UNIVERSITI TEKNOLOGI MARA

# IMPROVEMENT OF FAN AIRFLOW CHARACTERISTIC BY MODIFICATION TO BLADE GEOMETRY (CFD)

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## ABSTRACT

This research focused on the aerodynamic efficiency of automotive cooling fan via two-dimensional CFD simulation. The subject of this research was to study blade geometry design as a function of flow separation behavior and vortex formation. By doing blade design modifications in conjunction with CFD forecast results, improvement in boundary layer characteristic was achieved within the CFD realm. Irregular or unequal spacing of blades in subsonic turbomachinery has been observed in the field as well as in the literature to possess superior noise quality and this irregular spacing was modeled into the CFD domain. Flow vectors were studied from baseline blade geometry and improvement in flow vectors were achieved by modifying the blade geometry. For accurate and reliable flow vector behavior, the two-dimensional cascade model was pre-conditioned with realistic boundary conditions based on cited references and observed data from vehicle measurements in the industry. A more expensive turbulence model and very refined grid size near the wall was employed in order to tackle complex flow phenomena such as flow separation and vortex formation. Choice of turbulence model was based on cited references. Grid independence and convergence criteria were based on stability of monitored residuals, which necessitated very low residual values. A technique for obtaining CFD fan characteristic was established by extracting sufficient CFD data points from base fan model as a function of ram air and correlating with measured data of actual base fan. Blade airflow behavior near the surface revealed an airflow improvement near the trailing edge, instead of near the leading edge as in the case of a patent by GM (Razinsky et al, 1987). Roughness near trailing edge had reduced the magnitude of the reversing flow from trailing edge. This CFD modeling technique has a potential for robust usage in vehicle architecture of an automotive design industry.

# CHAPTER 1

# INTRODUCTION

## 1.0 Background

A growing number in research work on automotive fan blade cascade geometry is found in the literature. References found within these literatures often refer to other research in the aeronautics or aerospace industry, where a lot of focus was given to development in CFD analyses and its utilization in design predictions. In aeronautics, fan blade CFD analyses revolve around turbine or compressor stage design improvement for lower noise, higher output performance and higher efficiency. A lot of design analyses in turbine and compressor blades via CFD can be found in the literature. Detail CFD algorithms, techniques, and even tricks can be found therein. Validations of the CFD techniques are also found in literature. By following similar algorithms and techniques that have been validated, a CFD analysis can give a high level of confidence in design predictions for automotive fan blade design. A number of examples on automotive fan blade design can also be found in which the CFD techniques follow closely well established and validated techniques in the literature of aeronautics as will be discussed further.

## 1.1 Patents on Automotive Cooling Fans

In automotive cooling fan airflow design, a rapid rise in the number of patents is evident from patent search. These patents either deal with an optimization of the aero-acoustic phenomenon or an increase in the aerodynamic efficiency of the fan.

### 1.1.1 Aero-acoustic

With regards to aero-acoustic, airflow behavior near the tip of the fan blades has been identified as a key area for improvement (Robb and Gorman 1983, Longhouse 1980, 1982, Morris and Foss 2001, Savage and Neely 1998). In various works by fan researchers, works related to shroud geometry can be generalized into