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Research of Finishing Machining for Cylindrical Surface of Large-Scale Work Piece

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***Abstract*—With regard to the revolved surface of oversized part beyond the machining range of ordinary grinding machines, this article presents that to achieve cool extruding finishing on an ordinary lathe with the lathe-tool being reformed into cutter of finishing machining. The article analyses thoroughly the principle of the cool extruding finishing method, including the changes of molecular power, the remaining stress as well as the changes of microstructure and, accordingly, comes up with a reasonable cool extruding finishing technical parameter. It points out that the method is rather valuable actually and could be applied in a broad sense.**

***Keywords*—Revolution surface of part, Cool Extruding finishing, Strengthening Mechanism.**

I. INTRODUCTION

For a processed part being, some defects, such as uneven surface, obvious protrusion, traces of lathe-tool, microstructure cracks and some slight tensile stress, etc., will be left on its surface inevitably by almost whatever means of any mechanical processing method. Those defects, though slightly, are likely to have some bad effects on the surface and on the function as well. Thus, some measures have to be taken so as to overcome those defects utmost. The quality of a part's surface, usually a thinner coat after being processed, is determined by the ultimate forming method. Therefore, the quality of a part's surface differs considerably if taking use of different methods of processing technology methods, but also surface quality determines the use of performance parts and life expectancy indicators ultimately.

The rolling machining, precision grinding and grind methods are traditional cold-press cool extruding finishing methods commonly used. The rolling machining method can be applied in a broad sense, it can be used to process cylindrical, inner hole, flat, surface, etc. with such typical ones as holes for oil vessels, pistons and linking rods. Most common rolling methods, such as ball rolling, roller rolling, roll wheel rolling, etc. could be finished by means of specific tools. The precision grinding method is used to reduce the roughness and make it better by removing the extra metal materials on a part's surface, which could be finished on a specific lathe. However, the microstructure cracks and the slight tensile stress could not be changed and improved. What's more, due to the limits of apparatus and tools, it is even more difficult to the surface strengthen of a work piece such as its end planes, its plains and circled sealing surface, not to mention processing it. Its application is also limited due to lower efficiency.

To sum up, it is strongly recommended hereby that the alloy lathe-tool be reformed into cutter of cool Extruding finishing and achieve cool extruding finishing processing for strengthening the surface of a part by means of the relative motion of the parts and the cutters on the lathe.

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II. CUTTER OF FINISHING MACHINING AND PROCESSING PRINCIPLES

Figure 1 shows the structure of the cutter of finishing machining on a stereoscope lathe for a large revolution work piece beyond the processing range on an ordinary grinding. It is made of by grinding a 90° carbide turning tool and requires highly precision as well as the roughness of the surface for a cold stress less than 0.14 μ m (Ra < 0.14 μ m) .

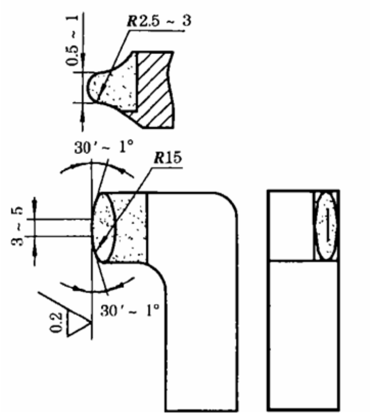

Figure.1 Cutter of Finishing Machining

Figure 2 indicates the processing course: fix the cutter of finishing onto the tool holder and the part onto the worktable; apply some extrusion pressure onto the part's surface through the cutter vertical feed; enforce the part's surface into plastic deformation by means of the extrusion pressure; and then, through the horizontal tool paths and the rotation of the cutter,
enforce the wave peaks of the part's cutting trace into self-deformation and filling in the wave valleys. This could improve the distributing situation for the surface wave peaks and reach the purpose of reducing roughness and upgrading the fatigue strength and corrosiveness-resistance. Remember: be sure to adjust the technological parameters considering different situations on the part's surface while being cool-extruding processed. For example, if any spots or scratches are seen, it indicates more roughness to the edge of the tool and the processing speed is too high; losing coats on the surface indicates too high cold pressure, repeated cold pressure, or poor plasticity of the part.

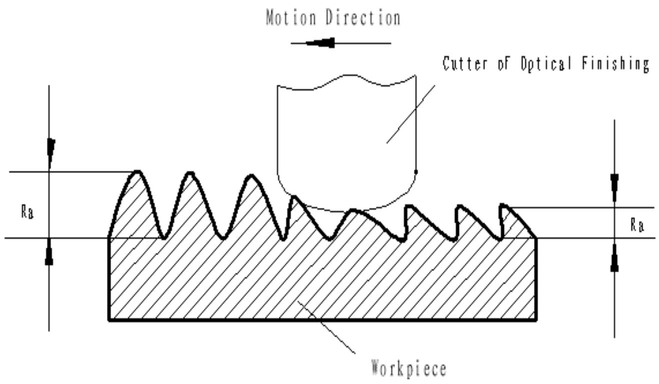

Figure.2 Layout of Processing Course

III. Strengthening Mechanism of Finishing Machining

A. The Deforming Mechanism of Substances

In the course of a part's cool extruding finishing, there exists both the elastic deformation and the plastic deformation. Both types of deformation happen to come due to the mutual motion of the atoms in any solid substances. In the first case, the distance of the motion for an atom from the original position is no more than that of the neighboring atom; with the increase of the infinitesimal force that causes an atom's motion, the distance for an atom to stay away from the original position increases accordingly. In the second case, the distance of the motion for an atom from the original position exceeds that of the neighboring atom, i.e. when the infinitesimal force that causes an atom's motion accumulates to a certain amount, the distance for the atom to stay away from the original position is longer than that of the neighborhood. Under the circumstance, though canceling the outer pushing power, the atom cannot go back to the original position. Instead, it finds out a new balanced position and forms into the solid shape and the permanent change for the size.

B. Prerequisites for Elastic Deformation

The revolution surface of a metal part comes into elastic deformation under load, and will come into plastic deformation with the load increasing. The prerequisite for any section of the metal part to be changed from elastic deformation into plastic deformation is that the stress strength reaches the level of yield stress under the condition of one-way plastic yield. That is, the total yield strength is higher or equals yield stress.

$$\sigma_1 = \frac{1}{\sqrt{2}} \times \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \geq \sigma_S \qquad (1)$$

Under cool extruding finishing condition, if $\sigma_1 = \sigma_s$ (assume the yield limit σ_s equals actual yield stress), the plastic deformation begins to come into being. As the deformation increases, the yield stress σ_s will also increase due to the part becoming harder and harder. To remain the plastic state, the amount for σ_s will increase as well. If square the above and substitute the principle stress differential for shearing stress, then

$$\tau_{12}^2 + \tau_{23}^2 + \tau_{31}^2 \geq 2\sigma_S^2 \qquad (2)$$

Thus the conclusion here should be that under plastic deformation condition, the sums of squares for the principal stress differential is a constant and equals two times of the sum of square for yield stress. So, while cool extruding finishing is being undertaken, with the metal surface being under the condition that the sum of squares for principle stress differential equals or is higher than the two times amount of yield stress due to load coming from outside, the metal's interior structure will slide, shift and come into plastic deformation; it will be extruded into concave from convex. As a result, the roughness on the surface is reduced [1] [5].

C. The causes on surface strengthening for plastic deformation

Due to plastic deformation, the acting forces among the molecules in the undercoat of the metal part have been changed. The acting force consists of two types: the internal force and the additional internal force. The former, also called the internal gathering force, exists inside originally and functions as to keep the balance of each molecule inside in a proper position and keep it remaining its proper size and shape. The latter, so called the additional internal force, comes into being as a result of the molecules' primary relative position being changed considerably due to acting force outside. This force has much to do with the part's deformation and its strength. When loaded with extra force outside, the distance among the molecules inside will increase in the same direction and in turn, the attraction force and repulsion force among the molecules will decrease. Because of the higher degree of the repulsion's change speed and decreasing intensity, the present additional internal force appears to be residual compressive stress. [2]

In the course of finishing machining, the grain and the impurities attached around the edge of the grain are stretched into fiber formation and create tensile stress outside the elastic region; and the elastic resuming force of the region, in turn, can make the extruded coat of the fiber organism create residual compressive stress. This residual compressive stress can restrict the newly-created fatigue cracks and keep the existed micro fatigue cracks in a closing state, which could lessen K_{max}, the maximum sum of stress strength for the cracks, and lower the extending drive force for the cracks. Also, the combination of this residual compressive force and applied tensile stress can lower the actual tensile stress on a certain region for the metal part, which can upgrade the fatigue strength considerably (See Figure 3 Schematic diagram of cold pressed to improve fatigue strength limit).

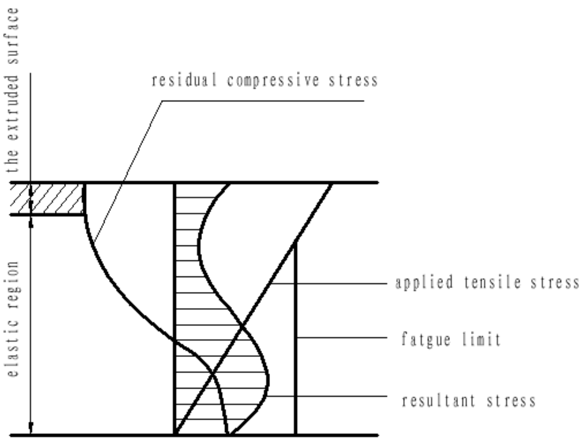

Figure.3 Schematic diagram of cold pressed to improve fatigue strength limit

Besides, cold pressed deformation can change the structure of the organism inside a metal part. The minor grain boundary, a grain boundary with slight angle, is formed as a result of a series of dislocation for the edges of tool. This minor grain boundary will increase more and more apparently in the course of plastic deformation and the deformed micro structure increases and becomes delicate. And the more minor grain boundary, the more delicate of the grain and the more dislocation density. These dislocations accumulated around the minor grain boundary and their mutual intervening stress can prevent the motion of the dislocation, make it difficult to slip and then help increase the deformation resistance and yield strength for the metal.

There exists the linear relationship for the metal material between its resistance function and yield strength within some extent. That is to say, the metal material with higher yield strength can make it difficult to slip and deform, and therefore it can lessen the peeling-off and splitting due to the surface crack's extending. So, it is of higher fatigue strength. Ref. [4] shows that, the relationship between the yield strength and the grain size D as well as the minor grain d can be:

$$\sigma_S = k_1 / \sqrt{D} \quad (3)$$

$$\sigma_S = k_2 / \sqrt{d} \quad (4)$$

In it, k_1,k_2 are indexes connected with the material. The yield strength increases as D and d decreases. Thus the becoming-delicate process for the grains and minor grains can up grade the yield strength of the material, which, of course, can increase the resistance strength and lengthen its service life for the material.

To sum up, the finishing processing method could make the grains on the surface be stretched into fiber formation and create residual compressive stress and delicate grains. This is the internal mechanism to strengthen the parts surface and to improve the of fatigue life.

IV. Selection of Technical Parameters for Finishing Machining

The extruding amount determines the sum of extruding force and the latter can have a direct impact on the effect of the former. If the extruding amount is too large, the lathe-tool will wear and tear promptly, which will result in the poor quality of the part's surface; on the contrary, if the extruding amount is too small, it will be too difficult to reach the processing target. Therefore, it is better to select the minimum extruding amount on the basis of ensuring the reasonable precision. Normally, when finishing carbon steel or alloy steel, it is better to select the extruding amount of 0.025-0.04mm while select 0.03-0.05mm for processing cast iron. If the material of a part is softer (e.g. ferrous metals), it is better to select larger extruding amount. For a part with a smaller size, it is better to select a smaller extruding amount so as to avoid the total deformation. Since the hardness of the cold pressed surface, the roughness of the surface before finishing as well as the wall thickness of the part could have impacts on the extruding amount, it is better to have trial finishing machining work before the confirmation of the most reasonable parameter amount. A higher finishing machining speed can make the temperature among the touching region for the cutter of finishing and surface of the part higher, make the yield strength on the surface lower, make the part ready to deform and lower the wave peak on the surface and thus upgrade the roughness on the part's surface. However, it is easier to destroy grease coating and result in some scratches and burning spots on the surface if the extruding speed is too high. Therefore, a best extruding speed is needed accordingly (this can be obtained through testing). When processing ferrous metals, the best speed can be 0.5-1m/ s and the cutting amount can be 0.01-0.03mm/ r. A larger amount can be selected when finishing an outer round while a smaller amount for an internal hole.

V. Conclusion

The test and practice on finishing machining method demonstrate that, by means of this method, the roughness on a surface could be improved to a degree of up to70 %-90 %; and the hard coating of a part can be 2mm thick after being processed. Therefore, this revolution surface of part based on lathe tool finishing machining has acquainted both advantages of rolling machining and precision grinding. It can reduce efficiently the surface roughness, upgrade the residual stress, strength the coating hardness of a part and reduce the microstructure defects significantly. To sum up, this method has the virtues of improving the quality of the products, upgrading a part's fatigue strength as well as bettering the mutual adapting ability of the part and its counterpart considerably. It can extend the service life of a product, offer higher efficiency and lower cost, be operated in an easy way and extend the range of finishing machining. With this method, both ferrous metals and nonferrous metals could be processed. It is of higher application value definitely.

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