

# Numerical Investigation on Tip Clearance Effects on Pressure Fluctuations in an Axial Flow Pump



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Long Abstract

## Introduction

Pressure fluctuations have been extensively investigated in radial pumps[1-3], but the work related to pressure fluctuations in axial pumps is relatively scarce[4-6]. In addition, the influence of tip clearance on pressure fluctuation needs to be examined in detail. Furthermore, pressure fluctuations have been obtained only on some selected points in CFD simulations or some limited measuring positions in experiments, thus resulting in possible neglecting of some important features due to the limited points of investigation. In this paper, the pressure fluctuation inside the whole pump has been calculated through a post-processing at all grid nodes. The standard deviation of unsteady pressure denotes the amount of pressure variation for a serial of fluctuating pressures. It is assumed to be more accurate to quantify the pressure fluctuation than the method of peak-to-peak difference of unsteady pressure. In addition, the influence of blade tip clearance on pressure fluctuation has been examined.

## 1. Numerical Methodology

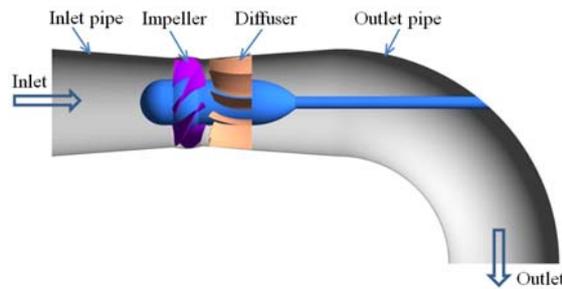


Figure. 1 Computational domain of the pump

The axial flow pump under investigation is shown in Fig. 1 in a three-dimensional view. The outer diameter of the impeller blade is  $D_2=0.3\text{m}$ , with a tip clearance of  $0.3\text{mm}$  to the impeller casing wall. The impeller has 6 three-dimensional blades, equipped with 11 two-dimensional vanes for the diffuser. The design rotating speed is  $n=1450\text{ rpm}$ , the design flow rate is  $Q=0.33\text{ m}^3/\text{s}$ , and the design head is  $H=8.5\text{ m}$ .

## 2. Results and discussion

The unsteady pressure at each grid node consists of two parts: the time-averaged part depending on the grid node location, as expressed in Eq. (1), and the fluctuating one changing periodically with the relative position between the rotor and stator during the impeller rotation, as defined in Eq. (2).

$$\bar{p}(\text{node}) = \frac{1}{N} \sum_{i=0}^{N-1} p(\text{node}, t_0 + i\Delta t), \quad \tilde{p}(\text{node}, t) = p(\text{node}, t) - \bar{p}(\text{node}) \quad (1)$$

The non-dimensional pressure coefficient  $Cp_{sdv}$  is defined in Eq. (2):

$$Cp_{sdv}(\text{node}) = \frac{\sqrt{\frac{1}{N} \sum_{i=0}^{N-1} \tilde{p}(\text{node}, t_0 + i\Delta t)^2}}{0.5\rho U_2^2} \quad (2)$$

where  $N$  is the sample number during the last 2 impeller revolutions for the statistics,  $t_0$  is the start time for the transient statistics and  $\Delta t$  is the time step used for the simulation.

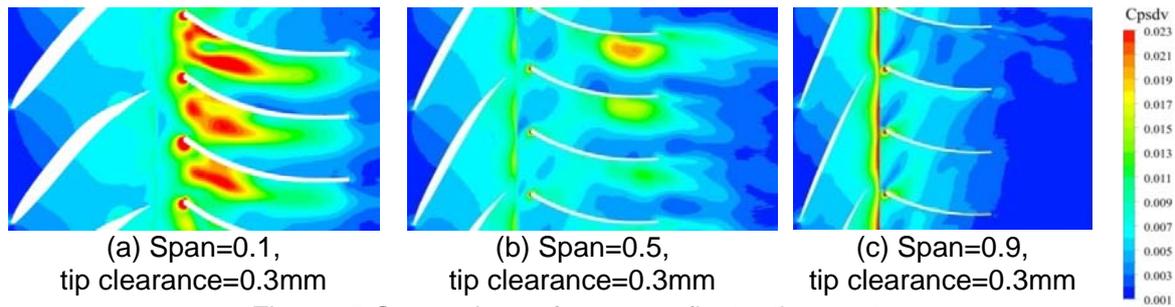
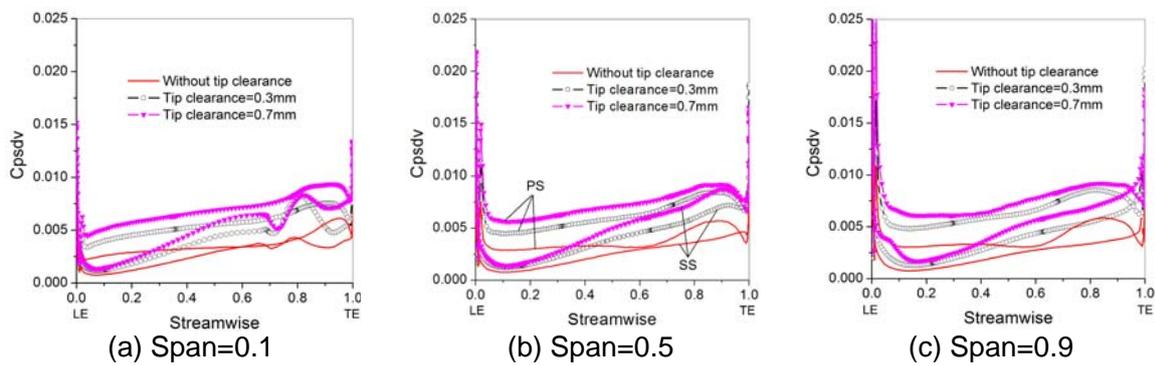


Figure 2 illustrates pressure fluctuation contours at tip clearance of 0.3mm, colored with  $Cpsdv$  defined in Eq.(2) on different blade-to-blade surfaces for different sizes of tip clearance: 0, 0.3mm and 0.7mm. In the impeller,  $Cpsdv$  on the impeller pressure side is bigger than on the suction side at all three blade heights, and it increases generally from the impeller leading edge (LE) to trailing edge (TE). At the impeller outlet, it can be observed clearly that  $Cpsdv$  increases generally in the impeller blade height direction from near hub (Span=0.1) to near shroud (Span=0.9), this could be due to the fact that the tip clearance affects the flow originally from the blade tip near the impeller shroud. In addition, the quantitative comparison of  $Cpsdv$  on the impeller blade is plotted in Fig. 3. The tip clearance effect on pressure fluctuation can be easily observed.  $Cpsdv$  becomes bigger with the increase of tip clearance at all blade heights, and this trend becomes more pronounced from the LE to TE.



## References

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