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Annie-Claude Bayeul-Laine, Patrick Dupont, Lucio Miccoli, Giovanna Cavazzini, Antoine Dazin, et al.. FLUID LEAKAGE EFFECT ON ANALYSIS OF A VANED DIFFUSER OF SHF. 15th International Symposium on Transport Phenomena and Dynamics of Rotating Machinery, ISROMAC-15, Feb 2014, United States. 8 p. hal-00967445

HAL Id: hal-00967445

<https://hal.science/hal-00967445>

Submitted on 28 Mar 2014

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FLUID LEAKAGE EFFECT ON ANALYSIS OF A VANED DIFFUSER OF SHF

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Keywords: Pump, diffuser, PIV measurements, numerical calculations, probes

Introduction

The paper presents the results of numerical analysis on the local and global internal flow behaviour at the inlet of the vaned diffuser of a radial flow pump model, taking into account the effect of fluid leakages for various flow rates and a given rotation of speed.

For each flow rate, numerical calculations were performed both with two different boundary conditions:

- Without any leakage effects.
- With calculated leakage effects

The numerical simulations were realized with the two commercial codes: i-Star CCM+ 8.02.011 (at LML), ii-CFX 10.0 (at University of Padova). RANS unsteady calculations, with a $k-\omega$ RNG model were performed with Star CCM+. Fully unsteady calculations of the whole pump were done with CFX with DES turbulent method (Cavazzini [1]).

For each flow rate, different angular positions of the impeller are considered.

First part of the paper shows global comparisons between numerical and experimental results already presented in ref [2-3], for which the effects of fluid leakage due to the gap between the rotating and fixed part of the pump model were found to be interesting to be analysed.

Second part is devoted to the local comparisons of flow structures at the inlet section of the diffuser, without and with leakages only with Star CCM+.

Leakage modeling

Two sources of fluid leakage occur (Fig. 1):

- The first one between the inlet and the impeller (leakage 1)
- The second one between the impeller and the diffuser (leakage 2)

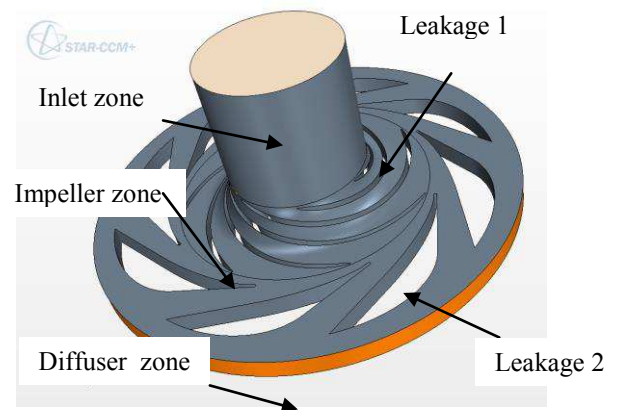


Fig.1 Numerical model

The two fluid leakages are taken account with the two codes:

- In CFX (Fig.2) , the seal systems both at the impeller inlet and outlet were modelled (At the labyrinth of the seal system close to the impeller inlet the mass flow rates determined from the experimental data was prescribed. At the impeller outlet the leakage mass flow rate was controlled by the known experimental pressure in the large plenums upstream the labyrinth).

- In Star CCM+, the sketches of the gaps are really taken account (Fig. 3, [4]), a complete meshing was realized including the real geometry of the gaps and external domain far upstream the labyrinth. In this respect, boundary conditions include the relative casing of the model.

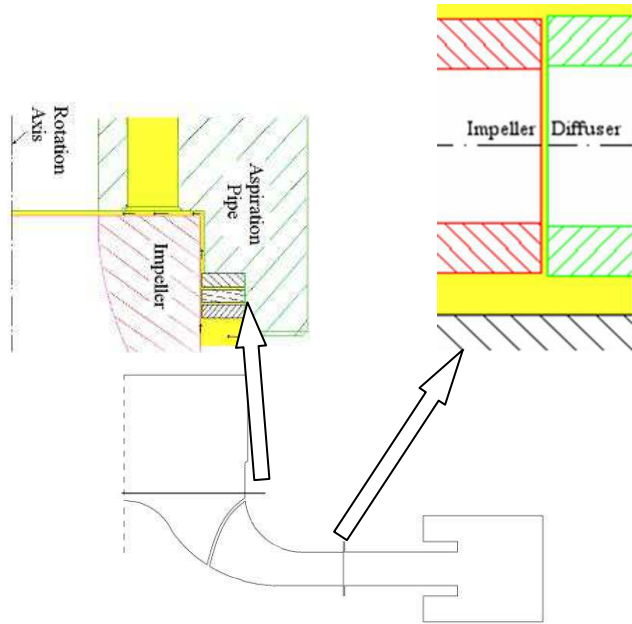


Fig.2 Fluid leakage models in CFX

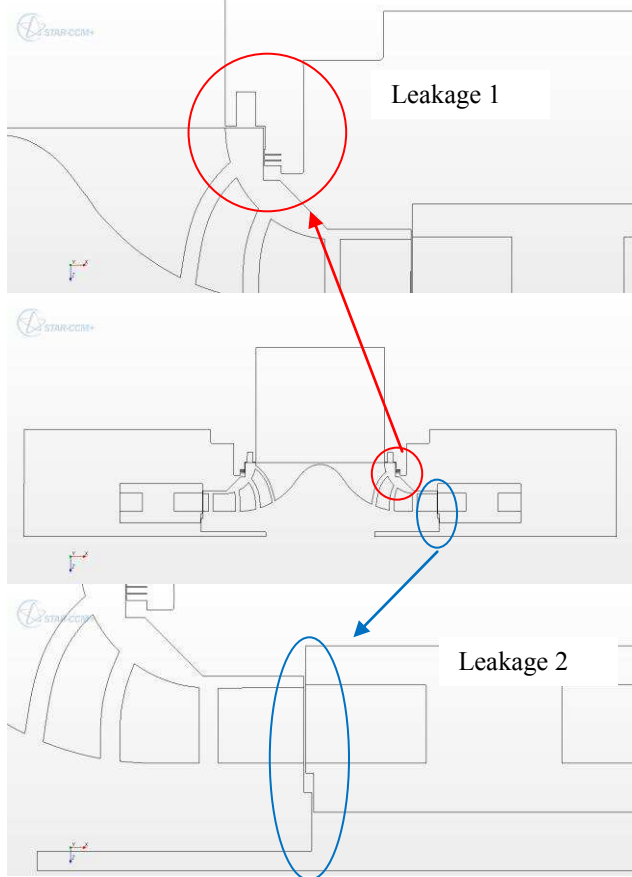


Fig.3 Fluid leakage models in Star CCM+

Global results

Global results of total theoretical head pump are in good agreement between Euler one dimensional approach and frozen rotor calculation. Unsteady calculation results, performed for the two non-dimensional flow rates, give the same level, as it can be seen in figures 4 in which:

$$Q^* = Q/Q_i \quad (1)$$

$$\Psi_{is} = C\Omega / (\rho Q U_2^2 / 2) \quad (2)$$

$$\Psi_t = dp_v / (\rho U_2^2 / 2) \quad (3)$$

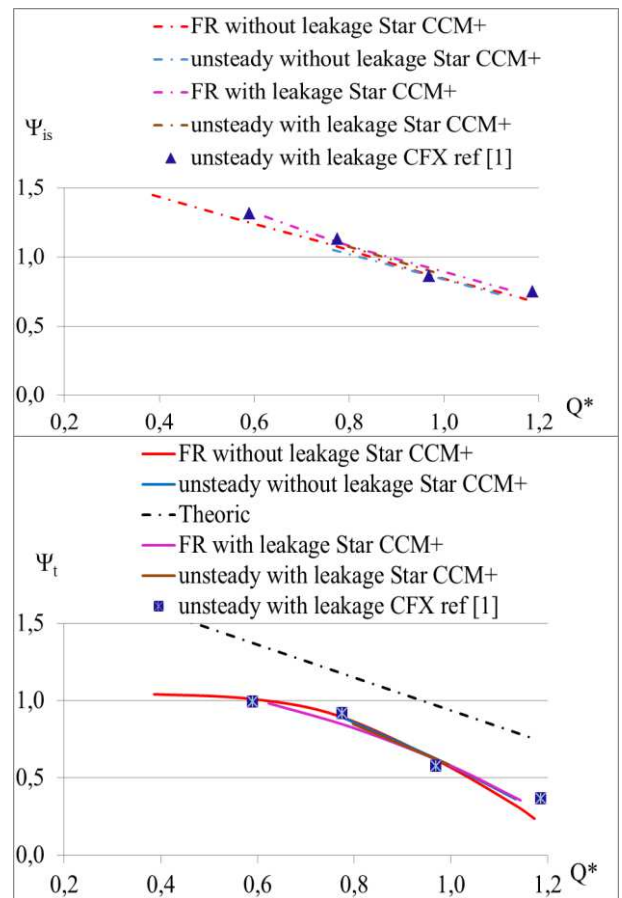


Fig.4 Pump non-dimensional head curves

Fluid leakages are calculated in each code for three different locations (inlet, hub side and shroud side) for the two codes. In star CCM+ frozen rotor and unsteady calculations are performed.

Analytical solutions, based on singularities, are also calculated.

All results are presented in Figure 5, fluid leakage are considered positive if they income inside the domain.

The values of non-dimensional flow rates of fluid leakages are defined by equation (4).

$$Ql^* = Ql/Q_i \quad (4)$$

As can be observed, at the inlet gap, all methods lead to quite same results. In case of Star CCM+, fluid leakages are smaller at high flow rate.

Concerning, leakages at hub and shroud sides, the amount of flow rate depends on the flow rate in the pump. At low values of Q^* , a positive leakage between impeller and diffuser was observed. At high values the tendency inverses as shown in figure 6.

These tendencies were also observed in previous study [4].

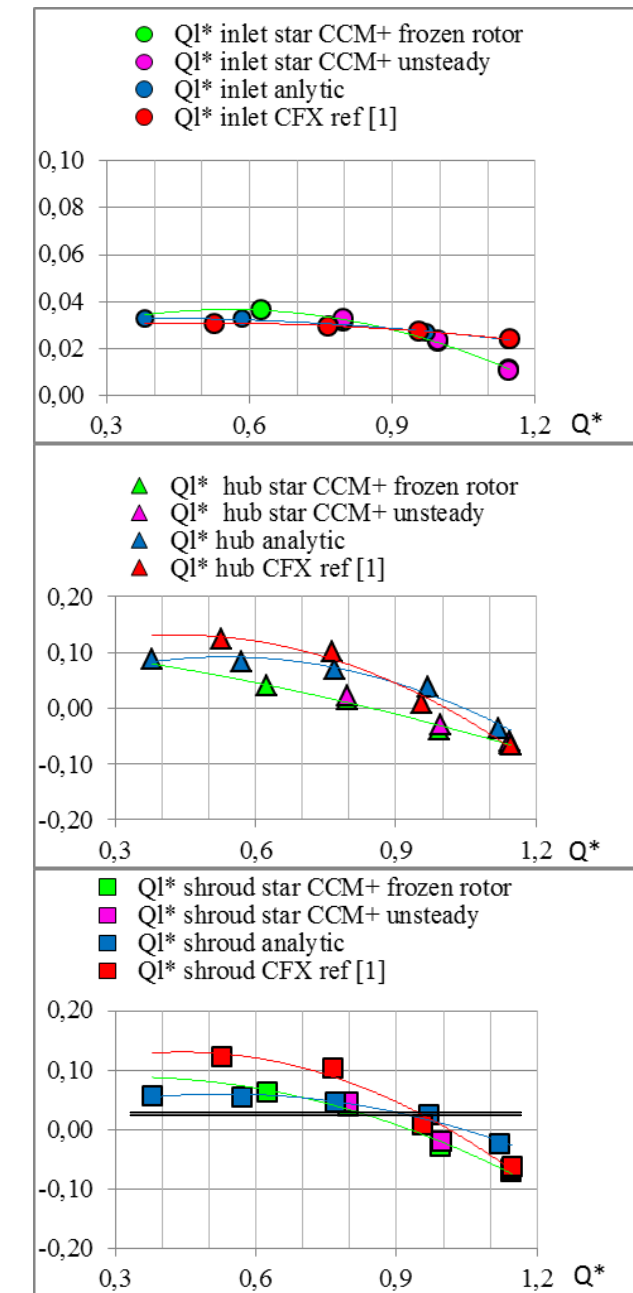


Fig.5 non-dimensional fluid leakages

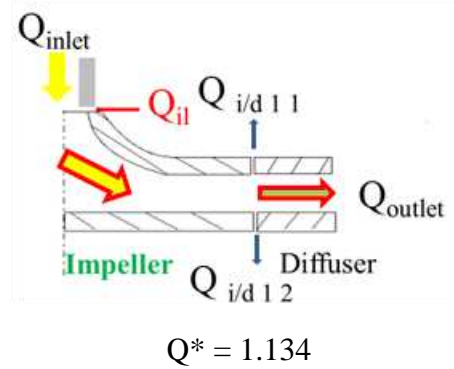
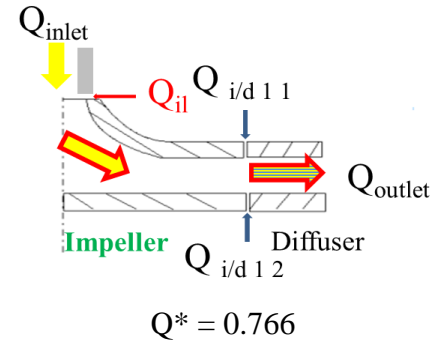


Fig.6 Fluid leakage results

Local velocity and pressure fields

Among all the numerical calculations that have been performed, only results for two specific flow rates are shown in this paper. These flow rates correspond to a positive and a negative leakage flow between impeller outlet and diffuser inlet.

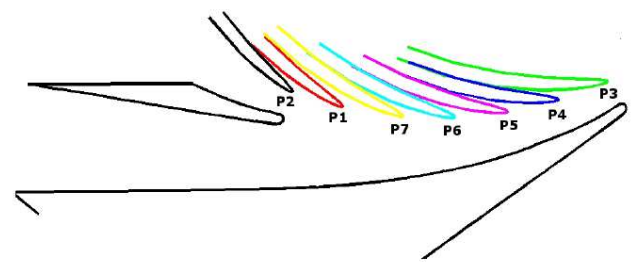


Fig.7 Impeller blade positions

Non-dimensional values of velocity are calculated with equations (5) and (6):

$$V_r^* = V_r / U_2 \quad (5)$$

$$V_z^* = V_z / U_2 \quad (6)$$

Constant values of non-dimensional radial and axial absolute velocity components are presented respectively on figures 8 and 9. Each set of figures corresponds to the case of low flow rate on the upper part (index a and b) of the page, the high

flow rate results are shown in the lower part (index c and d) of the same page.

The left part figures correspond to the case without leakage and the right one to the case with leakage. Other constant values such as non-dimensional static pressure and absolute angle are also shown respectively on figures 10 and 11. All the figures represent the diffuser blade to blade inlet section from hub to shroud.

For each figure, three different impeller positions, relative to the diffuser leading edge section, are given corresponding to positions P3, P5 to P7 as shown in figure 7.

It has been found, from calculation results, that leakage effects do not strongly affect tangential components of absolute velocity. So, only radial and axial velocity components have been chosen instead of tangential ones, in order to compare more clearly both results without and with leakage. Leakage is found to have an important effect mainly near the diffuser pressure side-shroud corner section. This can be seen on figures 8a and 8b for low mass flow rate corresponding to positive leakage. For high mass flow rate (figures 8c and 8d), the differences are more pronounced near the suction mid span region. Axial velocity components show more local differences as shown in figures 9a to 9d. Effect of impeller blade location on axial velocity differences is more visible near the suction side shroud corner since this location corresponds to low static pressure values especially for low mass flow rates for which incidence angle on the diffuser leading edge is important. For high mass flow rate, the incidence angle becomes negative and consequently, local static pressure is higher near the suction side as shown in figures 10.

As a consequence, the values of the absolute angle (figures 11) mainly differ in the suction side region and extend on the whole passage section at low mass flow rate. At high mass flow rate, slight modification occurs at the hub to shroud mid plane near the suction side region.

Conclusion

Numerical calculations have been performed in order to calculate local flow characteristics on the whole pump model geometry including leakage. The effects on pump global performances have been explained because of the change of leakage flow direction, which depend on the local static pressure downstream the impeller outlet plane

section. Local velocity components and static pressure evolutions in the inlet plane of the diffuser blade have been calculated and analysed with respect on the leakage effects. It has been shown that leakage may affect local flow characteristics depending on local rotating impeller locations compared with diffuser blade leading edge.

Nomenclature

b^*	[-]	Non-dimensional distance from hub
p	[Pa]	Pressure
p_t	[Pa]	Total pressure
Q^*	[m ³ /s]	Non-dimensional volume flow rate at impeller's inlet
Q_i	[m ³ /s]	Impeller design flow rate
V_r^*	[-]	Non-dimensional radial velocity
V_z^*	[-]	Non-dimensional axial velocity
U_2	[m/s]	rotational velocity at impeller outlet
α		Absolute velocity angle angle relative to radial direction
ρ	[kg/m ³]	Air density
ψ_{tc}	[-]	Non-dimensional total pump head
ψ_{ii}	[-]	Non-dimensional isentropic head

References

- [1] G. Cavazzini, 2006, "Experimental and numerical investigation of the rotor-stator interaction in radial turbomachines", *Ph.D. thesis*, University of Padova, Padova, Italy
- [2] G. Pavesi, G. Cavazzini, G. Ardizzon, P. Dupont, S. Coudert, G. Caignaert, G. Bois, 2006, "Analysis of Rotor-stator interactions effects within the vaned diffuser of a radial flow pump", IAHR Symposium, YOKOHAMA, Japan
- [3] G. Cavazzini, G. Pavesi, G. Ardizzon, P. Dupont, S. Coudert, G. Caignaert, G. Bois "Analysis of the rotor-stator interaction in a radial flow pump, *Houille blanche – revue internationale de l'eau*, 2009
- [4] AC Bayeul, P Dupont, G. Cavzzini, P Cherdieu, A Dazin, G Bois, O Roussette., Numerical and experimental investigations in a vaned diffuser of SHF impeller : fluid leakage effect, 21^{ème} Congrès Français de Mécanique, Bordeaux, 26-30 août 2013

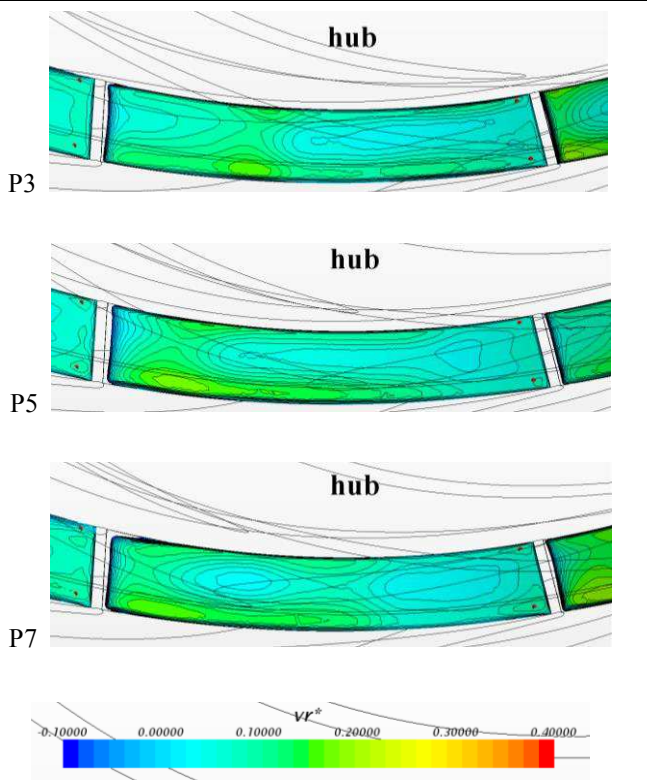


Fig 8a Non-dimensional radial Velocity V_r^* - $Q^*=0.766$ – case without leakage

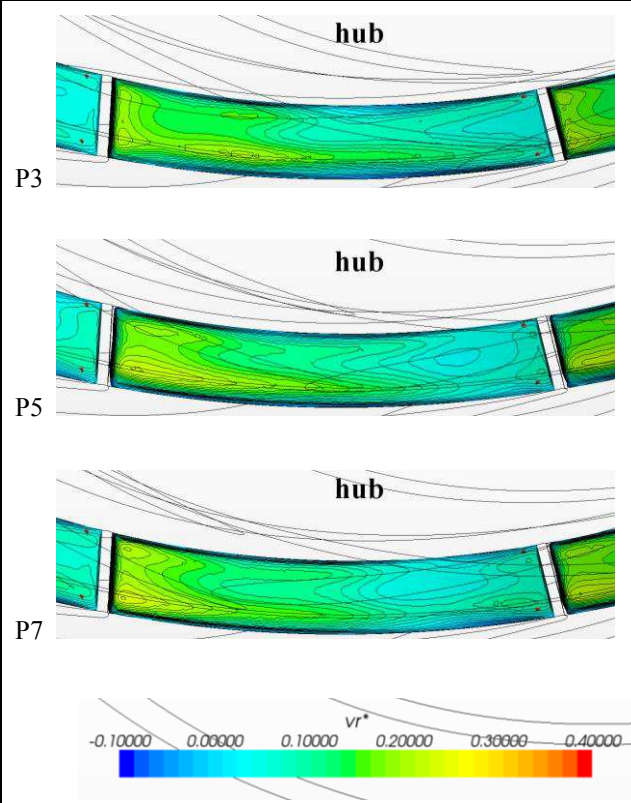


Fig 8b Non-dimensional radial Velocity V_r^* - $Q^*=0.766$ – case with leakage

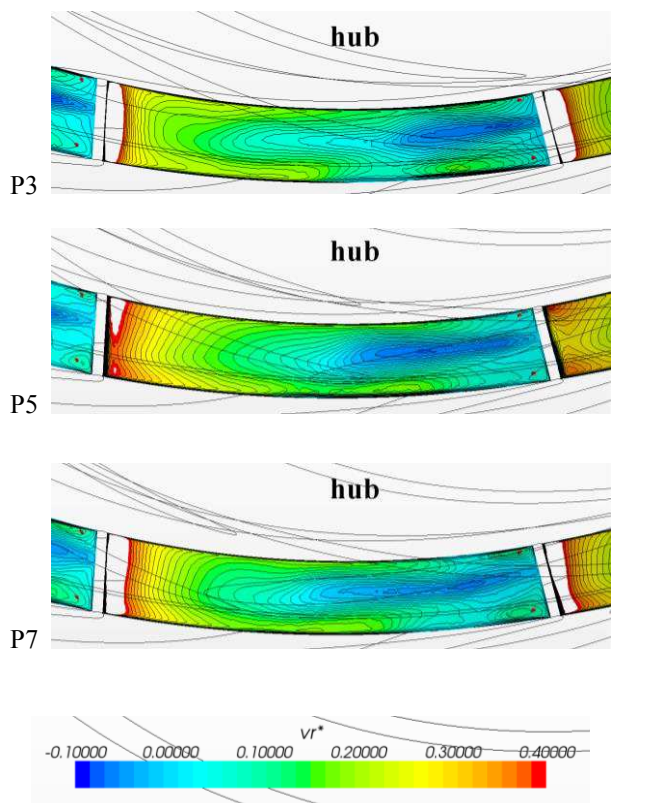


Fig 8c Non-dimensional radial Velocity V_r^* - $Q^*=1.134$ – case without leakage

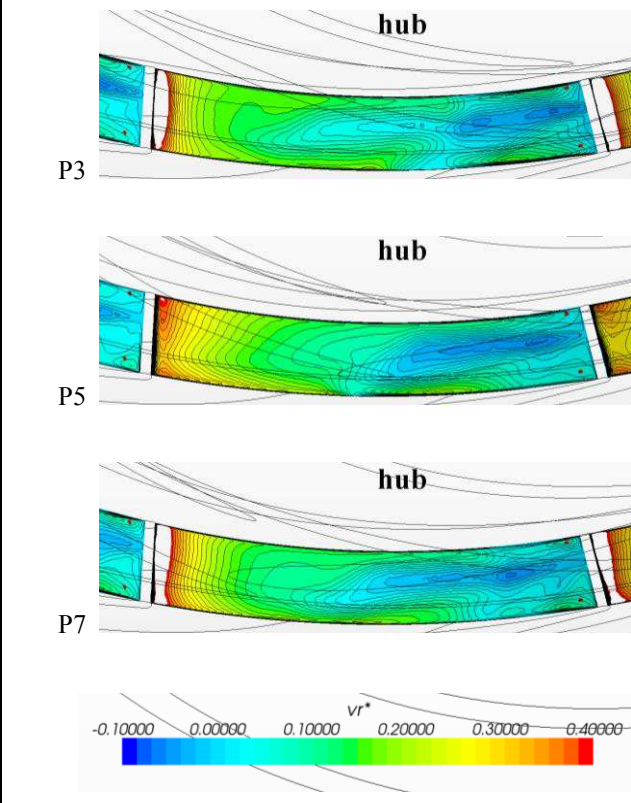


Fig 8d Non-dimensional radial Velocity V_r^* - $Q^*=1.134$ – case with leakage

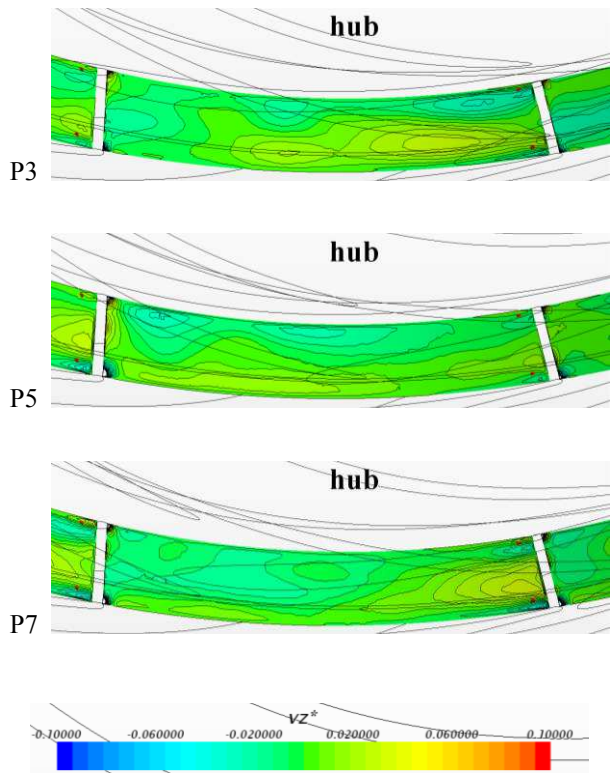


Fig 9a Non-dimensional axial Velocity Vz^* - $Q^*=0.766$ – case without leakage

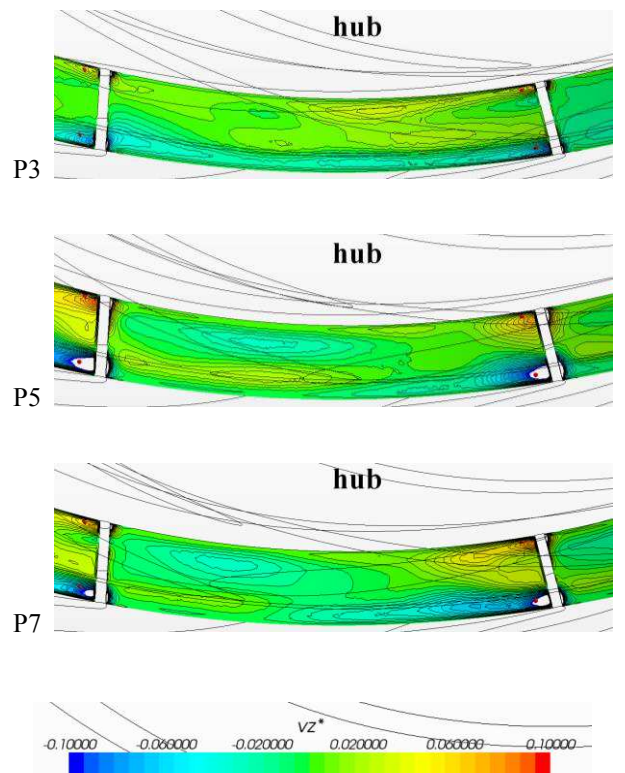


Fig 9b Non-dimensional axial Velocity Vz^* - $Q^*=0.766$ – case with leakage

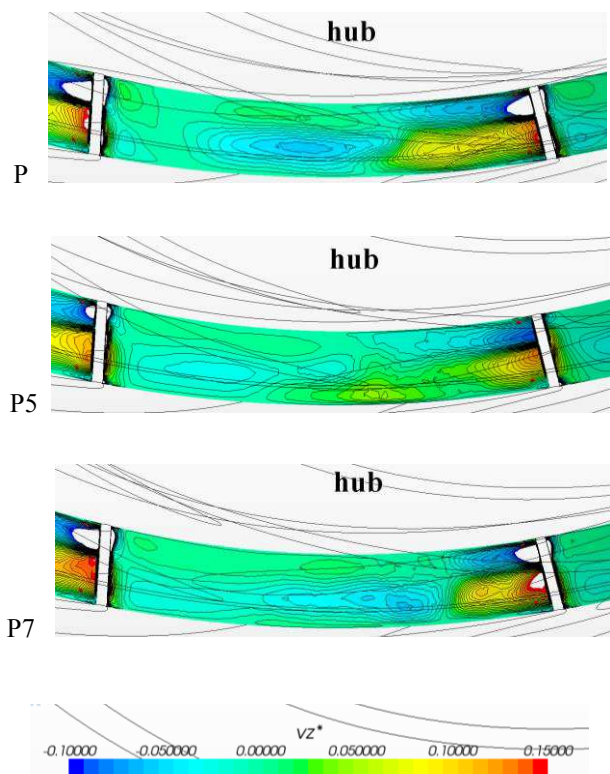


Fig 9c Non-dimensional axial Velocity Vz^* - $Q^*=1.134$ – case without leakage

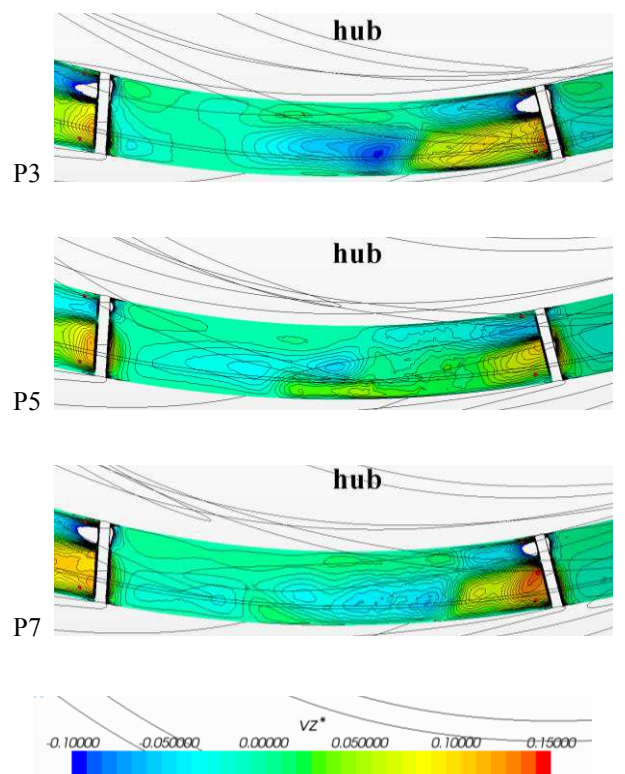


Fig 9d Non-dimensional axial Velocity Vz^* - $Q^*=1.134$ – case with leakage

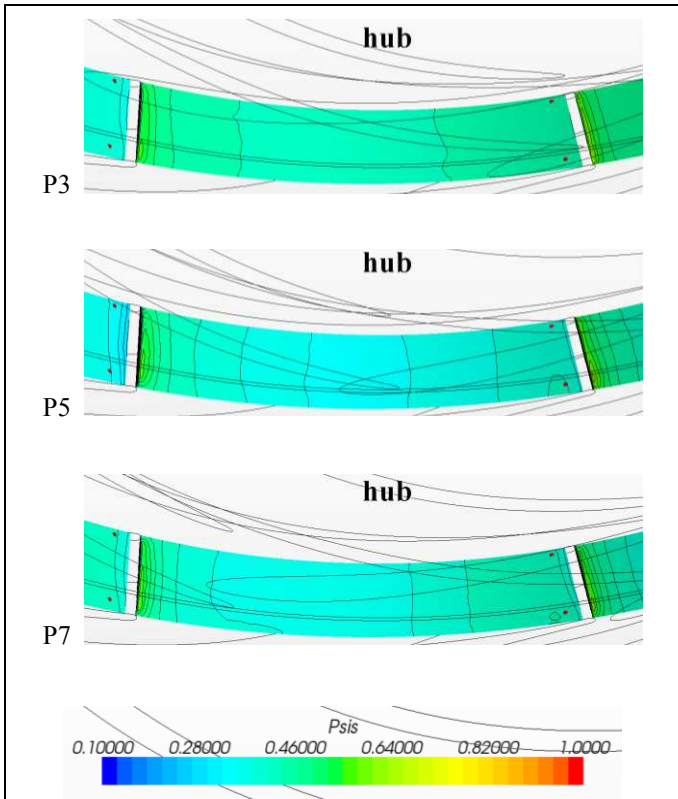


Fig 10a Non-dimensional static pressure Ψ_s - $Q^*=0.766$ – case without leakage

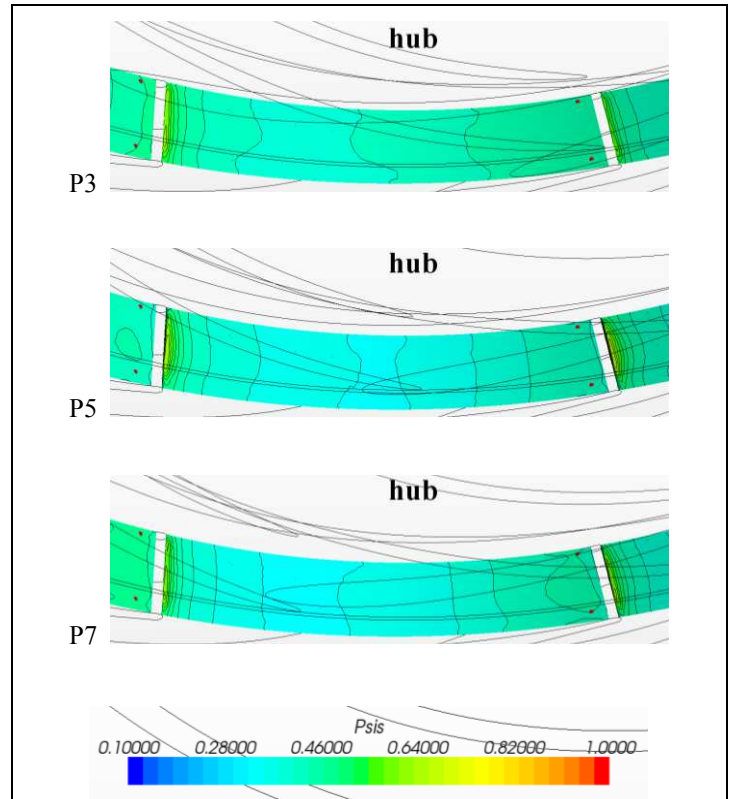


Fig 10b Non-dimensional static pressure Ψ_s - $Q^*=0.766$ – case with leakage

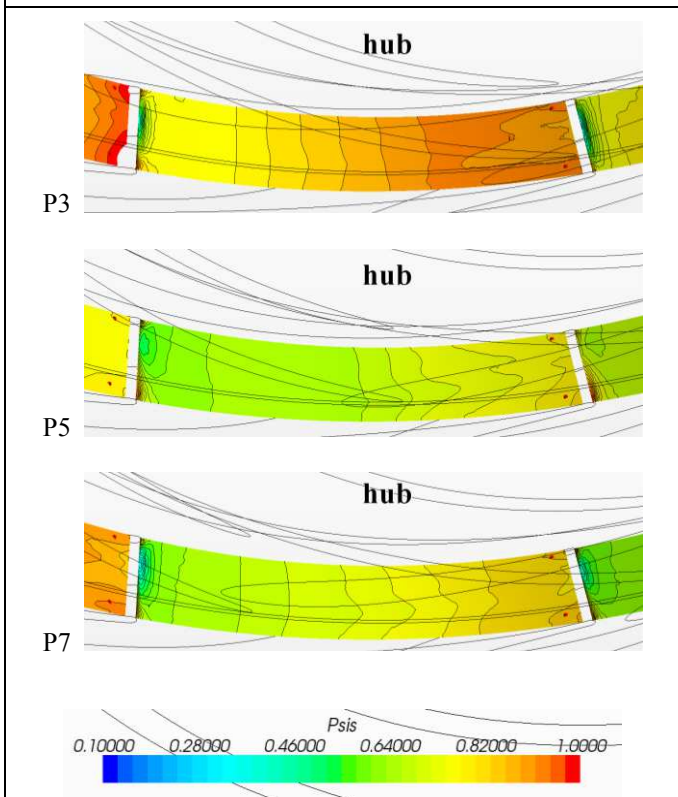


Fig 10c Non-dimensional static pressure Ψ_s - $Q^*=1.134$ – case without leakage

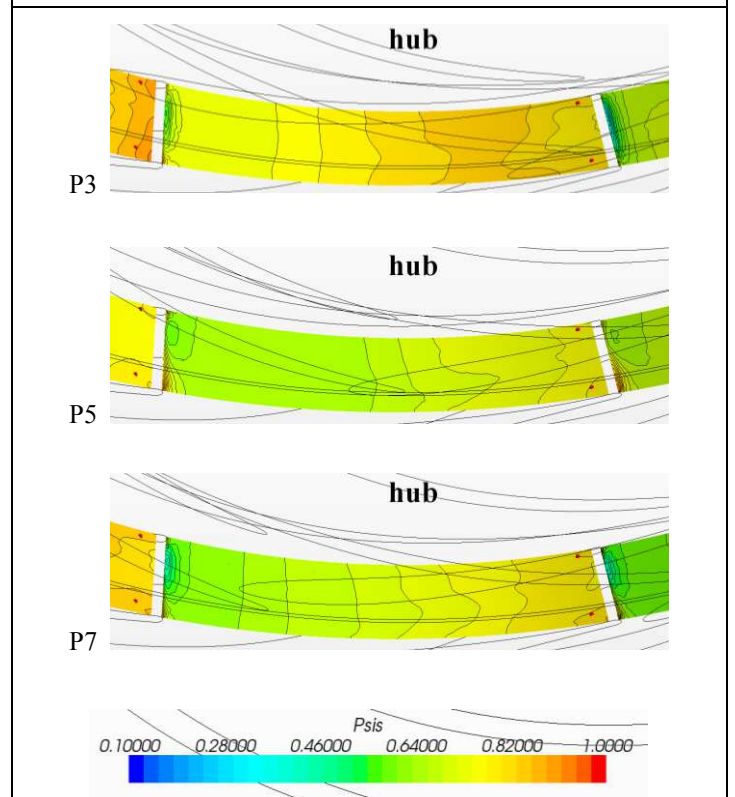
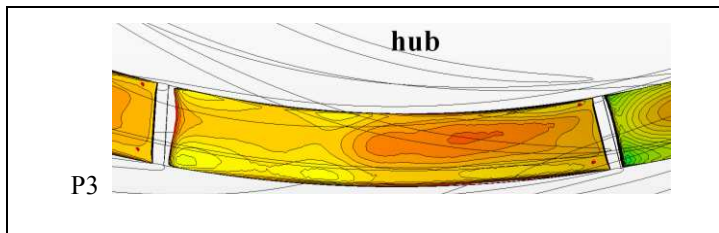
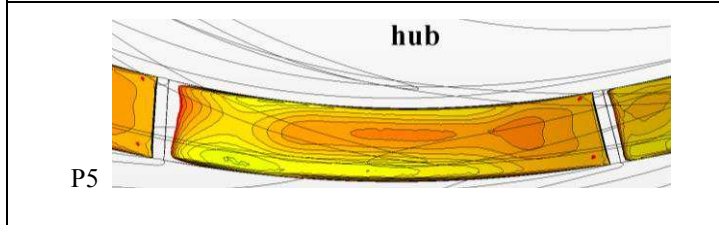


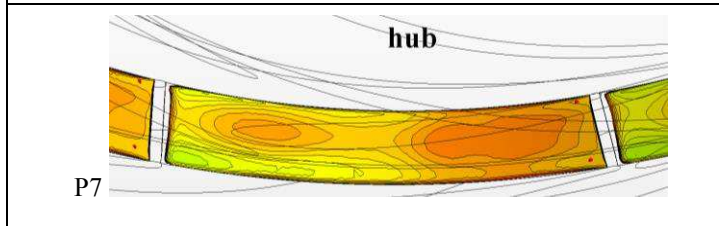
Fig 10d Non-dimensional static pressure Ψ_s - $Q^*=1.134$ – case with leakage



P3



P5



P7

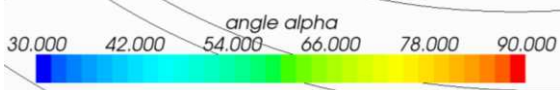
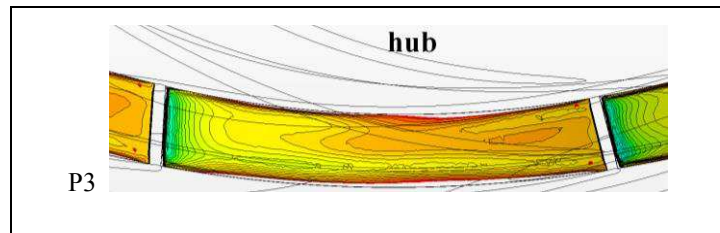
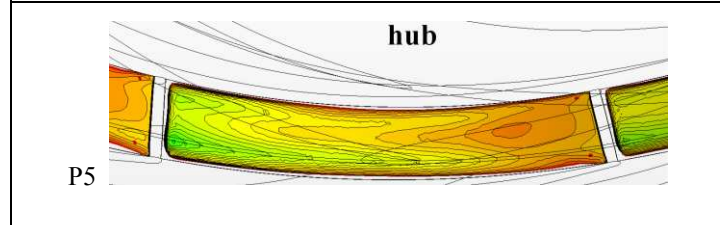


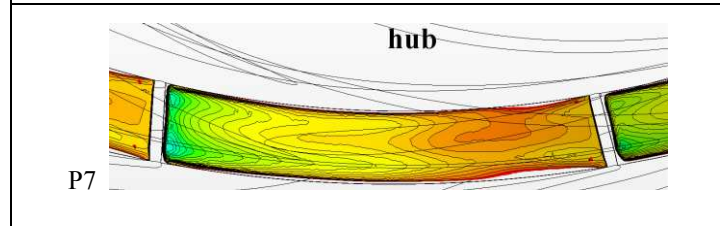
Fig 11a angle alpha - $Q^*=0.766$ – case without leakage



P3



P5



P7

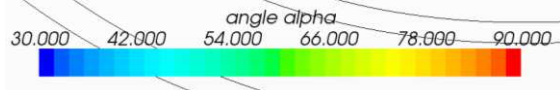
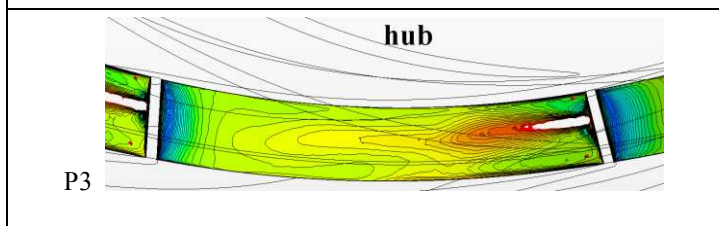
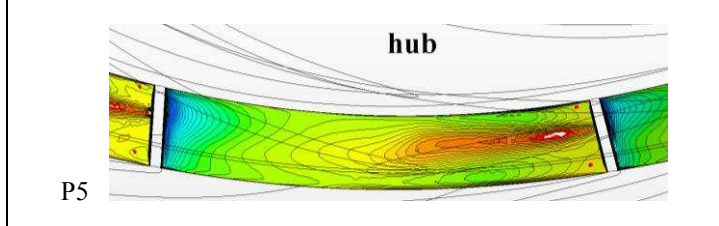


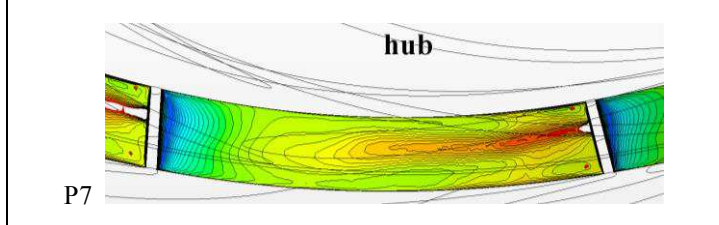
Fig 11b angle alpha - $Q^*=0.766$ – case with leakage



P3



P5



P7

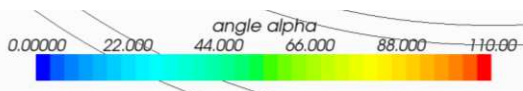
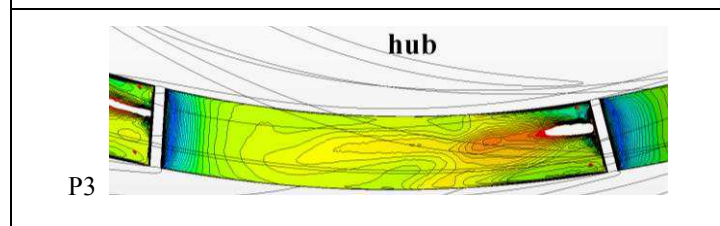
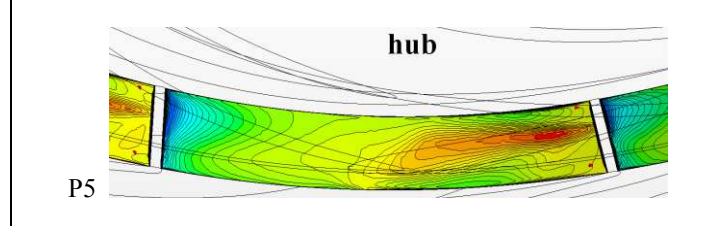


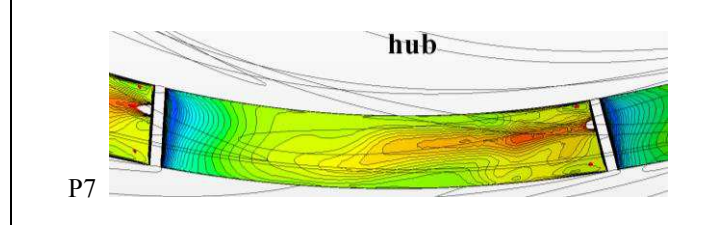
Fig 11c angle alpha - $Q^*=1.134$ – case without leakage



P3



P5



P7



Fig 11d angle alpha - $Q^*=1.134$ – case with leakage