Research on Surface Quality of 38CrMoAl Polished Based on Abrasive Water Jet

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Abstract—Because the screw surface is slender and complex, it is difficult to process by traditional polishing methods. In order to improve the surface quality of screw, the abrasive water jet polishing (AWJP) technology was used to polish 38CrMoAl steel, which is commonly used in screw. The effects of different inlet pressure, target distance and abrasive particle size on surface roughness are analyzed. The experimental results show that with the increase of inlet pressure, the surface roughness first decreases and then increases. With the increase of target distance, the surface roughness first decreases and then increases. The smaller the abrasive particle size, the better the polishing effect.

1. Introduction
Screw is the core component of plastic molding equipment, widely used in machining centers, CNC lathes, injection molding machines and other mechanical equipment. With the rapid development of manufacturing industries such as automobiles, instruments, medical equipment, and vehicle and ship equipment, people have higher and higher requirements for the accuracy of screw surfaces. The surface quality of the screw not only directly determines the surface accuracy of the product, but also improves the strength and wear resistance of the material to a certain extent. Because the surface of the screw is slender and complex, it is difficult or even impossible to process it by traditional methods. Therefore, a suitable surface treatment method is needed to improve the surface quality of screw. Abrasive water jet polishing (AWJP) is a new cold working technology developed on the basis of water jet machining. It has the advantages of wide application range, high machining accuracy and no thermal deformation [1]. It can polish the surface of special-shaped curved surface, slender pipe fittings and difficult-to-machine materials.

AWJP is to polish the workpiece surface by spraying the mixture of water and abrasive onto the workpiece surface, and making use of the cutting effect of abrasive on the workpiece material surface. In recent years, researchers have done a lot of research on AWJP technology, and obtained many valuable scientific research results. PENG et al. explored the influence of abrasive particle size on material removal mode. The results show that the particle size has great influence on the removal of materials. The removal rate of materials in plastic mode increases with the increase of particle size, and the smaller the particle size, the smoother the surface [2]. ANTHONY et al. carried out abrasive water jet polishing experiment on tungsten carbide, and found that under certain working conditions, polished abrasive particles can be embedded in tungsten carbide surface, and the surface can be avoided from being embedded with abrasive particles by using granular abrasive particles and low fluid pressure [3]. Zhu et al. carried out experimental research on polishing hard and brittle materials with abrasive water jet. It is found that the kinetic energy exerted by a single abrasive particle on the
surface of hard and brittle materials can be divided into fracture erosion and ductile erosion, and the ductile erosion method with low pressure and small erosion angle can be used to realize precision surface machining [4]. Matsumura and others put forward the process methods of glass abrasive water jet crack-free machining micro-grooves and fluid polishing micro-channels, which improved the surface finish of milled micro-grooves to 25nm [5]. Yansong Zhu and others put forward a hybrid polishing method using amino thermosetting plastic (ATP) particles with medium hardness for abrasive jet polishing (AJP). Experimental study shows that ATP has better surface finish than traditional AJP process for aluminum alloy polishing [6]. In order to study the random properties of abrasive particle size and the elastic rebound of abrasive from the workpiece surface, Wang et al. put forward a prediction model of the surface topography during abrasive jet polishing of Shi Ying glass. Through research, it is found that low pressure jet makes abrasive more likely to produce elastic workpiece deformation, and the elastic workpiece deformation may be restored [7]. Abrasive water jet machining (AJWM) of 7071 aluminum alloy (Al 7071) was studied experimentally by Gowthama et al. The results show that a better surface finish can be obtained when the traverse speed is 100 mm min-1 and the velocity of silicon carbide abrasive is 300 g min-1 and the interval distance is 0.5 mm [8].

In this paper, the abrasive water jet polishing technology was used to study the surface roughness of 38CrMoAl, which is a common material of screw, and the influence of different process parameters on the surface roughness of the material was studied. It provides reference for polishing of screw.

2. methods and materials

2.1. Experimental setup

Fig. 1 shows the equipment of AWJP experiment, which mainly includes fixture, water pipe, nozzle, work table, position adjudicator and abrasive pipe. The main polishing steps are as follows:

a) Install the 38CrMoAl steel piece on the work table, adjust the distance and position between the piece and the nozzle by fixture and position adjuster.

b) Connect the abrasive pipe to the abrasive and the water pipe to the high pressure pump.

c) Adjust the inlet pressure and start the high-pressure pump.

d) After polishing, turn off the high pressure pump, take out the workpiece, and use the surface roughness meter shown in Fig 2 to measure the roughness.

2.2. Experimental conditions

2.2.1. Surface roughness in different inlet pressures

In order to study the surface roughness of 38CrMoAl steel parts under different inlet pressures, the fixed-point abrasive water jet polishing experiments were carried out after grinding them to a roughness of about 5 μm. The diameter of the nozzle is 1.5 mm. The abrasive is garnet with a particle
size of 200 mesh. The single polishing time is set to 20S and the target distance is 15mm. The inlet pressures are set to 3, 6, 9, 12 and 15MPa respectively.

2.2.2. Surface roughness in different target distance
In order to study the surface roughness under different target distances, the single polishing time is set to 25S, the inlet pressure is set to 7 MPa, and the target distances are set to 5, 10, 15, 20 and 25mm respectively. Other conditions are the same as 2.2.1.

2.2.3. Surface roughness in different abrasive particle sizes
In order to study the surface roughness under different particle sizes, the single polishing time is set to 20S, the inlet pressure is set to 7 MPa, and the particle size distribution of abrasives is set to 80, 120 and 200 mesh. Other conditions are the same as 2.2.1.

3. Results and Discussions

3.1. Effect of inlet pressure
Fig. 3 shows the variation trend of inlet pressure and workpiece surface roughness. It can be seen that the surface roughness first decreases and then increases with the increase of inlet pressure. When the inlet pressure is 3MPa, the jet velocity is slow. The impact force of abrasive on the workpiece surface is limited, which leads to the lack of material removal ability of jet, and the surface roughness of polished workpiece is still large. With the increase of jet pressure, the material removal ability of the jet increases, and the jet begins to micro-cut the workpiece surface, which is beneficial to reduce the surface roughness of the workpiece. However, when the pressure is greater than 6MPa, the surface roughness gradually increases. This is because with the increase of the jet pressure, the kinetic energy of the jet becomes larger, the removal ability of a single abrasive particle becomes stronger, and the workpiece surface is subjected to excessive cutting action, resulting in obvious concave-convex feeling, thus making the workpiece surface roughness become larger.

Fig. 3 Effect of inlet pressure on surface roughness
3.2. effect of target distance

Fig. 4 shows the change trend of target distance and workpiece surface roughness. It can be seen that the surface roughness first decreases and then increases with the increase of target distance. When the target distance is 5 ~ 10mm, the jet is in the initial stage. Because of the small target distance, the jet kinetic energy is large and the focus of jet is good. At this stage, the abrasive impact per unit area of the workpiece is concentrated, and the impact deformation of the material is large, so the surface roughness of the material is high. With the increase of target distance, the interaction between jet and air increases. As the jet diverges gradually, its kinetic energy begins to weaken, which weakens the abrasive removal ability per unit area of the workpiece. The abrasive begins to micro-cut the workpiece surface. Therefore, the surface roughness of the workpiece also increases. When the target distance is greater than 15mm, the jet diverges further and the impact of abrasive on the workpiece becomes weaker due to the increase of the target distance. At this stage, the removal effect of abrasive on materials is not enough, the cutting effect is gradually uneven, and the surface roughness of workpiece begins to increase.

![Fig.4 Effect of Target Distance on Surface Roughness](image)

3.3. effect of abrasive particle sizes

Fig. 5 shows the variation trend of abrasive particle size and workpiece surface roughness. It can be seen that the higher the mesh number, the higher the surface roughness, that is, the smaller the abrasive particle size, the smoother the material surface. This is because the abrasive and water are fully accelerated under the action of high-pressure pump, which leads to the energy obtained by large-size abrasive is higher than that of small-size abrasive, and the removal effect of large-size abrasive on materials is too large, thus increasing the surface roughness of workpiece.

![Fig.5 Effect of Abrasive Particle Size on Surface Roughness](image)

4. Conclusion

The effects of inlet pressure, target distance and abrasive particle size on surface roughness of 38CrMoAl steel were studied by AWJP experiment, the conclusions are obtained as below:
(1) After polishing, the surface roughness of the workpiece first decreases and then increases with the increase of inlet pressure. When the inlet pressure is from 3 to 6MPa, the roughness decreases gradually, and the minimum roughness is obtained at about 6MPa, and then increases continuously.

(2) With the increase of target distance, the surface roughness of workpiece first decreases and then increases. It decreases gradually when the target distance is 5 to 15mm, and the minimum roughness is obtained when the target distance is about 15mm, and then increases continuously.

(3) Through the study of the abrasive particle size and the workpiece surface roughness, the results show that the higher the abrasive particle mesh number, the smoother the workpiece surface is.

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