across the surface of flat metal parts. When the metal parts are further finished, as by the previously described crude processes and as accomplished by my present invention, the said feed lines and all other projections on the surface of the metal, of any nature, are entirely removed to the point of achievement of the final finest tolerances required, and the primary object of my invention has been to devise novel mechanically operated instrumentalities for performing said method whereby to greatly facilitate the bringing of the work to the ultimate required tolerances above referred to.

In the carrying out of my invention, I avail of a new machine for carrying out a method involving novel technique in respect to certain consecutive grinding or finishing actions that are performed upon the work or metal parts, said machine including especially the novel instrumentality of a resilient grinding wheel with which to obtain a peculiar function in the grinding or finishing process. The said resilient wheel is not only applied to the work by arranging and working the same at special angles, or in peculiar parallel relation to the axis of the work, but the

inherent resiliency of the wheel is availed of in order to effect a variable grinding action upon the work in respect to different portions of the grinding surface of the wheel. I have found in practise that the said resilient grinding element as used by me, by being operated so that the greatest pressure is applied to the work thereby at the lead portion of the element with lessening pressure toward the trailing portion of the element, will grind the work in such a way as to reduce the forming of the so-called feed lines that I have referred to above, during initial operation of the grinding means. Eventually, furthermore, this peculiar variable pressure action of the grinding wheel or element will entirely remove the projection of the feed line and any other projections existing on the surface of the work as the latter is cut away to bring it to the required finest tolerances mentioned before.

Another important phase of my means of accomplishing the results of my invention lies in the mode of utilizing the choking effect of the ground off particles of metal during the grinding-finishing operation. In other words, my invention involves the use of the regulated or controlled choked condition of the grinding element or wheel to vary the grinding effect produced thereby, said control being obtained through the employment of variable quantities of tallow or equivalent substance with which the grinding surface of the grinding wheel is coated or treated, as well as by said manipulative technique as respects the degree of application of pressure of the grinding wheel of my machine to the surface being treated or finished.

In reference to the foregoing so-called control of the choking of the grinding surface of the grinding element, I avail of the phenomenon that the greater the amount of application of tallow to the grinding surface of the wheel, the less will be the degree of choking effect obtained, and vice versa. In this action, in other words, the choking effect may be regulated by reason of the peculiar quality of the tallow or similar material that may be used to lubricate the surface of the grinding element, and to increase or decrease, therefore, proportionate with the amount of the said material used, the affinity between the removed particles of metal ground off of the work and the surface of the grinding element.

A further object of my invention, in reference to the means employed as above outlined, has been to utilize the resilient grinding wheel or element, in performing its grinding function, to obviate any possibility of chattering of the wheel during its application to the work, an objectionable feature of the use of hard grinding wheels. Thus, according to the practise of my invention, an advantageous result flows from the employment of the resilient grinding wheel in that in the use thereof the balance of the wheel may be quickly changed and thus a perfect balanced condition maintained in the wheel. So far as I am advised, the foregoing technique of grinding wheel choking and variable pressure effect has never heretofore been employed in the art of metal grinding, broadly speaking, and irrespective of my specific mode of utilization of these features of my invention as hereinafter presented.

In the accompanying drawings, I have illustrated one type of machine of my invention, which may be operated manually for accomplishing the method referred to.

In the said drawings:

Figure 1 is a front elevation, somewhat diagrammatic in nature, illustrating the embodiment of my invention in a machine of the engine lathe class wherein many of the lathe parts are utilized after the manner of ordinary lathe operation, the dotted line showing of the vertical angle pitch of the grinding wheel being exaggerated for clearness and greater than obtainable in the rightward pitched direction.

Figure 2 is a vertical section taken approximately on the line 2—2 of Figure 1, looking in the direction of the arrows.

Figure 3 is a horizontal section of a portion of the machine, taken about on the line 3—3 of Figure 1.

Figure 4 is a top plan view of the central mechanism of the machine to show more fully the mounting of the motor cradle, grinding wheel, shaft, and carriage for the same, upon the superstructure of the machine.

Figures 5, 6, and 7 are diagrammatic views illustrating the angular disposition of the work to the grinding wheel during the first, second, and third operations or treatments of the said work, the views being front elevations.

Figures 8, 9 and 10 are disposed below Figures 5, 6 and 7, respectively, and diagrammatically illustrate the relation of the work to the grinding wheel during the three different operations previously referred to as illustrated by Figures 5, 6 and 7, respectively. In Figures 8, 9 and 10 the dotted line position of the work indicates the position of the same during one traverse of the work across the face of the grinding wheel, and the work is illustrated in full lines during another traverse thereof across the face of the grinding wheel.

Figure 11 is a greatly exaggerated view showing a fragmentary portion of the grinding wheel to illustrate its face as acting upon the work, also shown in contact with the face, and the movement of the work being in the direction of the arrow, said view being taken looking down upon the wheel and work.

Figure 12 is a view similar to Figure 11, but viewing the parts in front elevation, the dotted lines showing the approximate formation of the pressure contact area of the work with the face of the wheel.

Figure 13 is an enlarged or magnified elevational view of the work and grinding wheel broken away and bringing out more clearly the resilient pressure action between the work and wheel.

In Figures 11 and 12, the dotted lines at the pressure area between the grinding wheel face and work show approximately the gradually decreasing pressure area from the point of the leading edge to the trailing portion of the face of the wheel.

Figure 14 is a fragmentary view of a grinding wheel having a somewhat different form of grinding face useful for handling of certain types of work.

I shall now describe generally the construction of the one embodiment of a machine illustrated in the drawings designed for the practise of the method of my invention.

The engine lathe type machine illustrated in the drawings comprises the bed 1 supported by the legs 2 and carrying a customary type of headstock 3 and tailstock 4. Upon the bed 1 is mounted the saddle or carriage 5 slidable to traverse the bed 1 in the customary manner of lathe construction and operated by a motor 6 supported on the carriage, the manner of movement of the

carriage being conventional in the art. In lieu of the customary tool rest or support mounted upon the carriage 5, I provide a superstructure frame comprising the four corner posts 7 connected at the upper ends thereof by crosspieces 8 arranged transversely and longitudinally of the machine. A crossplate 9 is connected at its ends and thereby supported upon the longitudinal cross members 8 connecting certain of the posts or standards 7 of said superstructure frame. The plate 9 forms a support for the outer cradle 10 of inverted U-shape, substantially speaking, which cradle is carried from the plate 9 by the pivotal connection 11, which comprises a screw enabling the cradle 10 to be raised and lowered and permitting the pivotal movement of the cradle about said screw as a vertical axis. The cradle 10 is provided with laterally and downwardly extending arms 12 at its opposite sides, which arms are pivotally connected at 13 to similar arms 14 carried by an inner motor cradle 15 shaped generally similar to the cradle 10 and disposed between the sides of the later.

The cradle 15 may be pivotally moved by reason of the pivotal connections 13 aforesaid, and may be held in adjusted positions after such movement by means of a set screw 16 received by a threaded opening on a side of the inner cradle 15 and passing through an arcuate shaped opening or slot 17 on the adjacent side of the outer cradle 10. The movement of the inner cradle 15 relatively to the outer cradle 10 may be effected by a pinion shaft 18 having a handle on its outer end and protruding through an opening in the side of the cradle 10. The pinion of said shaft is carried at the inner face of the said outer side of the cradle 10 and meshes with an arc-shaped rack 19 fixed to the adjacent outer face of the inner cradle side. Simple turning movement of the shaft 18 and its pinion designated 18*a* will effect relative movement of the cradles 10 and 15, and their proper relative positions when reached for operation of the machine may be fixed by the set screw 16. The motor 20 carried by the inner cradle 15 is mounted in any suitable manner therein and the shaft 21 of said motor has removably attached thereto the grinding wheel 22.

From the foregoing, it will be understood that the motor 20 is provided with a universal mounting by reason of the provision of the pivots 13 connecting the arms of the cradles 10 and 15 and by reason of the method of pivotally supporting the outer cradle 10 by the pivot member 11. The pivots 13 connecting the arms 12 and 14 of the cradles as described are adapted to be positioned so as to intersect the horizontal plane coincident with the upper surface of the work being operated upon. Likewise, the grinding wheel 22 is so disposed, by reason of its mounting upon the shaft 21, that its face may operate in a vertical plane coincident with the pivotal points 13 of the cradles.

The motor cradle 10 is fixed by any suitable means to the screw member 11, the said screw member passing through an opening in the crossplate 9. Adjacent the upper surface of the crossplate 9 a locking member 11*a* is threadedly engaged with the screw member 11 whereby rotation of the member 11*a* by means of the handle portion 11*b* will raise or lower the cradle. A suitable lock nut 11*c* is provided to prevent the cradle 10 from becoming misaligned during operation of the wheel 22 and to maintain the cradle in the desired adjustment, axially of the screw member 11.

This adjustment may be made during the movement of the carriage 5 and associated parts as required by grinding technique to be described as being carried out by my method.

In connection with the operating instrumentalities above described, in reference to the superstructure of the machine carried by the carriage 5, there will be employed for supporting the shaft 23 which is the work being operated upon, the customary centers 24 and 25. The center 24 is carried by the usual shaft 26 on the headstock 3 and the center 25 by the usual adjusting screw 27, on the tailstock 4. The shaft 26 is adapted to be driven by any suitable motor, and is equipped with the usual face plate 28 having the lathe dog 29 for coupling to the work to drive the same.

The motor 20 is capable of rotating the wheel 22 at high speed, and the spindle 26 of the lathe is adapted to be rotated at a considerably slower speed to facilitate the grinding action between the shaft 23 and the grinding wheel 22. Under most conditions, the shaft 23 is rotated in a direction opposite to the direction of rotation of the wheel 22 to most effectively produce the finish on the surface of the shaft, in accordance with the process.

Reference is now made to Figures 11 to 13 of the drawings, showing primarily the grinding wheel 22, which as before stated, is formed of a resilient body preferably laminated in construction. The face of the wheel 22 is prepared with a grinding surface, and, since different wheels are employed for certain of the separate operations to be performed by my method, said grinding surface is modified accordingly for such wheels. The contour of the face of the wheel may likewise be modified to take different forms, one of which is illustrated in Figure 14 of the drawings, said contour depending upon the kind of work to be performed, especially in regard to the nature of the surface of the metal part that has to be finished or ground by means of my method and machine.

In fully developing the foregoing grinding wheel structure, it is notable that in the use of my machine there are utilized three method steps of grinding, and the grinding wheel employed for each step is differently prepared on its grinding face because of the nature of the work to be performed by each step of the process.

Describing the grinding wheel as prepared for the first step, it is notable that I utilize for the face of the wheel a relatively coarse #320 emery. The term "relatively" as above used, is merely employed for purposes of comparison, because the emery is obviously fine-grained. The said emery is applied to the face of the wheel by the use of a suitable glue or adhesive. In a similar manner the emery wheel or wheels used for the second step of my process are set up with #400 emery and the wheel or wheels used in the third step of the process are set up with #500 grain emery.

Referring now to Figures 5 to 10 inclusive of the drawings, the method to be carried out by the machine of my invention will be described first as it may be performed by hand and in relation further to the preparation of the emery wheels used at each step of the process for carrying out such step. Thereafter, the mode of practising such method by the machine herein described will be explained.

In Figures 5 and 8, my first process step is depicted diagrammatically, and it is to be under-

stood that the work 23 may be held in the hands of the operator and caused to be pressed against the grinding wheel 22 by manual pressure, including body pressure as may be necessary. As viewed from the front elevation of Figure 5, the work or shaft 23 is disposed at a vertical angle to the face of the wheel 22 approximately 30° preferably, and said shaft is carried across the face of the wheel in one direction to enable the latter to perform its grinding operation throughout the area of the surface which is being finished. In the above action, the wheel causes the rotation of the work in the hands of the operator who will, by means of his hands, retard the turning of the metal piece 23 for controlled operation of the grinding. In addition to the vertical angularity of the work 23 as depicted in Figure 5, the shaft is held in a horizontally angular position as depicted in full lines in Figure 8 while moving in the direction of the arrow in Figure 8. Thereupon, when the stroke of movement of the work across the face of the wheel 22 is completed as above described, the horizontal angle of the work is shifted to a reverse position as depicted in dotted lines in Figure 8, while the vertical angle remains substantially the same and the work is then carried in the opposite direction. In the above operation, the shaft or work 23 is pressed against the left portion of the peripheral face of the wheel 22 as the work is carried rightward, and then, when the work is moved on the reverse stroke, it is pressed against the right peripheral portion of the face of the wheel. Now it is understood that the wheel as used in the step just described is that set up with #320 grain emery. According to my process, furthermore, as the work 23 is carried across the face portion of the wheel 22, see Figure 11, in the direction of the arrow, the leading edge of the resilient wheel 22 is pressed against with the greatest force and the pressure along the trailing portion of the face gradually diminishes because of the contour of the face, the resiliency of the wheel, and the angles at which the work is presented to the face of the wheel.

The foregoing is also true in relation to the movement of the work reversely to that described and in a position reversely to that illustrated in Figure 11, and more clearly shown by the dotted line position of the work in Figure 8. In the operation as described in Figures 5, 8 and 11 above given, it is obvious that the feed lines shown on the work in Figure 11 designated 30 are substantially perpendicular to the surface of the work or piece 23 as defined thereon by previous action in the pre-grinding operation referred to, and when the work is presented to the face of the grinding wheel 22 as above set forth, and permitted to rotate in contact therewith, the said feed lines 30 are acted upon by the emery on the face of the wheel 22 in a gradually decreasing amount as the pressure of the face of the wheel on the work decreases. In other words, at the point of contact of the work 23 with the wheel 22 shown in Figure 11, the same being the leading edge of the wheel, designated *a*, the amount of cutting at this point by the emery on the face will be greatest in view of the fact that the greatest pressure is exerted at this point and the wheel affords the greatest resistance at the said point. From the foregoing it will be seen that the pressure diminishes as the surface contact of the sides of the wheel with the work 23 decreases due to the angularity with which the work is presented to the wheel and to the conformation of

the face of the wheel, the said pressure decreasing to a point somewhere substantially beyond the center of the wheel where it is no longer effective to perform the cutting or grinding operation, thereby becoming zero since the face of the wheel no longer contacts the work piece. This effectively prevents the formation of a trailing line or an additional feed line that would normally prevail if full surface contact of the face of the wheel with the work obtained. In Figure 12 the surface contact of the wheel face is illustrated in dotted lines over the pressure area on the work or piece 23 as presented by Figure 11, and from this view it will be fully noted that the pressure area decreases to the zero or minimum point at the end or junction of said dotted lines, designated *b*, and, thereafter, since there is no contact of the face of the wheel with the work as previously set forth, there is no pressure area shown.

In Figure 13, a view taken as previously explained on the line 13—13 of Figure 11, the actual contact of the portion of the wheel performing the grinding operation is shown in somewhat exaggerated manner as following the contour of the work being operated on throughout the contact of the face of the wheel therewith, and is seen to be a reverse curve to that of the normal contour of the wheel periphery, and, as is apparent, the periphery assumes that normal contour after it has performed its cutting operation, and, thereafter, retains the proper circumferential relationship until again presented to the work for the cutting operation at the end of a complete revolution of the wheel. This is due to the inherent resiliency of the wheel structure, and this resiliency has been availed of by me in an entirely new way for the purpose of grinding metal parts, so far as I am aware.

During the operation of the first step, as above described, the face of the wheel is prepared by applying tallow (grease stick), or an equivalent material thereto, very freely, and the quantity of tallow of free application, as above referred to, is maintained throughout the reverse movements of the work held at the proper angles stated. The reason for freely applying the tallow, as above described, is to avoid the choking of the wheel face with the metal particles removed by the grinding action of the emery on the face, the tallow, practically speaking, providing a lubricant for retarding or preventing the adhesion of the said metal particles to the face and to the interstices between the emery grains.

I pass now to the second step of my process, which is virtually a repetition of the method of presenting and moving the work across the face portion of the grinding wheel 22 as above described, with the notable exception, however, that in commencing the second step of operation depicted by Figures 6 and 9 of the drawings, the work is disposed at the opposite vertical angle to that shown in Figure 5, whilst the horizontal angle of the work remains the same. The purpose in reversing the vertical angle is to reverse the formation of any feed lines and cut across any possible finer feed lines left by the first operation on the surface of the work. In this second step of operation of my method, the #400 grain emery wheel is employed as previously indicated, and, of course, by the second step any feed lines left on the surface of the work are reduced in number and in size by the grinding effect produced. However, it is to be understood that in the second step, I utilize choking of the wheel for obtaining the finer grinding ac-

tion that is desired in such step. Therefore, the operator will apply the tallow sparingly in this second step, as compared with the first step, so as to let the metal particles or fines ground off the work partially fill into the face of the grinding wheel and the interstices between the grains for effecting the above important second step of operation.

Referring now to the third step of the operation of my method, Figures 7 and 10 of the drawings are illustrative. The work at this period of the method is supposed now to be clean down to the true grain of the metal and therefore in this third step I employ a #500 grain emery wheel face and the same type resilient wheel as stated with reference to the first two steps. Likewise, in this third step, the tallow is so sparingly used, much more so than in the second step described, as to completely or almost completely permit choking of the wheel and this action may be enhanced somewhat by the employment of a little rosin or rouge. Such treatment of the wheel face by the tallow with utmost sparing necessarily promotes the affinity between the face and the metal particles ground off the work, affording the desired adhesion to substantially fully choke the face in the manner in which this terminology is employed in this specification. According to the operation of the third step now discussed, it is contemplated that the work shall be carried across the face of the wheel in a horizontal plane substantially parallel with the plane of the axis of the grinding wheel, as shown in Figure 7, though the work is disposed at a horizontal angle with respect to the face of the wheel during its movement in opposite directions, depicted by Figure 10.

In the third and last step of my method as above set forth, the final tolerance necessary for the final grinding or completion of the work is obtained and the grinding action straightens out the cross-grains on the metal surface of the work and brings the latter to the ultimate finished condition for use, at which time it reaches the true color of the metal.

It is within the purview of my invention, dependent upon the tolerances that are required for the finished metal parts treated according to the practice above described, that I may use the practise of one or a combination of any two of the steps recited, but it is important and preferable that the grinding wheel shall be resilient and shall be constructed and treated substantially in the manner set forth.

I have described the fineness of the emery employed for the different grinding wheels of the different steps in the sense of relativity of the sizes of the grains employed, and do not wish to be bound to the exact sizes because the grains for each step may be varied somewhat within a desired range of same most suitable for the work to be performed by that particular step.

By the practise of the method above set forth, by the performance of a machine such as hereinafter described, I have accomplished a tremendous saving of time in the finishing of metal parts of different types or kinds, and I have eliminated a great quantity of wastage or spoilage that has heretofore been incident to the finishing of such parts to obtain the tolerances referred to herein as susceptible of being achieved, as compared with previously known methods commonly being used today.

Also, the practise of my invention, has been adopted and used extensively in the manufacture

of metal parts required to be finished to such tolerances as have been secured according to the foregoing description, and which metal parts have been of great consequence and importance to the machines wherein they are used.

Referring to Figures 1 to 4 of the drawings, and the machine therein illustrated, it will be very evident that the work or shaft 23 supported in said machine is disposed to turn about a predetermined axis and, therefore, is not susceptible of being shifted as is the work illustrated in Figures 5 to 10 of the drawings when manually supported. The design of my machine aforesaid contemplates that the grinding wheel 22 shall be operated and shall be adjusted for angular dispositions both vertically and horizontally to perform its grinding action upon the work or shaft 23. It is obvious, according to the showing in Figure 1, that the grinding wheel 22 may be caused to take the positions of relative angularity to the work as depicted by Figures 5, 6, 8 and 9 of the drawings, and is likewise capable of having its face presented to the work while the axis of the wheel is in a horizontal plane parallel to the axis of the work. The universal mounting of the motor cradle 15 is the means whereby the wheel 22 may be shifted along with the motor shaft to present the face of the wheel at the desired angles according to the method depicted in Figures 5 to 10 and described above. Of course, in conjunction with said universal mounting, the tilting of the motor shaft 21 by tilting of the cradle 15 within the cradle 10 also permits of the desired adjustments of the grinding wheel 22 necessary for the practice of the method.

Since it is the adopted practise, according to the method of my invention, generally to check the diameter of the work or the amount of metal ground off, the surface of the work periodically, it is easy for the operator of the machine to effect the desired angular adjustments of the wheel or the adjustment illustrated in Figure 9 between the work checking operations and at the end of the traverse of the carriage 5 with the superstructure framework in which the motor is mounted.

The manner of effecting the desired horizontal and vertical angular adjustments of the shaft and wheel in the machine described, is readily understood by reference to Figure 1.

During the traverse of the carriage 5 in a leftward direction, the axis of the wheel 22 is tilted forwardly by means of loosening the set screw 16 and manipulation of the pinion 18a, the contact of the periphery of the wheel being thereby similar to the contact illustrated in Figure 8. This angular relationship was referred to previously as the horizontal angular adjustment, but it is apparent that in the use of the machine to carry out the described process, when the wheel is adjusted, and the shaft being finished is supported for rotation on fixed centers, this change is a vertical angular change. Similarly, the vertical angular shifting of the wheel respecting the work now becomes a horizontal angular relationship accomplished by rotating the motor and wheel about the screw member 11 as a pivot. The wheel thus assumes the position respecting the shaft, as shown in Figure 5.

Traverse of the carriage 5 in a rightward direction will necessarily involve shifting of the wheel 22 respecting the shaft as illustrated in Figure 8, the shaft being then in the dotted line position in that figure.

The procedure with the grinding wheels of steps two and three, illustrated in Figures 6 and 9, and 7 and 10, respectively, will be carried out in the manner previously described, the wheel being shifted and traversing the shaft or work on the machine, as contrasted with movement of the shaft and shifting of the same respecting the wheel, as set forth in the hand method.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent of the United States, is:

1. In a machine for grinding metal parts to fine finished tolerances, in combination, a support for the work, a grinding wheel having a resilient face, a mounting for the said wheel including complemental relatively movable cradle members disposed one within the other and pivotally connected together, one of which members supports the wheel, instrumentalities for adjusting said complemental members independently to adjust the wheel with its face in positions at a vertical angle and a horizontal angle to the work and for holding the wheel engaged with the work, and means to effect relative bodily movement of the work and wheel including a carriage supporting the other of the complemental members to cause passing of the wheel over the surface of the work to be finished.

2. In a machine for grinding metal parts to fine finished tolerances, in combination, a support for the work, a grinding wheel having a resilient face, a mounting for the said wheel including complemental relatively movable cradle members disposed one within the other and pivotally connected together, one of which members supports the wheel, instrumentalities for adjusting said complemental members independently to adjust the wheel with its face in positions at a vertical angle and a horizontal angle to the work and for holding the wheel engaged with the work, and means to effect relative bodily movement of the work and wheel including a carriage supporting the other of the complemental members to cause passing of the wheel over the surface of the work to be finished, the axis of the pivot connection of the cradle members being disposed to intersect a plane coincident with the surface to be ground by the wheel.

3. In a machine for grinding metal parts to fine finished tolerances, in combination, a support for the work, a grinding wheel having a resilient face, a mounting for the said wheel including complemental relatively movable members, one

of which directly supports the grinding wheel, a pivotal connection between said complemental members the axis of which is substantially in a plane coinciding with the plane of the grinding face of the wheel, means to adjust the wheel supporting complemental members to change the angle of the wheel to the vertical, means to adjust the complemental members bodily to change the angle of the wheel to the horizontal, work supporting axis means generally disposed horizontally crosswise of the grinding wheel face, and means to move the complemental members simultaneously to carry the face of the grinding wheel longitudinally of the work on the work supporting axis.

4. A machine as claimed in claim 3, combined with means to adjust the complemental members bodily to move the wheel in a direction transverse to the work axis.

5. A machine as claimed in claim 3, combined with means to adjust the complemental members bodily to move the wheel in a direction transverse to the work axis, the last means including a lowering and elevating screw.

6. A machine as claimed in claim 3, combined with means to adjust the complemental members bodily to move the wheel in a direction transverse to the work axis, the last means including a lowering and elevating screw, and a frame providing an axis for said screw and forming a part of the means to move the complemental members along the work.

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