# Numerical Simulation of the Dynamic Process for Positive Displacement Motor by Immersed Boundary Method

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## Abstract

The positive displacement motor (PDM) is a typical hydraulic machine, which is widely used in oil-drilling, geologic exploration and so on. In our study, the immersed boundary method (IBM) is applied to simulate the whole dynamic process for this particular fluid-structure interactive system, which includes the FEM and FDM modeling for the both of solid and fluid domains of PDM, separating and reuniting of fluid domain when PDM works, the problem of contact and deal between its rotor and stator, and the numerical scheme respectively. At last, the pressure and stress distribution of the elastomeric housing attached to the stator of PDM is determined, which is not sufficiently researched before and of importance to PDM's work-life.

**Keywords:** PDM; IBM; FSI; FEM; FDM

## 1. Introduction

The PDM consists of a bypass valve, power section, transmission assembly and bearing assembly. In this study, the power section is our main interest. The power section of a PDM consists of a shaft in an elastomeric housing which is one lobe more than the shaft in configuration. Difference of configuration between the shaft and stator creates the cavity. That is the power source of PDM [Samuel G et al. (1997); Samuel G et al. (2003); Samuel G et al. (2006); Samuel G (2007)]. The seal cavity composed by compressing the shaft with fluid drives the shaft in an eccentric rotation inside the elastomeric housing without slipping. Revolution and rotation motion of the shaft are generated. The rotation motion is the output part which is used to drive other devices in engineering [Regener T, (2005)].

Theoretical basis of this work is the immersed boundary method. It was first used in reference to a method developed by Peskin (1972) to simulate cardiac mechanics and associated blood flow [Peskin C S, (2002)]. It is also widely used in engineering, such as the interactions of solid movement and fluid flow [Mittal R, (2005)], dynamic responses of heart devices [Peskin C S, (1977); Peskin C S, (1972)], modeling anguilliform swimming [Tyson R, (2008)], and 3-D analysis of parachute performance [Kim Y, (2009)], etc.

Two different types of numerical models are conducted for comparison; that is, five-lobed shaft and six-lobed shaft of PDM. Determination of the relationship between configuration difference and performance of PDM are obtained and presented under the same load cases. Pressure and stress distribution of the elastomeric housing are obtained by the programmed computation of immersed boundary equations.

## 2. Numerical modeling

Positive displacement motor is the power section of screw drillings. It consists of two main sections, the shaft (rotor) and stator. The stator is made up of steel housing outside and elastomeric housing inside. Three different configurations of PDM are calculated in this work which makes the relations between dynamic performances and lobes more clear with comparison. Cross sections of finite element assembly for 5-lobed, 6-lobed motors are presented in Fig. 1.

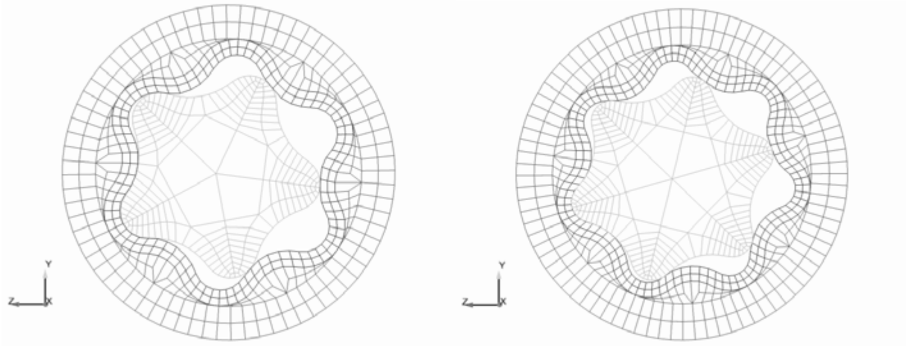

**Fig. 1 Cross section of finite element assembly of PDM**

Free surfaces of solid region are taken as interactions of the fluid and solid parts. Surfaces between the shaft and elastomeric housing have a contact definition. Interactions exist between solid parts too. Fig. 2 shows the immersed boundary between the fluid and solid regions.

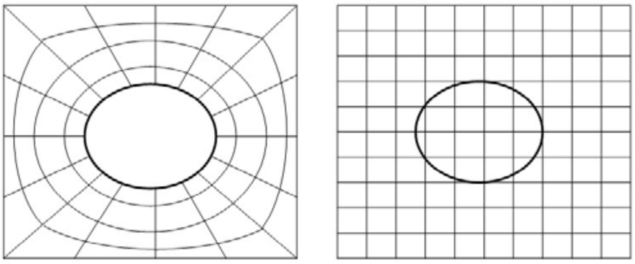

**Fig. 2 Body conformal mesh and immersed boundary mesh scheme**

## 3. Results

Pressure and stress distribution are obtained and contours are discussed below. Direction rotation of shaft is counter clockwise while it is clockwise for revolution of the shaft.

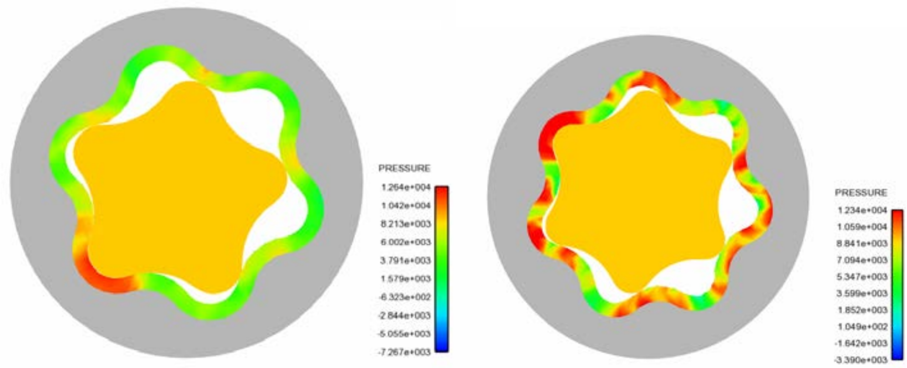


**Fig. 3 Pressure distribution**

Contours of pressure and effective stress on cross section of the motor are shown in Fig. 3 and Fig. 4. Position of the chosen cross section is on the middle plane of the axial direction. Results on the cross sections represent the qualitative distribution property only. The contact parts of the lobes and housing are of the maximum pressure and effective stress. During revolution motion, when contact is building up, the lobe would extrude the housing and when contact is receding, the lobe would degrade the extrusion of housing. In conclusion, the effective stress on the slide-in side is greater than that on the slide-out side which is demonstrated in the following.

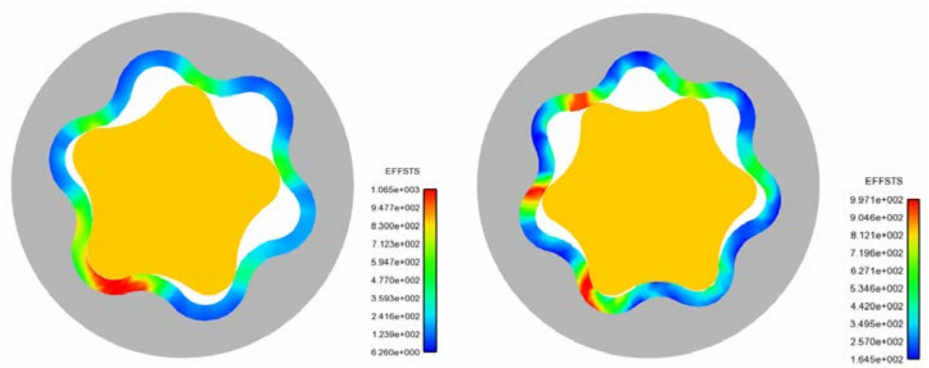


**Fig. 4 Stress distribution**

## 4. Conclusion

The numerical simulation of PDM using the immersed boundary method category is accomplished successfully in this paper. Fluid region and structure region are cut apart on the immersed interface and immersed boundary scheme is built in this way. Immersed boundary pressures have been calculated and comparison results give us an idea that a larger lobe number lead to larger sealing pressure. Numerical results of stress state show the stability of elastomeric housing and for successive working of PDM.

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