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Evaluation of Perforated Plates Manufacturing with 3D Printing Process

W.Souza[1], Maria A. F. Veloso [1] and.A.A.C.Santos[2,1]

[1] *wallenfds@yahoo.com.br,*
[1] *mdora@nuclear.ufmg.br*
Departamento de Engenharia Nuclear-UFMG
Av. Antônio Carlos 6627
31270-901- Belo Horizonte - MG -Brasil
[2] *aacs@cdtn.br,*
Centro de Desenvolvimento da Tecnologia Nuclear-CNEN
Avenida Antônio Carlos, 6.627
31270-901- Belo Horizonte – MG - Brasil

1. Introduction

Perforated plates are studied frequently around the world. There are a lot researches about effects turbulence downstream of a perforated plates (1) and analysis on the pressure loss (2), (3), (4), (5). However there is not much research on perforated plates manufacturing with 3D printing process. Numerical studies of fluid dynamic parameters on the perforated plates are presented in (4).The objective of this paper is assessment the perforated plates manufacturing with Additive Manufacturing (AM) processes in 3D printing. In this paper the perforated plates with 9 holes are inlet in an experimental section for research about pressure drop through the printed perforated plates. CFX code was used for to simulate and comparison of the pressure. The results showed that the printed plates have a pressure drop due to the characteristic roughness of 3d printing plus the pressure drop due the permeability caused by porous and internal holes.

2. Methodology

The thermo-hydraulic laboratory of the CDTN has a Water-Air Circuit (CAA). The test section enclosure is a square channel 76,2x76,2 mm made of acrylic with a flange adapted to receive the perforated plates. The circuit has a 15 HP pump with a 15 mca capacity. The reservoir has 1000 liter capacity. Flow rate is measured through the pressure difference DPo in an orifice plate and the water temperature is adjusted to the desired value by a chiller. The tests are carried out for a temperature of 20 º C.

The gol is to use a PVC (polyvinyl chloride) plate with 9 holes, as shown in the Fig. 1. With the same geometry were manufactured 3 impressed plates to measure the pressure when inserting water at different speeds getting different Reynolds numbers and pressure drops.

One plate was manufactured in PVC (polyvinyl chloride) and used as a reference for the production of 3 plates manufactured in a Raise 3D PRO 2 model printer. The PLA material was used with a layer thickness of (0 .15 mm), (0.25 mm), and (0.35 mm) respectively on the plates 1, 2 and 3. To measure the roughness, was used the Mitutoyo Surf Test Model sj-301.

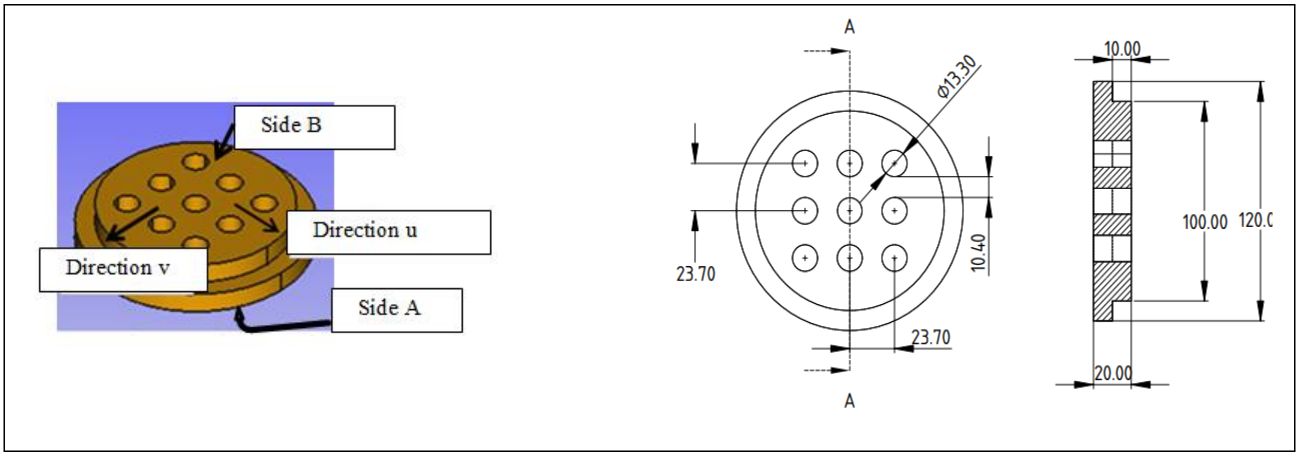

Figure 1: Experimental set up

Fig. 1 shows the directions of the measurements of the roughness carried out on the side "A" and measurements on the side "B". In addition, 5 holes will be chosen to measure roughness. PVC plate roughness is approximately the same for different directions on the surface, therefore was measurements only direction u. Roughness on the surface has a little influence on the pressure loss and was disregarded. Table I is the mean value of the roughness in internal surface of the holes.

Table I: Roughness in the plate's holes (Ra)

	PVC	Plate (01)	Plate (02)	Plate (03)
Holes	5.40	4.56	12.82	18.25
Direction u_ side A	0.82	19.55	19.29	18.71
Direction u_side B	0.96	9.86	1.31	1.32
Direction v_ side A	-	9.1	10.42	12.01
Direction v_side B	-	0.96	1.40	1.03

The Eq. 1 provides the dimensionless k value of the pressure loss coefficient, ΔP=P_n-P_{n-1} static pressure of perforated plate (Pa), where ρ is fluid density (kg/m^3), $\bar{u}$ is averaged value of velocity (m/s).

$$k_p = \frac{\Delta P}{\frac{1}{2}\rho \bar{u}^2} \tag{1}$$

When perforated plates are subjected to water pressure, water flows through the holes and flows through the surface as well. Surface flow changes the differential pressure. To evaluate this feature, plate 2 was waterproofed with acrylic glue on sides A and B. To not change the diameter of the holes and not to influence the pressure drop due to roughness, the surface area of the holes is small therefore the flow through them was neglected.

The results of the pressure of the plate 2 and "plate 2 waterproofed (Plate2w)" were compared.

Numerical model was developed in CFX Ansys 19.2 software. Design geometric model (CAD) was made with "SpaceClaim" software, with 20 hydraulic diameters downstream and 10 hydraulic diameters upstream of the orifice plate. Adopted geometry can be represented by 1/8. There are two refined regions, the most refined region is near the plate for cover velocity effects caused by perforate

plate.
The turbulence model used was K-ε. In the part labeled "Inflation," the height of the first element has been set to give a y + value of 11. The thinnest grid has 5 layers near the walls and a growth rate of 1.2. The methodology for evaluate the simulation follow the Procedure V&V(20), Standard for Verification and Validation in Computational Fluid Mechanics and Heat Transfer and the procedure work (7) . The uncertainty was calculated by the equivalent method CGI (8).

3. Results and Discussion

Fig.2 shows that the PVC plate has the biggest k value. This occurs as all the water flow passes through the holes and does not pass through the surface of the PVC plate. The printed plates allow a small passage of water over its surface, even if on a small scale, and this influences the final pressure drop.

Table II presents a comparison of the results of the simulation in CFD for Reynolds $3x10^4$ and $6x10^4$. The differences in the values indicate that there is influence of the flux through the plate on the experimental.

Table II: Percentual differences at numerical models and experimental

	Plate 01		Plate 02		Plate 03	
Re	3,7E+04	6,6E+04	3,3E+04	6,6E+04	3,3E+04	6,6E+04
ΔP1	-10,0%	-11,07%	-7,75%	-10,76%	-1,65%	-8,21%
ΔP2	-9,0%	-8,66%	-7,12%	-11,98%	0,19%	-9,00%
ΔP3	-12,0%	-12,73%	-3,52%	-8,61%	0,21%	-8,96%
ΔP4	-13,0%	-12,51%	-1,86%	-11,57%	1,34%	-8,79%

Table III shows the difference between the plates. The difference is bigger in flow rate 3 and 3.3.

Table III: Percentual differences of the plate 02 and plate 02w

Flow rate(kg/s)	%
3	10,04%
3,3	10,79%
4,4	3,92%
5,5	2,60%
6,6	2,52%

Pressure loss coefficient is a dimensionless value. Fig.2 shows that the coefficient k of the plate pvc has bigger value than other plates. The Fig. 3 is the comparison of the coefficient of the plate 02 and the plate 02w. Percentual difference between the simulation result and the experimental result is bigger 11% for plate 02 and less than 8% for plate 02w.

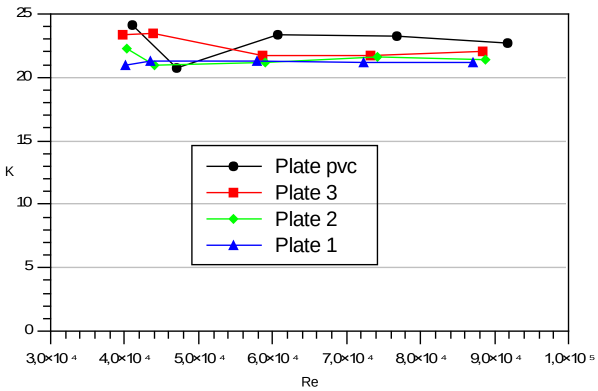

Figure 2: Pressure loss coef. x Reynolds number

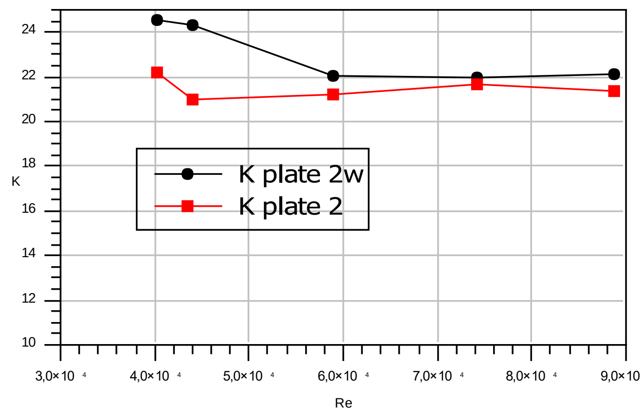

Figure 3: Comparison of the coefficient k.

4. Conclusions

The assessment of the perforated plate impressed with 3d printing was carried out on perforated plates the same geometry dimensions and different roughness. Roughness is the parameter that has a little influence, although the difference indicated that there is bigger influence of the flux through the plate surface. The plate 02, are not totally waterproof. The acrylic glue was not used on the inlet holes and the a little flux can be fluid through the plate.

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