Study of the flow and heat transfer of pulsed sinusoidal impinging jet at distances close to the concave surface

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ABSTRACT

The main purpose of this study is to investigate the effect of the pulsating of the inlet jet on the heat transfer rate short distances of nozzle from the concave surface. For this purpose, three-dimensional simulation of flow and heat transfer of sinusoidal pulsed jets on the concave surface has been performed at distances of 0.5 times of nozzle diameter to 4 and for Reynolds numbers of 7000 and 14000. The results of numerical simulation are in good agreement with the experimental results of the steady jet. The result shows that the effect of pulsating the flow with the sine function decreases at short distances between the jet and the concave surface. So that at distance of 4 times of nozzle diameter , pulsating jet led to a 10% increase in the average Nu, while this value is equal to 5% for distance of 0.5 times of nozzle diameter. It can be found that pulsating the flow decreases Nu at low frequencies, and then with increasing the frequency of the pulsed jet, the Nu number increases. Furthermore with increasing the distance between the surface and the inlet jet, the Nu number decreases significantly. This rate of reduction is lower in comparison to the steady jet.

KEYWORDS: Sinusoidal pulsed jets, Concave surface, Impinging jet, Heat transfer, Nu number

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1. Introduction

Impinging jet is one of the most effective and common methods of increasing heat transfer in widely used industries such as gas turbines, electronic components, dryers, etc. Methods of improving the heat transfer of the impinging jet include changing the nozzle geometry, pulsating the inlet jet, and using non-flat surfaces. Each of these methods has been studied by previous researchers. Pulsed jet impinging has been studied by previous researchers [1-3]. As previous research has shown, the use of non-flat surfaces increases and improves the heat transfer of the impinging jet from the surface. It can be said that the use of concave surface causes a secondary flow which increases the heat transfer rate on the surface[4, 5].

In this research, the aim is to investigate the flow and heat transfer of a sinusoidal pulsed jet to a concave surface at short distances between the jet and the impinging surface. The effect of pulse inlet jet frequency and Reynolds number at different distances of the jet from surface on the heat transfer rate is investigated.

2. Numerical Solution

Figure (1) shows a schematic of the present problem. As shown in figure circular jet of diameter *d* is located on the concave surface and the exit distance of the jet from the concave surface is *H*.

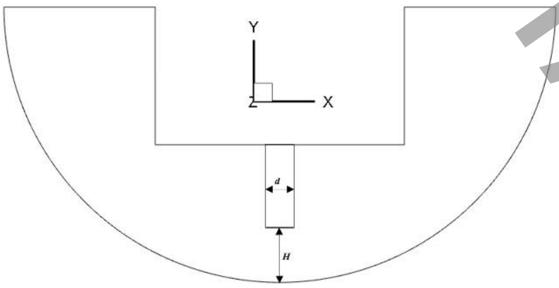

Fig.1 2d view of problem in x-y plane

The governing equations for solving this problem are the equations of mass, momentum and energy. In order to model turbulence terms, two-equation turbulence models are used. And according to the ability to predict the results and its compliance with laboratory results, a model is selected to continue numerical solution in different conditions. Previous research has reported a better ability of the *k-ε RNG* model than other turbulence models [6-9]. The velocity inlet boundary condition is for the inlet jet, the boundary condition of the wall with a constant flux for the collision surfaces, and the boundary condition of the pressure outlet for the other surfaces.

3. Experiments

The apparatus was designed and manufactured for an impinging jet. The setup consists of main parts including a control box that shows the ambient temperature and air temperature of the inlet jet, temperature sensors, concave surface exposed to constant heat flux, pitot tube, infrared thermal camera pressure sensor and inlet flow regulating valve. The systematic error of the *Nu* number is 8%. The uncertainty of calculating the *Nu* number, including the uncertainty of the measuring equipment and the method of measurement, is a total of about 11.7% [10].

4. Result and Discussion

Figure 2 shows that as the distance between the jet and the concave surface decreases, the Nu number increases significantly, although this increase reaches its lowest value in the stagnation region and its maximum in the wall jet region. At the end of the impingement surface, the effect of pulsating flow and the distance of the jet from the surface is minimized.

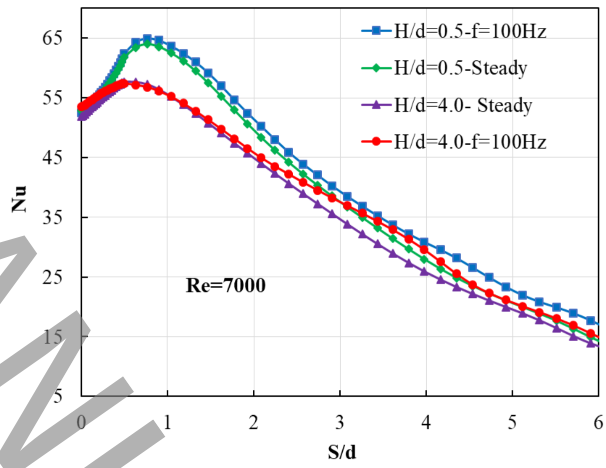

Fig.2 the effect of pulsating the flow on the Nu distribution for the high and low distances of the jet to surface

According to the Fig.3, It is observed that pulsating the inlet jet with low frequencies reduces the Nu number in the stagnation zone. By increasing the pulse frequency to 50 Hz, the Nu distribution increases compared to the steady jet mode, and by increasing the frequency to 100 Hz, this trend continues.

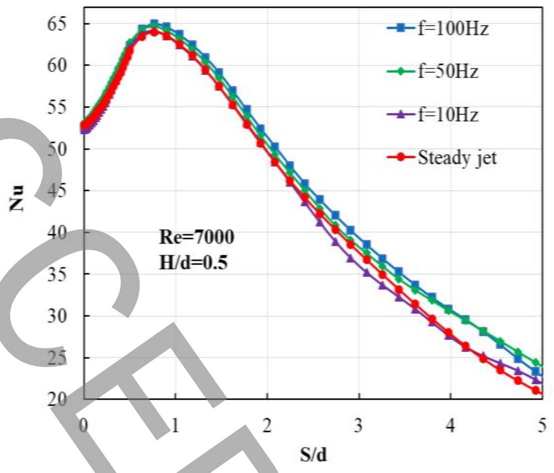

Fig.3 effect of pulse frequency of inlet jet on the Nu distribution of concave surface

In order to investigate the heat transfer from the concave surface, the time and area average of the Nu number on the surface has been calculated and presented in Table 1

Table 1 the time and area averaged of Nu number at the various distance of jet to surface and frequency of inlet jet

	steady	*f* =10Hz	*f* =50Hz	*f*=100Hz
H/d=0.5	31.6	30.4	32.1	34
H/d=4	29.2	28.1	30.3	31.7

According to the table, it is observed that by pulsating the flow with a frequency of 10 Hz, the average Nu number on the surface decreases and by increasing the frequency to 50 Hz and 100 Hz, the average Nu for dimensionless distance 0.5 by 1.2% and 5%, respectively. These values for the dimensionless distance 4 are 4% and 9%, respectively. Therefore, by increasing the distance of the jet from the surface, the effect of pulsating the inlet jet on the average Nu number increases.

5. Conclusion

The summary of the results can be presented as follows:

- The *k-ε RNG* turbulence model differs less from the experimental data compared to other turbulence models.

- pulsating the jet with sinusoidal function, at long distances of the jet from the surface, has a greater effect on the distribution of *Nu* number.

- pulsating the jet leads to an increase in the distribution of *Nu* number in the wall area and its effect is much less in the stagnation zone.

- Increasing the frequency and decreasing the distance of the jet from the surface, increases the average Nu number of the surface. The effect of increasing the frequency is greater at long distances of the jet from the concave surface.

6. References

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