Disk brake design for cooling improvement using Computational Fluid Dynamics (CFD)

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Abstract. The car disk brake design is improved with two different blade designs compared to the baseline blade design. The two designs were simulated in Computational fluid dynamics (CFD) to obtain heat transfer properties such as Nusselt number and Heat transfer coefficient. The heat transfer property is compared against the baseline design. The improved shape has the highest heat transfer performance. The curved design is inferior to baseline design in heat transfer performance.

1. Introduction
Disk brake is the component in the wheel to slow up vehicles when moving. It is essential function to slow rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of callipers [1]. The downside of it, in fast cars like in racing cars, they push the car to the limit whereas the cars always speed up at high speed. This leads to a lot of braking in use during a race. As we know, friction created by the disk brake to slowing down the cars causing increasing in temperature on the disk brake [2]. As the temperature increases the functionality of the brake faded as high temperature causing the disk brake to lose it friction [3]. Less friction ends up making the racing cars to slow down more difficult. To have a good racing line before cornering the car needed to slow. So less grip to brakes making the drive brakes earlier before corner hence optimum time cannot be optimize end up having a slow lap time.

It is interesting that by doing a small improvement to the cooling system [4] on the disk brake can make the car more easier to slow down and also can increase the optimization of the racing car to get a better lap time.

Until now the problem is not completely solve but many things has been implemented to get the optimum cooling which can decrease the problem [5]. Some of the implement that had been taken was by replacing the material of the disk itself with material of name such as ceramics, mixing metal materials to succeed in creating new material and etc. Brake will fade due to high temperature because it will expand and losses the strength and surface friction. So by replacing it with material that has a higher faded point it will increase the time it loses it function. But to do this task, it cost a lot of money because it is expensive. So to avoid this problem, the aim is to report the effect on cooling of blade with streamlining [6] the conventional unidirectional racing disk brake passage flow. The improvement in the cooling will directly affects the car performance especially for racing cars in critical corners and achieving top speed. Only with specific aerodynamic manipulation can be achieved without any additional of mass of extra gadget at the brake system.
2. CFD Simulation of Flow and Heat Transfer
All of the disk designs are cast iron disc and has 32 equal spaced blades. The designs are modelled in 2D and the commercial CFD software FLUENT™.

Turbulence equation that was selected for this study is the RNG k-ε with standard wall treatment is employed. The disc is simulated with six different velocity and rotational speeds as given in Table 1. The brake disk is set to be in isothermal temperature of 600°C. The simulation is run till convergence is achieved.

| Velocity in (m/s) | Rotational Speed (rad/s) | Pout |
|------------------|--------------------------|------|
| 2.46             | 67.34                    | 0 gage |
| 2.89             | 84.18                    | 0 gage |
| 3.28             | 101.01                   | 0 gage |
| 4.00             | 117.85                   | 0 gage |
| 4.41             | 134.68                   | 0 gage |
| 5.54             | 168                      | 0 gage |

The Figure 1 below illustrates the comparison of the three designs for Nusselt Number against rotational speed.

![Figure 1. Nusselt Number against Rotational Speed](image-url)
From Figure 1, it can be deduced that by increasing the rotational speed the Nusselt Number is increasing almost linearly. Curved design is the most superior in heat transfer performance. It is about 40% better than baseline design. The improved design is 20% better than the baseline design. Figure 2 below shows the temperature distribution in Kelvin. The curved design shows lowest temperature distribution in the flow passage compared to all the other designs.

| Baseline | Improved | Curved |
|----------|----------|--------|
| Rotational speed 67.34 rad/s | Rotational speed 168.00 rad/s |

**Figure 2.** Temperature distribution for baseline, improved baseline, and curve model

3. Conclusion
The Nusselt number of the brake disk is increasing with increasing rotational speed. The blade design has significant effect on the heat transfer property. The curved design above with specific profile has the best heat transfer property compared the other two blade designs.

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