# Heat Transfer Enhancement of a Two-Pass Cooling Channel for Gas Turbine Blades

**Farah Nazifa Nourin, Ryoichi S. Amano**
Department of Mechanical Engineering, University of Wisconsin-Milwaukee

## Introduction

It is crucial to perform high thermal efficiency in a gas turbine. Increasing the inlet temperature in the combustor is the way to achieve this goal for a gas turbine. Nonetheless, increasing the temperature causes a significant difference in temperature gradient within the blade material, which causes thermal stresses. These effects must be reduced to achieve higher thermal efficiency. The two-pass cooling channels have been studied due to their performance in heat transfer. The dimpled surface on a pass wall cooling technology gets popular in recent years as it shows a low-pressure loss penalty. It is also advantageous to the turbine stages where lower pressure cooling is employed. This study is going to investigate turbulent flow and heat transfer in a two-pass duct. Three cases were considered here-

a) Case A: Hemispherical Dimpled Channel
b) Case B: Leaf Dimpled Channel
c) Case C: Hemispherical Dimpled Channel without Bend

## Methods

The Computational Fluid Dynamics (CFD) method was used for modeling the setup and analyzing the flow and heat transfer using Star CCM+ software. The turbulent flow field was conducted through the two-pass duct with k- ω SST model by the following literature [1,2,3]. The inlet is chosen larger than the outlet to balance the pressure on both sides.

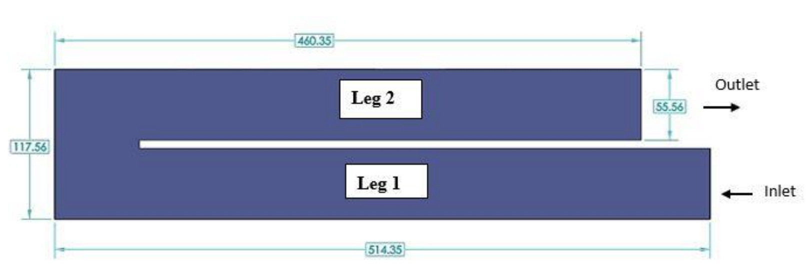


**Figure 1: Two pass cooling channel (Front view, all dimensions in mm)**

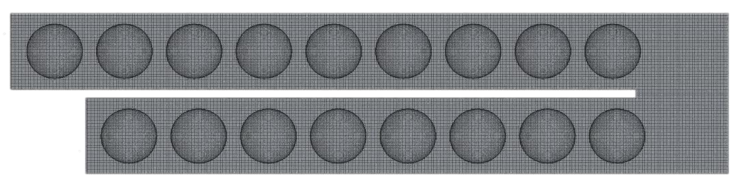

**Figure 2: Hemispherical dimpled channel( Meshed scene, Bottom View)**

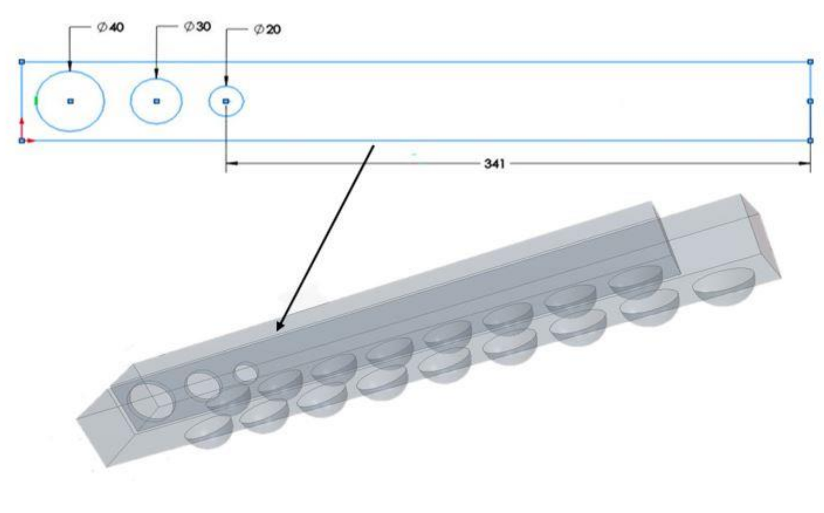


**Figure 3: Two-pass cooling channel eliminating bend (all dimension in mm, Case C)**

**Table 1: Dimple Parameters**

| Name | Depth to Diameter ratio | Number of Dimples in Leg-1 | Number of Dimples in Leg-2 |
|---|---|---|---|
| Case A | 0.5 | 9 | 8 |
| Case B | 0.5 | 9 | 8 |
| Case C | 0.5 | 9 | 8 |

**Table 2: CFD Study Parameters**

| | |
|---|---|
| Model used | RANS (K-ω SST) |
| Number of cells | 6.2 Million |
| Working fluid | Air |
| Inlet velocity | 6.25 m/s |
| Reynolds number | 20,000 |
| Outlet | Pressure outlet |
| Heat flux (Bottom wall) | 2,700 W/m$^2$ |

## Results

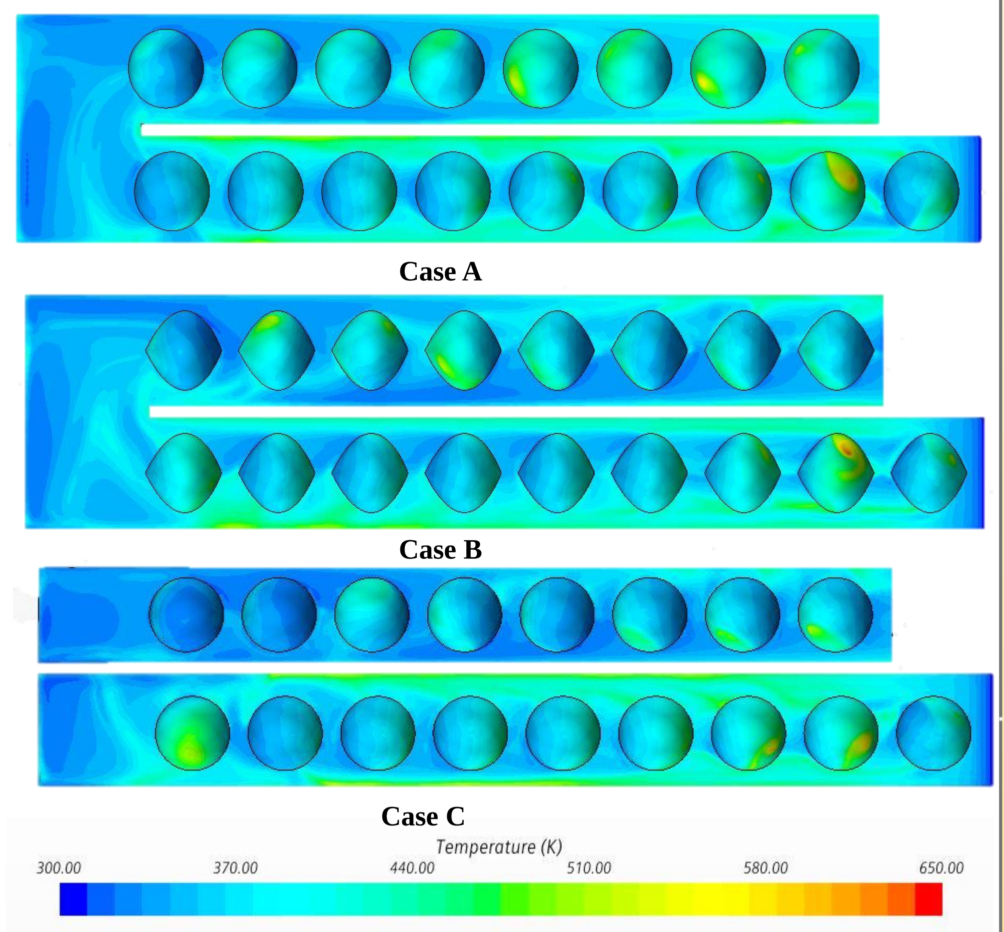


**Figure 4:Temperature distribution along the channel at Reynolds number = 20,000**

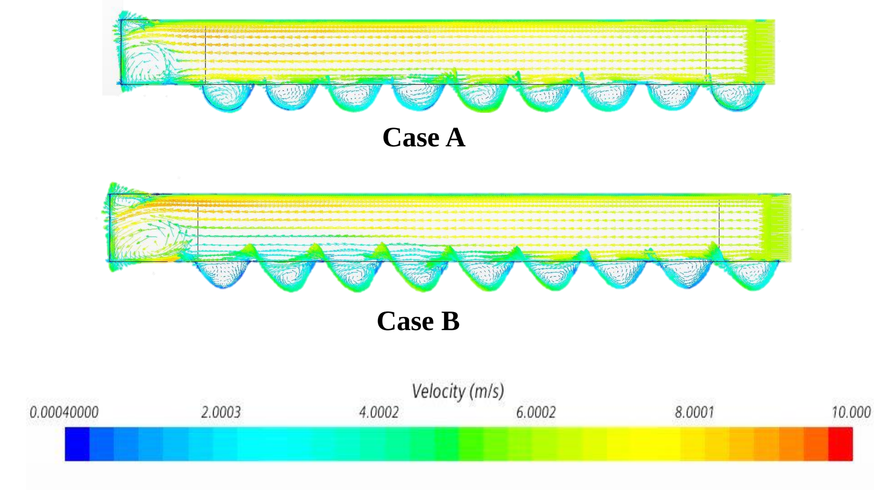


**Figure 5:Velocity distribution along the leg-1 at Reynolds number = 20,000 (Side view)**

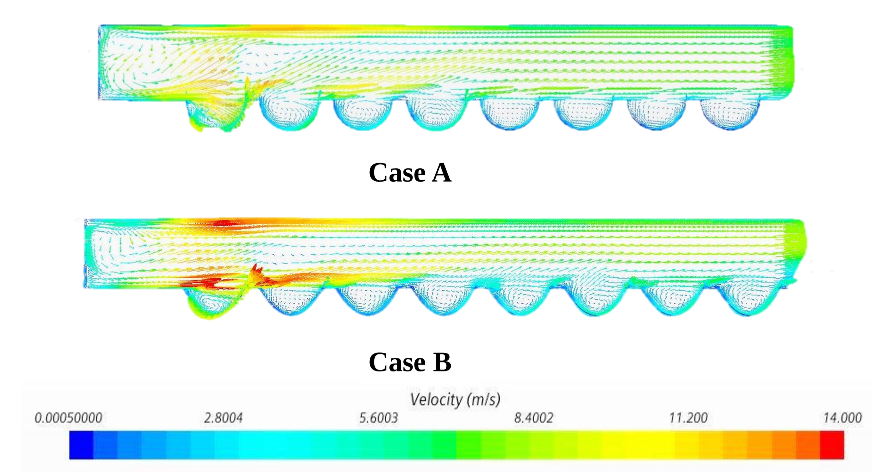


**Figure 6:Velocity distribution along the leg-2 at Reynolds number = 20,000 (Side view)**

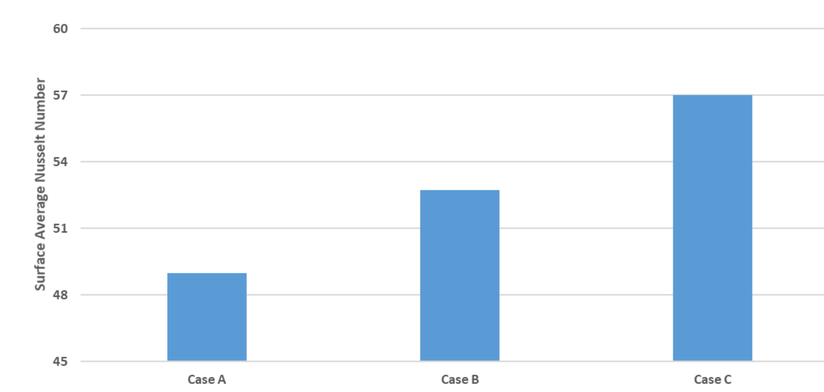


**Figure 7:Surface average Nusselt number at Reynolds number = 20,000**

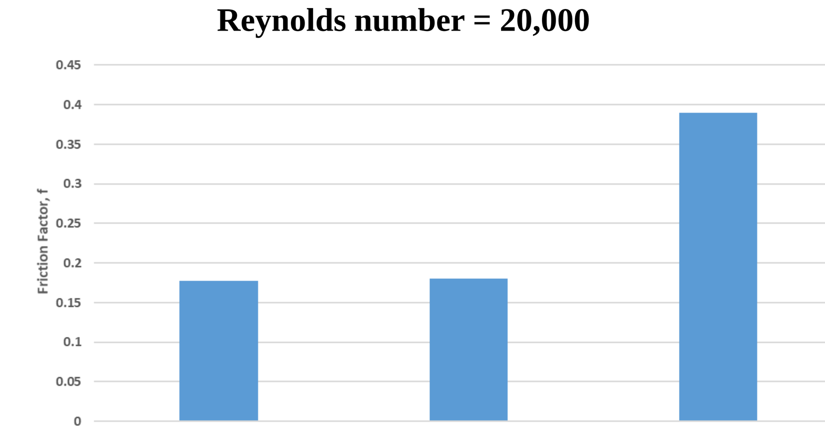


**Figure 8: Friction factor at Reynolds number = 20,000**

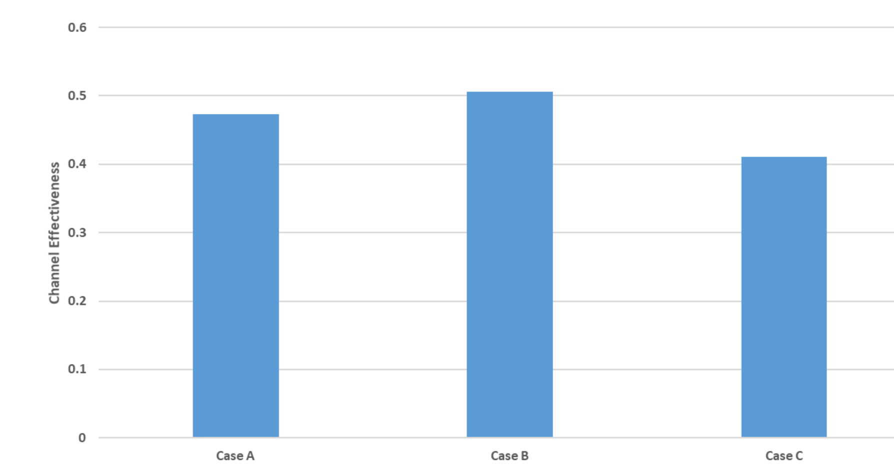


**Figure 9: Channel effectiveness at Reynolds number = 20,000**

## Conclusions

- Computational Fluid Dynamics was used to investigate the heat transfer phenomena in the dimpled channel at Reynolds number=20,000.
- Three cases were studied-
  a) Case A-Hemispherical Dimpled Channel
  b) Case B- Leaf Dimpled Channel
  c) Case C-Hemispherical Dimpled Channel without Bend
- After mesh independence study, 6.2 million cells were selected with surface remesher, prism layer and trimmer. k- ω SST model was used to solve the heat transfer model with air as a coolant.
- Heat transfer is the highest in Case C as the it experiences the combination of impingement and cross-flow. The strong air jet impingement contributes a better heat transfer distribution in the second leg even though the total holes' area is less than the bend region.
- Case A and B experience flow attachment, vortex rolls in the downstream. The flow pattern explains the better heat transfer phenomena of the leaf dimpled channel than the hemispherical one.
- Even though the heat transfer enhancement is the highest in Case C, it is less effective than the other two channels due to excessive pressure drop. Case B shows the best performance in terms of heat transfer, pressure drop and effectiveness.

## Literature cited

1. Rao, Y., Feng, Y., Li, B. and Weigand, B., 2015. Experimental and numerical study of heat transfer and flow friction in channels with dimples of different shapes. Journal of Heat Transfer, 137(3), p.031901
2. Xie, G., Sundén, B. and Zhang, W., 2011. Comparisons of pins/dimples/protrusions cooling concepts for a turbine blade tip-wall at high Reynolds numbers. *Journal of Heat Transfer*, *133*(6), p.061902.
3. Shen, Z., Qu, H., Zhang, D. and Xie, Y., 2013. Effect of bleed hole on flow and heat transfer performance of U-shaped channel with dimple structure. International Journal of Heat and Mass Transfer, 66, pp.10-22

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## For further information

Farah Nazifa Nourin
fnourin@uwm.edu.