Rigid flexible coupling dynamic analysis of piezoelectric jetting dispenser based on ADAMS

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Abstract. As dispensing technology needs accurate flow control, high performance spray dispensing has become the mainstream of dispensing technology. In this paper, the rigid flexible coupling dynamic simulation of piezoelectric jetting dispenser is carried out by using the dynamic simulation software ADAMS. In this process, the displacement and velocity of the needle under certain conditions are obtained. Then, according to the simulation results, the jetting dispenser driven by piezoelectric stack and the experimental test system are established. The dispensing process of the piezoelectric jetting dispenser is studied. The displacement of the needle in the dispensing process of the piezoelectric jetting dispenser is obtained by laser sensor, and the needle speed is obtained by analyzing the displacement of the needle. The experimental results are in good agreement with the simulation results, which proves the accuracy and feasibility of the simulation, and provides a method for the design and research of piezoelectric jetting dispenser.

1. Introduction

The dynamic performance of the amplification mechanism directly determines the dispensing performance of the piezoelectric jetting dispenser, so the dynamic analysis is of great significance.

In the field of jetting dispensing, many experts have carried out in-depth research [1-4]. Can Zhou designed a kind of piezoelectric jetting dispenser with lever typed mechanical amplification mechanism [5], established a multi physical coupling simulation model, and carried out numerical simulation using MATLAB Simulink. Na Wang designed the piezoelectric jetting dispenser with diamond amplification mechanism [6], and realized the kinematic analysis of the diamond amplification mechanism with a single degree of freedom dynamic model. Lingyun Wang has designed a kind of piezoelectric jetting dispenser driven by double piezoelectric actuator with triangle mechanical amplification mechanism [7], and carried out the hydrodynamic analysis of dispensing process. Wenjian Cui has designed a piezoelectric jetting dispenser with a pin joint [8], established the dynamic simulation model through SolidWorks and Simmechanics, and carried out dynamic analysis.

Because most of the researches are based on the magnifying mechanism as a rigid body or simplified simply, in order to solve the model more accurately, it is necessary to make the amplification mechanism flexible. In this paper, the piezoelectric jetting dispenser is taken as the research object, and the virtual prototype model of the piezoelectric jetting dispenser is established by SolidWorks and ADAMS.
software. Through the dynamic simulation of rigid flexible coupling, the change law of the speed and displacement of the needle is obtained. The influence of voltage on the dynamic characteristics of the piezoelectric jetting dispenser was studied. The displacement and velocity of the needle in the dispensing process of the piezoelectric jetting dispenser were obtained by laser sensor, which verified the accuracy of the simulation. Compared with the ordinary Simulink dynamic simulation, this method does not need to establish a complex function model, and the modeling is convenient and fast, and the simulation process is intuitive and real-time controllable. The experimental results show that the simulation method is reliable and provides a method for the design and optimization of jetting dispenser.

2. Experimental system
In order to evaluate the simulation model of the piezoelectric jetting dispenser, the experimental platform is established as shown in Fig. 1. In this study, a self-made controller was used to drive the piezoelectric actuator. Precise pressure regulating valve is used to control the filling pressure. A kience laser sensor (lk-g80) was used to measure the needle displacement. The sampling frequency of the sensor can reach 50 kHz and the accuracy can reach 0.2 μm, the velocity can be obtained by solving the displacement difference.

![Figure 1. Experimental system.](image)

3. Simulation model of jetting dispenser
Adams/view is a core module of Adams. As a user-centered interactive graphic environment, ADAMS/view provides abundant constraint library and force library. It can analyze the statics, kinematics and dynamics of mechanical system, and draw the curves of displacement, velocity, acceleration and force. In ADAMS/view, as long as the relevant boundary conditions are set, the dynamic performance of mechanical system can be analyzed without the need to establish complex mathematical model and programming. Adams/view is compatible with Solidworks. SolidWorks is used for 3D modeling and assembly of jetting dispenser, and then the model is imported into Adams/view to define the material and boundary conditions of each part, as shown in Fig.2.
In order to be more in line with the actual situation, the piezoelectric actuator is not simplified as a spring in the simulation model, but the mass of the piezoelectric actuator is the same as the real situation by setting the material parameters, and the stiffness of the piezoelectric actuator is 50N/μm. In ADAMS/view, all parts are rigid bodies by default, but the hinge and amplification arm of piezoelectric actuator and amplification mechanism will deform. In order to simulate the working process of the injection dispensing valve, the flexible module in ADAMS/view was used to make the piezoelectric actuator and amplification mechanism flexible. The piezoelectric actuator is fixed with the ejector block, and a force is applied on the ejector block to simulate the driving force of the piezoelectric actuator. The function of force is as follows:

![Figure 2. Dispenser Adams model diagram.](image1)

![Figure 3. Driving force of piezoelectric actuator.](image2)
\[ F = \text{STEP}( \text{SIN}(2\pi P \cdot \text{time}) \cdot -0.454, 0, 0.31, F_N) \]  

Where \( P \) is the working frequency of the piezoelectric actuator, \( F_N \) is the maximum output force of the piezoelectric actuator under the corresponding voltage, as shown in Fig. 3. It is the driving force of the piezoelectric actuator at the frequency of 500 Hz and the working voltage of 80 V. The collision force is added between the ejector block and the amplification mechanism, between the hammer and the needle, and between the needle and the nozzle to simulate the working state of the injection dispensing valve when collision occurs. Finally, damping was added to the recovery spring of the needle to simulate the effect of the glue. After the simulation is completed, the displacement, velocity, and acceleration of the marked points on each part can be viewed to obtain the dynamic characteristics.

4. Result and discussion

The velocity before the collision between the needle and the nozzle is an important index to measure the dynamic performance of the jetting dispenser. In order to evaluate the dynamic characteristics of the new jetting dispenser, the displacement curve of the needle was measured with a laser sensor. The experimental conditions are as follows: the driving voltage is 80 V, the working frequency is 500 Hz, and the duty ratio is 40%. As shown in Fig. 4, the displacement and velocity curves of the needle are obtained by experiment and simulation. Since the piezoelectric actuator is initially subjected to continuous high pressure input, the needle initially contacts the nozzle. When the power is turned off, the amplification mechanism begins to return to the balance position, and the needle starts to move upward. When the needle reaches the highest point, the power is turned on again, and the piezoelectric actuator receives high voltage input, which makes the needle move downward and collide with the nozzle, and the displacement reaches about 0.12 mm. When the needle collides with the nozzle, the maximum velocity of the needle is about 0.32 m/s. Through the comparison of displacement curve and velocity curve, it can be seen that the experimental results are basically consistent with the simulation results. The simulation model and method are reliable.

In order to explore the influence of voltage on the dynamic characteristics of piezoelectric injection valve needle, a voltage of 60 V to 110 V was applied to the piezoelectric actuator at the frequency of 200 Hz, and the duty ratio was 50%. As shown in Fig. 5, with the increase of driving voltage, the displacement of needle will increase. It should be noted that the needle will have elastic deformation when it works, but in the simulation model, the part is set as a rigid body, and the deformation is ignored. It can be seen from Fig. 8 that with the increase of driving voltage, the movement speed of the needle also increases.
Figure 4. Displacement and velocity of the needle.

Figure 5. Needle displacement and velocity under different voltages.
5. Conclusion
In conclusion, according to the simulation model established by SolidWorks and Adams, an experimental platform is built to verify the simulation results, and the experimental results are basically consistent with the simulation results. The velocity of the needle can reach 0.32 m/s at the stroke of 0.12 mm. The displacement and speed of the needle can be adjusted by changing the driving voltage. The rigid flexible coupling dynamic analysis method based on ADAMS also provides a theoretical basis for the development of piezoelectric jetting dispenser.

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