Numerical Simulation Analysis of High-precision Dispensing Needles for Solid-liquid Two-phase Grinding

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Abstract. In order to investigate the effect of abrasive flow polishing surface variable diameter pipe parts, with high precision dispensing needles as the research object, the numerical simulation of the process of polishing high precision dispensing needle was carried out. Analysis of different volume fraction conditions, the distribution of the dynamic pressure and the turbulence viscosity of the abrasive flow field in the high precision dispensing needle, through comparative analysis, the effectiveness of the abrasive grain polishing high precision dispensing needle was studied, controlling the volume fraction of silicon carbide can change the viscosity characteristics of the abrasive flow during the polishing process, so that the polishing quality of the abrasive grains can be controlled.

1. Introduction

Abrasive Flow Machining (referred to as AFM), also known as extrusion grinding or extrusion honing, mainly used for polishing shaped holes and complex cavities and other traditional methods difficult to process the site, its principle is to help the pressure provided by the machine, the semi-solid processing medium containing high hardness abrasive grains is extruded through the inner and outer surfaces, edges and the channels of the workpiece, so as to achieve a certain processing purposes.

Abrasive grain processing technology is the last century developed by the United States, initially used in the aerospace field of complex geometric shape of the alloy workpiece deburring processing, after decades of development, has been applied in a number of areas. Domestic and foreign scholars related to its polishing method and polishing mechanism for in-depth study, and made a lot of results[1,2].

Sushil M et al. on the silicon carbide composite materials for abrasive grain polishing test study, the effects of processing parameters on the removal rate of the material, the change of surface roughness and surface morphology were observed, through the final experimental analysis, it is concluded that the squeezing force is the most significant factor affecting the roughness[3]. Wan S et al. Analyzed the effects of non-linear viscoelasticity and temperature on the viscosity of abrasive media, a non-elastic non-Newtonian model is used to obtain the shear dilution of the abrasive medium in the flow state, and the establishment of wall slip model, the wall shear rate function is used to calculate the relative motion between the abrasive medium and the wall[4]. Ding Jinfu et al. Analyzed the polishing mechanism of abrasive grain flow from the perspective of stress tensor, and according to Bowden theory, when the abrasive grains adhere to the surface of the workpiece, with the carrier flow forward, in the workpiece surface slip phenomenon, so that uneven surface of the workpiece plastic deformation; In addition, the abrasive particles in the radial force, will be pressed into the workpiece surface, produce plowing, so as to achieve the purpose of removing the material[5]. Zhao Jia et al. use the viscometer to get the relationship between the viscosity of the abrasive, based on the Rabinowicz
single particle cutting model, the wear relationship of abrasive viscosity and temperature was obtained. The effects of abrasive viscosity on the metal wear were studied[6].

With the development of various dispensing processes, high-precision dispensing needle used in the LCD panel frame coating, vibration package, CCD sealant coating, BGA package coating range. Therefore, the accuracy of dispensing needles are getting higher and higher, high-precision dispensing needle surface quality directly affect the use of dispensing performance, when the high-precision dispensing needle hole on the inner wall of the existence of burr phenomenon, not smooth or residual pollutants, it is easy to cause dispensing uneven or lead to easy to plug the needle, so improve the surface quality of high-precision dispensing needles, it is very important to study the precision finishing of high precision dispensing needles[7-11].

2. Numerical Simulation of High Precision Dispensing Needles for Polishing Gravel

In this paper, high precision dispensing needle as the research object, The surface processing characteristics of the solid - liquid two - phase abrasive grains were numerically simulated. In the case of ensuring that the inlet pressure and the outlet pressure are constant, the effects of the volume fraction of silicon carbide particles on the dynamic pressure and turbulence viscosity of high precision dispensing needle channel were studied. As shown in Fig. 1 for the high-precision dispensing needle three-dimensional solid cross-section model, wherein the diameter of the small hole is 0.2 mm, big hole diameter of 2mm.

![Figure 1](image1.png)

**Figure 1.** high-precision dispensing needle three-dimensional solid cross-section model

After the non-structured hexahedral mesh is divided into high precision dispensing needle model, using the import and export pressure boundary conditions for numerical simulation, according to the actual situation, set the inlet pressure to 6MPa, the volume fraction of silicon carbide is set to 0.1, 0.15, 0.2 and 0.25 for numerical simulation, the simulation results of the multi - physics coupling field under four volume fraction are obtained. Fig. 2 shows the dynamic pressure cloud image at different volume fractions.

![Figure 2](image2.png)

**Figure 2.** Dynamic pressure cloud diagram under different particle volume fraction

As can be seen from Fig. 2, from the entrance to the exit, dynamic pressure gradually increased, layered more obvious, the maximum pressure in the small hole, that is, abrasive flow on the hole grinding the most serious, polished the best.
Select the entry section as data 1 area, cross hole as data 2 area, small hole as data 3 area, the numerical values of the dynamic pressure values listed in the three data areas are shown in Table 1.

**Table 1** Different abrasive volume fraction of high precision dispensing needle dynamic pressure data distribution table

| Particle volume fraction | Dynamic pressure (10^5 MPa) |
|--------------------------|----------------------------|
|                          | Data 1 area | Data 2 area | Data 3 area |
| 0.1                      | 0.184       | 8.54        | 71.4        |
| 0.15                     | 0.190       | 8.60        | 71.6        |
| 0.2                      | 0.195       | 8.69        | 71.7        |
| 0.25                     | 0.199       | 8.76        | 71.8        |

Analysis of Table 1 data, can be derived from different abrasive volume fraction under the pressure changes: (1) First, the change of the dynamic pressure under the same particle volume fraction is analyzed, can be analyzed by the table to see the number of 3 areas> data 2 area> data 1 area, abrasive into the workpiece cavity, the minimum pressure at the abrasive inlet, with the inflow of abrasive, dynamic pressure gradually increased, dynamic pressure distribution of the distribution of more obvious, this is because the workpiece from the entrance to the hole of the cavity diameter is more smooth, no special mutation caliber, the pressure at the cross hole of the workpiece increases significantly, indicating that the abrasive at this time on the cross hole have a greater grinding effect, That is, the workpiece rounded; While the dynamic pressure in the small hole to reach the maximum, at this point the abrasive movement is more intense, the hole on the inner wall of the best polishing effect. (2) Second, the analysis of different abrasive volume fraction under the pressure of the situation, from the table analysis, with the abrasive grain volume fraction gradually increased, the whole workpiece flow in the dynamic pressure has increased, this is because the abrasive concentration increases, abrasive and the workpiece surface contact area increases, the grinding effect on the wall of the workpiece increases, thereby improving the abrasive flow on the workpiece surface polishing effect.

Under the same initial conditions, the numerical simulation of the turbulence viscosity in the grinding process of the workpiece under different volume fraction is carried out. The turbulence viscosity cloud images with different particle volume fraction are shown in Fig. 3.

![Turbulence viscosity cloud images](image)

*Figure 3.* Cloud turbulence viscosities under different volume fraction

It can be seen from the turbulent viscosity cloud diagram under different volume fraction of Fig.3, due to the movement of viscoelastic silicon carbide abrasives in turbulent state, under the same inlet pressure boundary conditions, with the increase of the abrasive volume fraction, turbulence viscosity increases, due to the velocity gradient and viscoelasticity of the fluid, will inevitably lead to abrasive grain on the workpiece surface friction, so the abrasive particle volume fraction increases, the turbulence viscosity increases, thus improving the polishing effect of the workpiece.
3. Conclusion
Through the numerical analysis of the simulation results of the high precision dispensing needles, under certain pressure and abrasive volume fraction, the effect of volume fraction of silicon carbide on the processing effect was simulated by changing the effect of solid-liquid two-phase abrasive grains. The changes of dynamic pressure and turbulent viscosity in the process are analyzed. Can get the greater the dynamic pressure, the greater the turbulence viscosity of the grinding effect has a significant impact, which can improve the polishing effect of abrasive grain flow.

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