

Motorcycle Dual Exhaust Muffler Design Improvement to Eliminate Failure Caused by Thermal Stress

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ABSTRACT

A single cylinder gasoline engine of a sports bike generates sufficient hot gases to pose great challenge to the designers of exhaust system. The high temperature exhaust gases in muffler creates thermal elongation on the solid parts of exhaust system, which is mounted on the chassis. This arrangement induces thermal stress in exhaust assembly. It is necessary to analyze this thermal stress to ensure the durability of muffler components.

The exhaust design has a diversion at the header pipe to distribute the flow in two branches. This junction and the branches heated up excessively and showed repeated failure. To analyze the thermal stress, the temperature distribution in the muffler components is obtained from Computational Fluid Dynamics (CFD) analysis. The complete motorcycle with detailed exhaust system is modelled in the standard wind tunnel using a commercial CFD software. Conjugate heat transfer (CHT) study is done for normal and adverse operating conditions considering transfer of heat between hot exhaust gases passing through muffler assembly, muffler solid components and external air flowing over motorcycle. The heat generation in the catalytic convertor and the radiation between muffler components are also considered.

Parallely, complete muffler assembly is modelled in a commercially available FEA code. All the muffler mountings are considered including the bushings and bolted connections. Material properties are defined for each of the muffler components. The temperature distribution obtained from CFD analysis is applied to simulate for thermal expansion, stress and deformation in the exhaust system. Results showed excessive stress on a certain component of the muffler. Design modification is implemented and is validated following similar analysis work flow. Thermal stress is found to have reduced considerably in the modified design as compared to the base design.

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INTRODUCTION

Internal combustion engines generate high temperature gases which may damage the engine components if their temperatures exceed the material limits. Exhaust system of engine, also known as muffler, is designed to throw out these hot gases to atmosphere considering their effect on performance of the engine and the noise generation. Targets for reliability must be satisfied keeping in mind the constraints of manufacturing, weight and packaging. Muffler components receive heat from the hot exhaust gas by convection. This heat is transferred to other components by conduction and radiation; to external cooling air by convection and some heat is stored in the muffler components. The yield strength and young's modulus of most materials (especially metals) gradually reduces when subjected to elevated temperatures [1]. Thus, the thermal deformations and thermal plasticity of the

material induce stress which may cause critical failure of muffler components. A fundamental issue in the design of exhaust systems is how to minimize stress resulting from thermal deformation.

FIELD TESTING OF ASSEMBLY WITH SPLITTER BASE DESIGN

In the base design of muffler for a single cylinder water cooled SI engine, a Y-shaped pipe called as splitter hereafter, is incorporated to divulge the exhaust gas flow towards the two silencers. Hence, exhaust gas coming from engine will go through header pipe through the catalytic converter and get diverted in two silencers by the splitter as shown in [Figure 1](#).

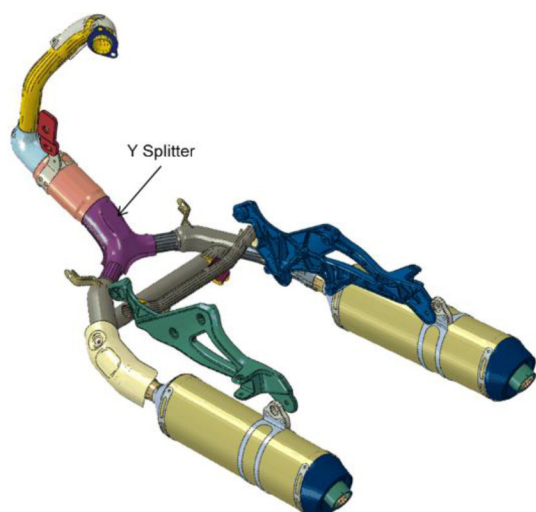


Figure 1. Exhaust system and splitter pipe.

After performing several road endurance tests on actual vehicle, heating marks and cracks are observed on this splitter as shown in [Figure 2](#). It is very important to address this issue as it is failure of the exhaust system. This will leak exhaust gases to atmosphere undesirably and will affect the performance and noise of the engine. The strict pollution norms will also not be met [2].

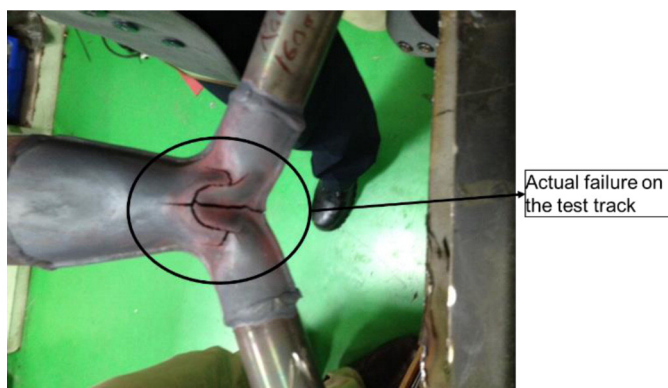


Figure 2. Failure of splitter in road endurance test.

Making number of design proposals and validating each of them physically would be a process inviting lot of cost and time. This called for the use of virtual prediction techniques to finalize an optimum design for the pipe. The problem is solved by analyzing current design in virtual simulation and providing a design change with an objective of reducing the thermal stresses on the failing part. CAE has become a common tool for every engineering problem ever since rapid advancements in simulation technology has started a couple of decades ago. By simulating the CFD and FEA model, this activity also helped to understand the effects of coupled loads in a muffler assembly structure. The workflow is as shown in [Figure 3](#).

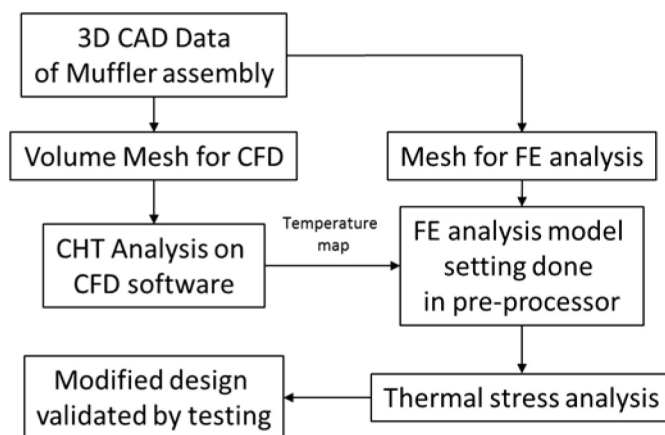


Figure 3. Process workflow of combined CFD and FE analysis

CFD ANALYSIS

Model Setup

Cooling air flowing over motorcycle with driver and exhaust gas flowing through the exhaust system is simulated in commercially available CFD code. [Figure 4](#) shows the complete air domain considered for the analysis with motorcycle, driver and detailed exhaust system. The heat transfer from exhaust gas to solid parts of exhaust system and to cooling air is also solved. This complete motorcycle with detailed exhaust system is modelled in the air domain with dimensions 3.133 m length, 1.65 m width and 0.95 m height [3]. Tetra mesh is created for solid and fluid volumes with prism layers on the surfaces to capture boundary layer effect.

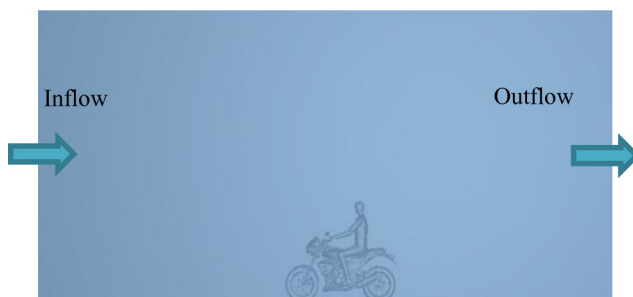


Figure 4. Model setup 1 for CFD analysis

In first phase conduction and convection heat transfer analysis is carried out. Top speed of vehicle is considered for the analysis. Hence, inflow velocity of cooling air equal to the vehicle speed is given as input to the inflow surface of the air domain. Mass flow rate of exhaust gas corresponding to the engine speed at the top speed of vehicle is given as input to exhaust system [4] as shown in [Figure 5](#). Boundary conditions are mentioned in [Table 1](#) and material properties used are given in [Table 2](#).