ANSYS DOE and Design Optimization on Vehicle Brake Design

PROJECT REPORT

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ABSTRACT

The primary objective of this project **"ANSYS DOE and Design Optimization on Vehicle Brake Design"** determine the optimum dimensions for the brake disc for a four-wheeler vehicle using ANSYS. These dimensions are for the disc inner radius, outer radius and thickness. Static Structural, modal and Transient thermal load cases for emergency braking conditions are individually considered to determine these dimensions. The optimization objective is to minimize the brake disc volume, whereas the other objectives are to minimize the stress, temperature and maximize the first natural frequency of the disc. These goals are accomplished using ANSYS. The system is optimized using MOGA by integrating all the load cases.

1. Design Problem Statement

Primary objective: To minimize the brake disc volume for emergency braking conditions

Secondary objectives:

- Minimize the maximum stress in the brake disc
- Maximize the first natural frequency of the brake disc
- Minimize the maximum temperature in the brake disc

The three subsystems are as follows:

Structural Analysis: The brake disc has to sustain the pressure from the hydraulically actuated brake pads during sudden braking conditions. Stresses are induced due to friction between the brake pads and the disc. The disc also experiences centrifugal body forces due to its rotation. Resultant stresses generated due these forces can lead to material failure. Therefore, it is of prime importance to make sure that the stresses in the disc are minimized.

Modal Analysis: Free modal analysis is performed to ensure that the disc's first natural frequency is higher than the engine firing frequency. This guarantees that the disc does not experience failure due to resonance.

Thermal Analysis: Braking in a vehicle takes place due to friction between the brake pads and the rotor disc. This leads to heat flux generation in the disc which consequently results in increase in its temperature and thermal stresses. Emergency braking conditions induce high temperatures that damage the contact surfaces. It is therefore essential to minimize the temperature to prevent disc wear and tear.

Mathematical Model:

In this optimization study, the brake disc inner radius (P1), outer radius (P2) and thickness (P3) are the design variables. Firstly, the static structural, modal and Transient thermal analyses are performed in ANSYS. For the assumed geometric constraints, Design Of Experiment (DOE) points are generated. Mathematical model is then generated by performing regression analysis on these DOE points to obtain the volume, stress, frequency and temperature quadratic functions. The

optimization problem is designed as follows:

Minimize : f1 : V =

Geometrical constraints for all subsystems:

$$g1 : -P1 \leq -66$$

$$g2 : P1 \leq 90$$

$$g3 : -P2 \leq -124$$

$$g4 : P2 \leq 150$$

$$g5 : -P3 \leq -5$$

$$g6 : P3 \leq 27$$

Design constraints:

$$g7 : S \leq 14\text{MPa}$$

$$g8 : -F \leq -1200\ \text{Hz}$$

$$g9 : T \leq 400\ \text{C}$$