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Three-dimensional flow field mathematical model inside the pilot stage of the deflector jet servo valve

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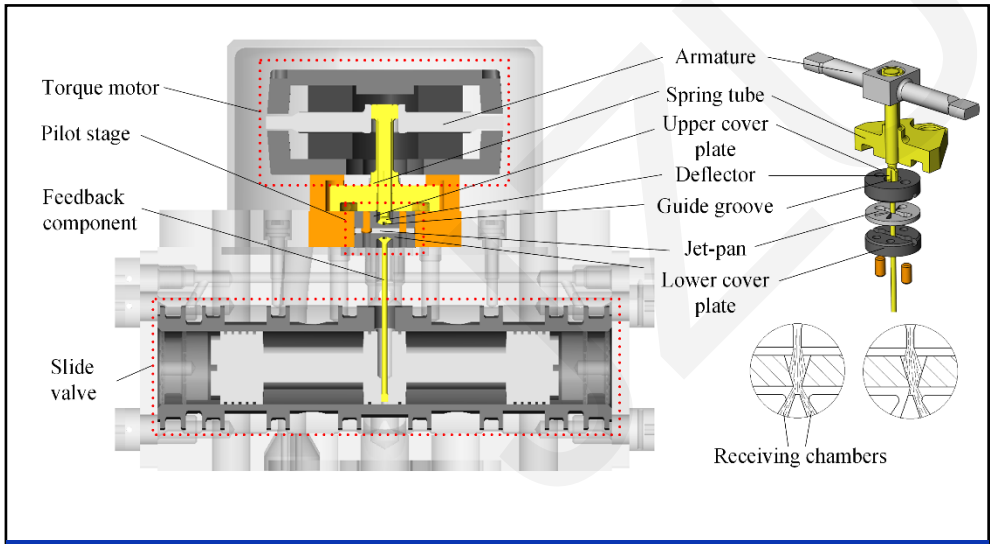
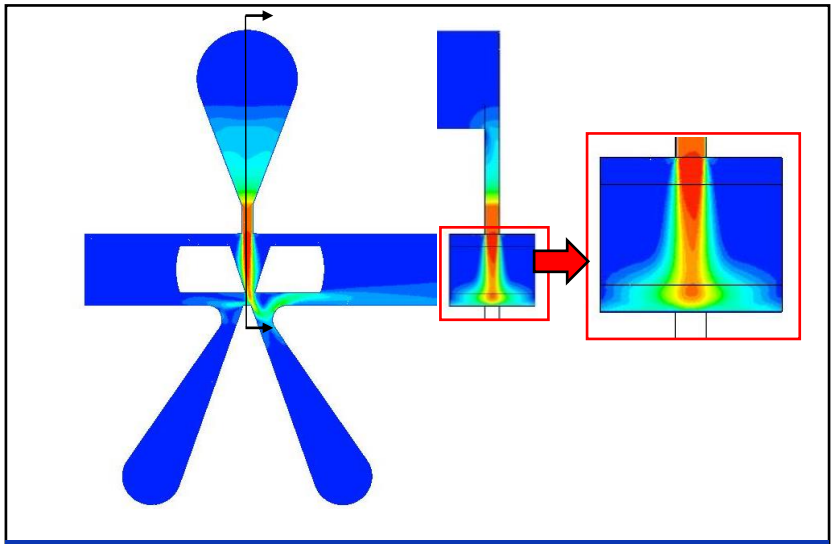
Key words: Deflector jet servo valve; Pilot stage; Three-dimensional jets; Jets entrainment; Static characteristics; Mathematical model

Introduction

- The two-dimensional(2D) mathematical model of the pilot stage of the deflector jet servo valve(DJSV) can not accurately describe the flow field structure because the expansion of the jets in the direction of jet-pan thickness was ignored.
- In order to describe the flow field structure and calculate the static characteristics of the pilot stage more accurately, a three-dimensional (3D) mathematical model of the flow field which is more in line with the real state is proposed, and the static characteristics of the pilot stage are obtained.



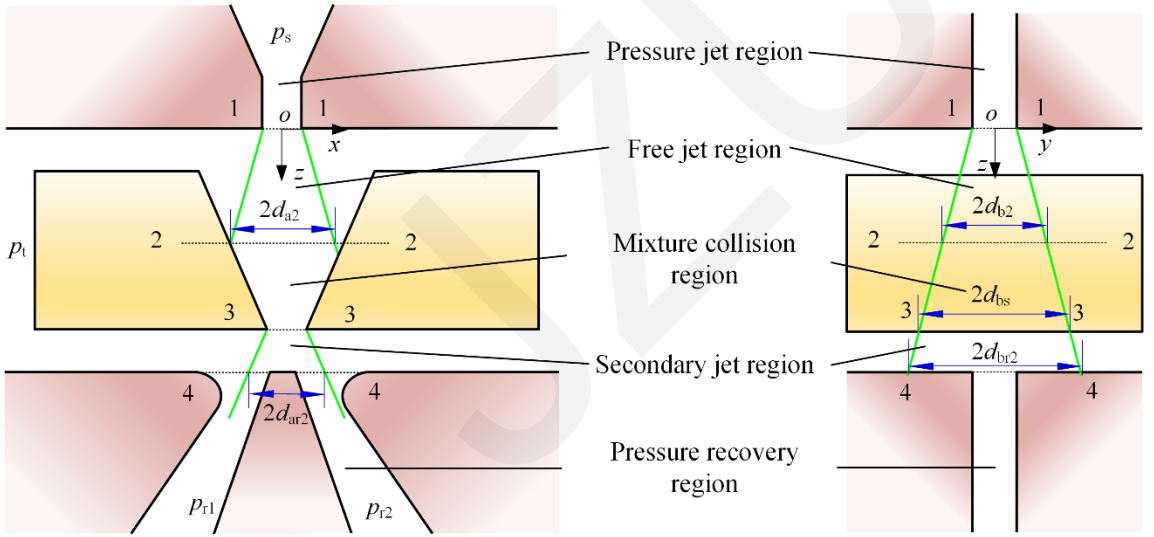
Working principle of the DJSV



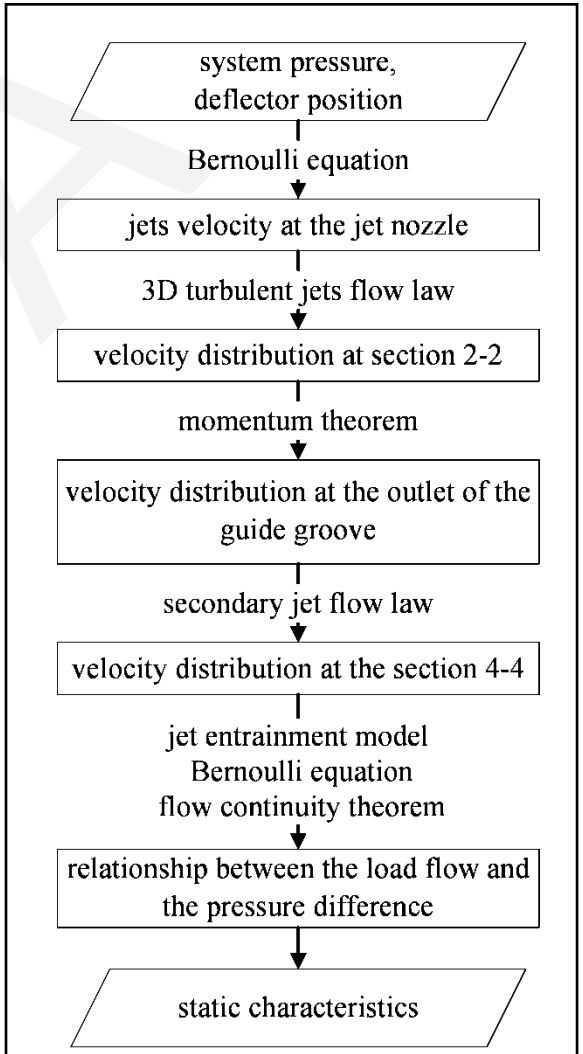
Three dimensional flow field in pilot stage

Method

- The flow field of the pilot stage is divided into five regions.
- Bernoulli equation and momentum theorem are applied to obtain the velocity distribution law of each region, and the 3D mathematical model of the pilot stage is established.
- Based on the 3D mathematical model, the static characteristics of the pilot stage are obtained



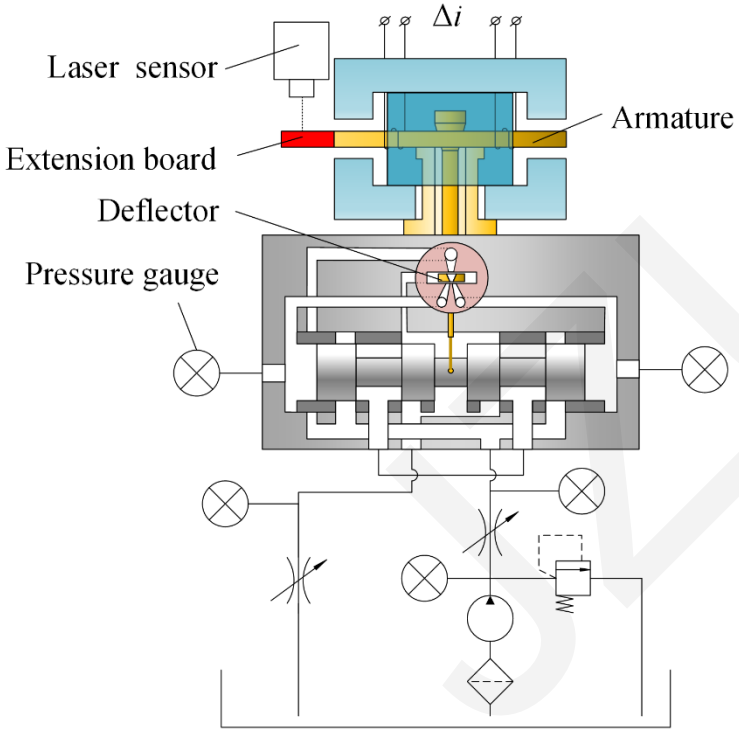
Flow field partition diagram



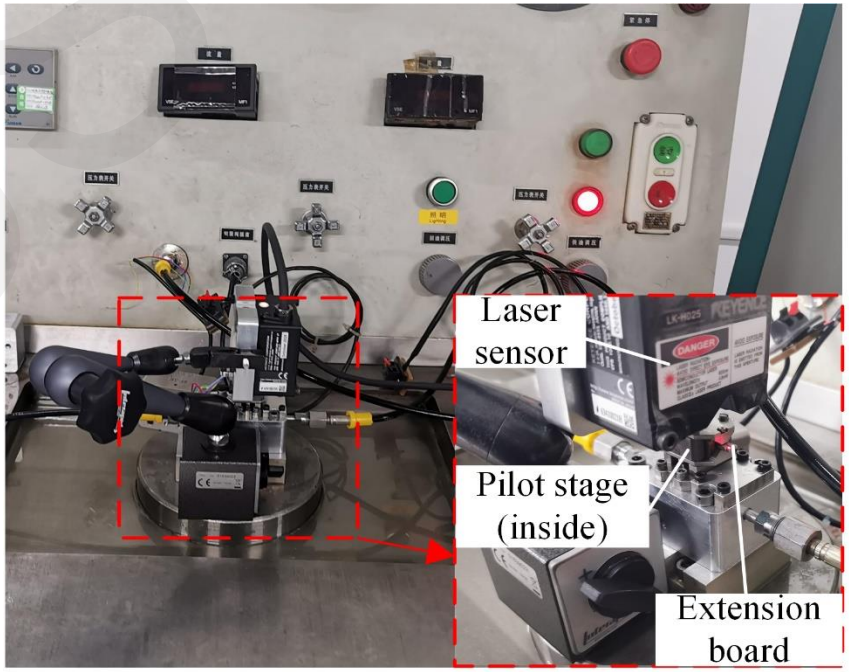
Calculation process of static characteristics

Experiment

- By **indirectly** measuring the deflector displacement under different signals, **the cut-off load pressure characteristics** of the pilot stage under different oil supply pressures are obtained.



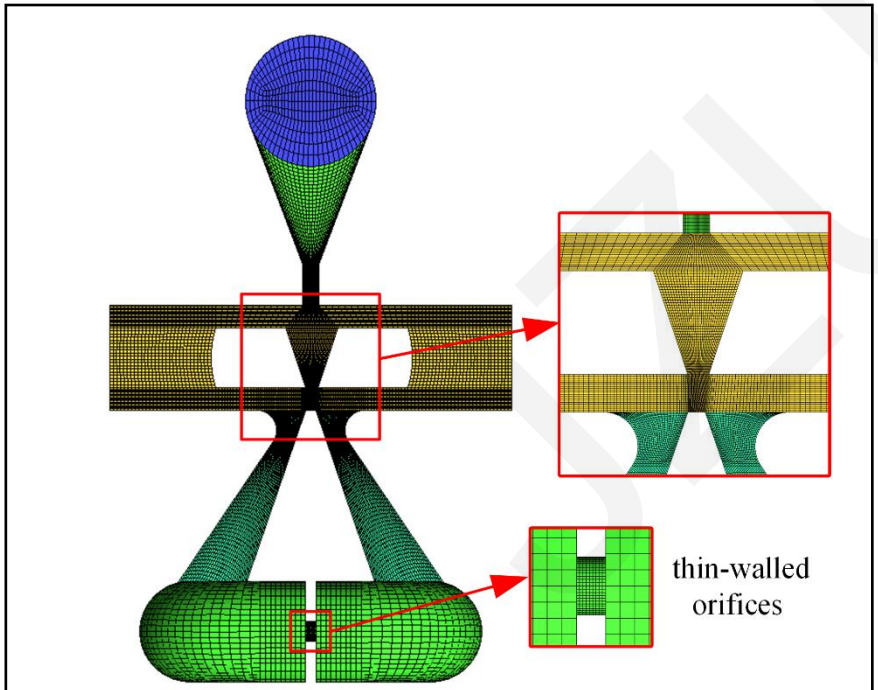
Schematic diagram of experimental set-up



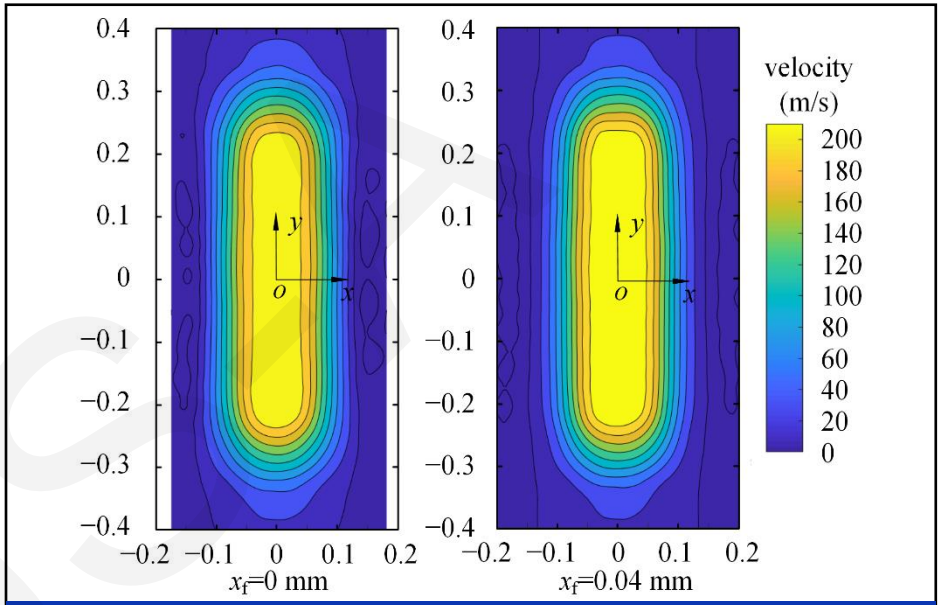
Experimental setup

FEA Simulation

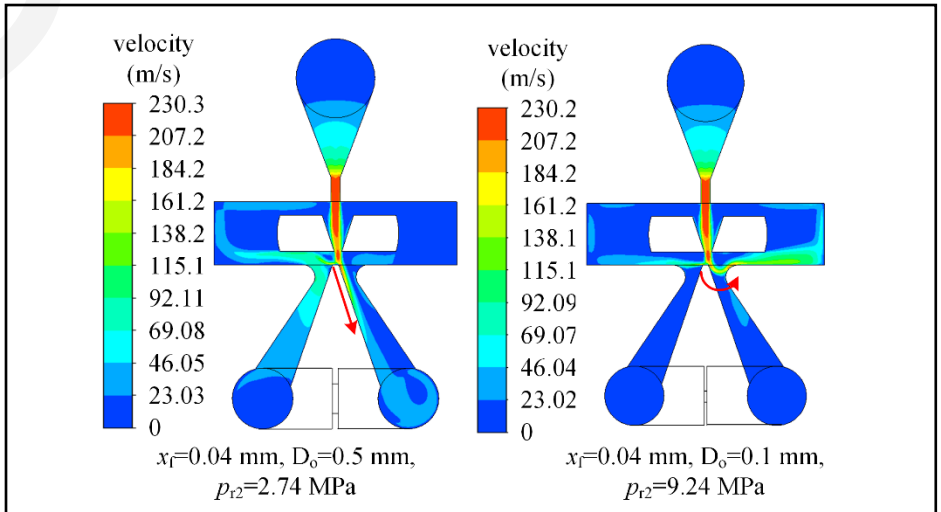
- A thin-wall orifice is used to simulate the load between two chambers, and orifices with different diameters can simulate the influence of different loads on the flow field.



Schematic diagram of the experimental set-up



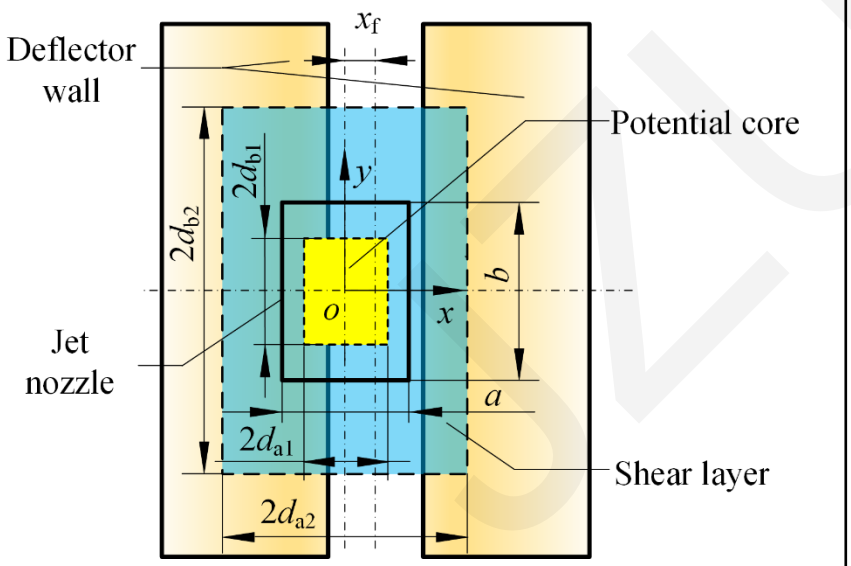
3D velocity distribution at section 2-2



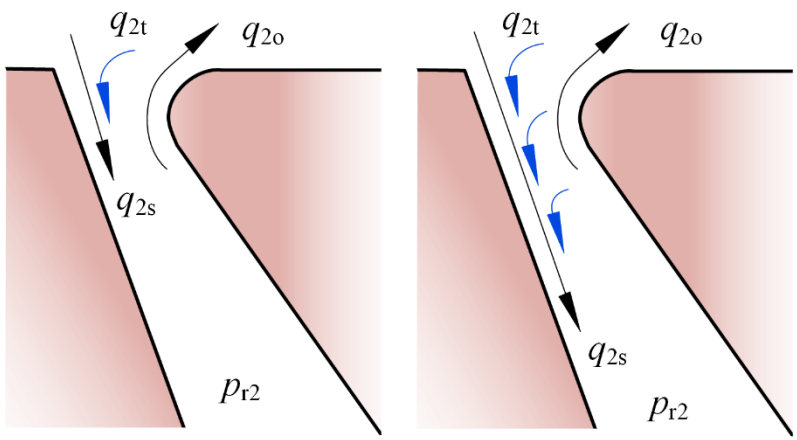
Jet entrainment in receiving chamber

Innovation

- The **3D expansion** of the jet is considered.
- **The 3D turbulent jet model** is used to describe the flow field structure in the **free jet area**, and the jet velocity distribution expression in this area is proposed.
- The **jet entrainment model** is proposed in the pressure recovery area, and the coupling relationship between the jet flow and the recovery pressure in the receiving chamber is established.



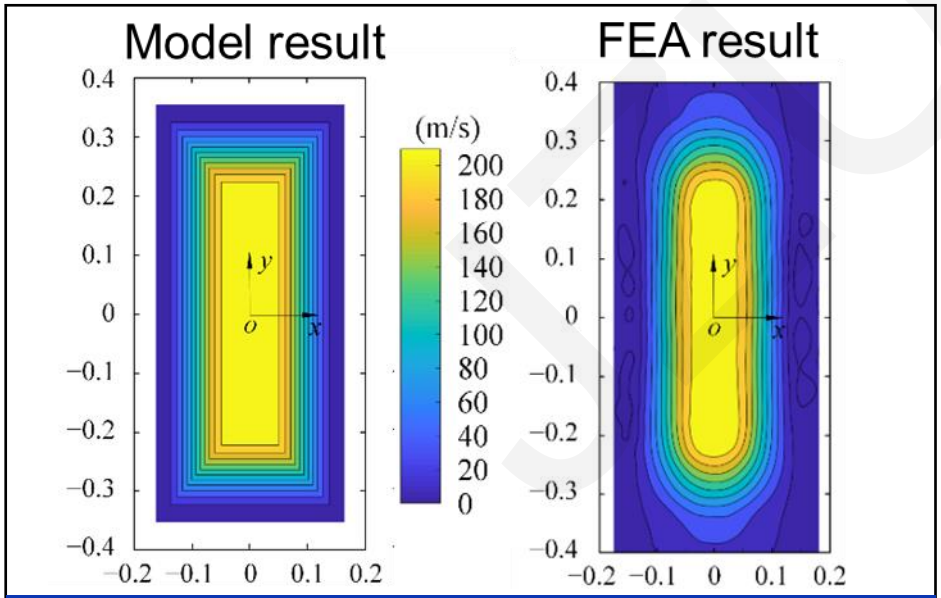
Schematic diagram of the free jet region



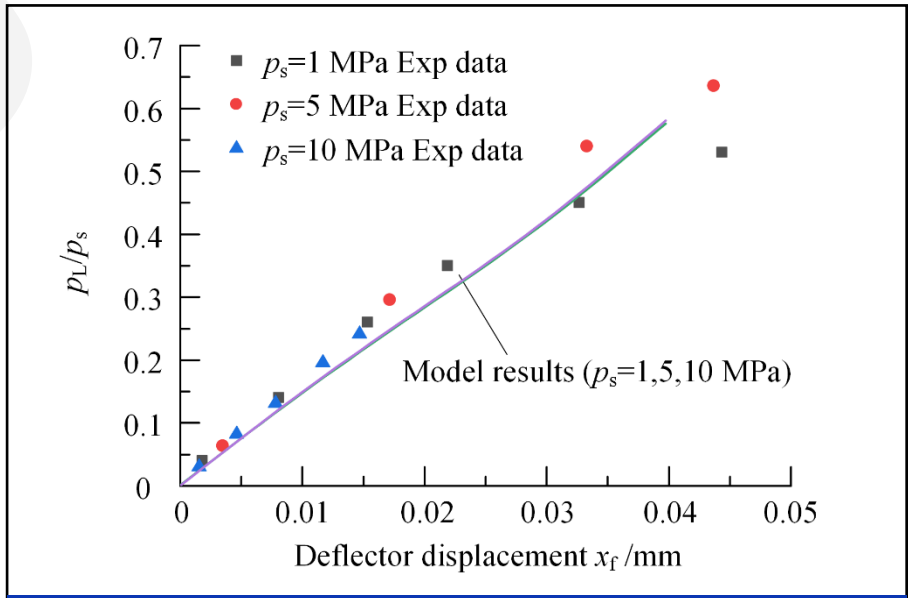
Schematic diagram of jet entrainment

Conclusion

- The jet in the pilot stage flow field belongs to three-dimensional jet, which can more accurately describe the structure of the flow .
- The isovelocity line in the free jet area is close to the straight slot shape and can be described by a rectangular isovelocity line. The entrainment jet model proposed in this paper can describe the coupling relationship between jet flow and recovery pressure in the receiving chamber.
- The dimensionless cut-off load pressure characteristics are basically the same under different supply pressures. The experimental results are in agreement with the theoretical results.



Comparison of velocity distribution of section 2-2



Dimensional cut-off load pressure characteristics