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ANALYSIS OF TWO WHEELER EXHAUST SILENCER WITH THERMODYNAMICS PRINCIPLE AND COMPUTER AIDED DESIGN

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ABSTRACT

The hot gases from engine passes through the exhaust system of the automobile at very high temperature. Exhaust system of an automobile consist of three parts such as exhaust manifold, catalytic converter and silencer out of those silencer having very short life span as there is lot of restriction provided to the flow of hot gases due to complex geometry in order to reduce the noise level hence gases staying more time in this section as compare to other two part of exhaust system. Hence silencer needs to be focused for thermal analysis in order to increase its life span. for this improvement in life span the uniform distribution of heat over the entire exhaust system which consequently enhanced life of the elements in the exhaust system is necessary . The problem recognized for this proposed study is to assess the heat flow during the passage of hot gasesand design the passage in such a way that it will minimize the destructive effects of hot-spots and localised heating due to heat transfer barriers over the length of thesilencer, especially at the front end mating with the exhaust manifold

INTRODUCTION

The main objective of exhaust system of Automobile is to reduce the pollution and noise produced by the engine. Therefore controlling level of these two parameters is quite essential for effective working of exhaust system which can be done by making use of catalytic converter and Silencer (resonator) respectively. In order to make catalytic converter effective the temperature of it should be reach up to 900˚C which is possible in four wheel drive and heavy duty vehicles. Therefore in case of two wheelers, catalytic converter is not used instead of that only silencer are placed in exhaust system with different modern pollution control device like EGR, etc. The size, shape and construction of silencer vary according to the type and size of the engine. Silencers are normally classified in to two types such as “Reactive Silencer” and “Absorptive Silencer”. Reactive silencers generally consist of several pipe segments that interconnect with a number of larger chambers. The noise reduction mechanism of reactive silencer is that the area discontinuity provides an impedance mismatch for the sound wave travelling along the pipe. This impedance mismatch results in a reflection of part of the sound wave back toward the source or back and forth among the chambers. The reflective effect of the Silencer chambers and piping (typically referred to as resonators) essentially prevents some sound wave elements from being transmitted past the silencer [12]. The reactive silencers are more effective at lower frequencies than at high frequencies, and are most widely used to attenuate the exhaust noise of internal combustion engines. Absorptive silencers contain fibrous or porous sound-absorbing materials and attenuate noise by converting the sound energy propagating in the passages into heat caused by friction in the voids between the oscillating gas particles and the fibrous or porous sound-absorbing material [13]. Absorptive silencers usually have relatively wideband noise reduction characteristics at middle and higher frequencies. Absorptive silencers are often used to attenuate the engine intake noise or supplement the performance of reactive silencers for the engine exhaust noise control. The sound absorbing materials are generally held in position by the use of a perforated metal liner. .For both the types of silencers, uniform distribution of heat is desirable. But because of acoustic reason some area undergoes in thermal failure which reduces life span of exhaust system. So without affecting acoustic structure of the current system modification was done for uniform heat distribution.

LITERATURE REVIEW

R. L. Edlabadkar et al. [1] In the analysis they examine fin of three categories which is made of steel and mounted on the steel plain plate of dimension 2.1 m × 0.5 m × 0.45 m. the categories of fin are as follow. 1) Vertical plate with horizontal fin 2) Vertical plate with vertical fin 3) Vertical plate with V type fin a) 60° V fin b) 90° V fin c) 120° V fin For comparison purpose all the fins having same surface area and boundary condition. The base plate and fin having same temperature and they kept temperature difference between surface and atmosphere is 150°C for all fins. After the analysis it is clear experimental data are approximately matched with CFD data with +/- 10% error. And CFD analysis al so shows 90° V type fin is more effective over the other fin. This gives base plat heat transfer coefficient 6.26w/m2k. It is because 90° V fin offers fewer obstacles for flow disturbance in the upside region and most effective high heat transfer region in the downside region of the base plate. It observed that out of all type of fins partition maximum heat transfer achieved in case of 90° V-partition plates as compared to other.

Dattatray et al. (2013) [2] carried out the thermal analysis for motor bike exhaust silence to reduce hot spots through design modification. They design the muffler made with hot spot reduction and made enhancement in the life of the components of exhaust system. They used high temperature heat resistance powder coating for mufflers of automobile application with improved aqueous corrosion, high temperature corrosion which started from the formation of the hot spot at front section of muffler. They investigated the modified design of muffler for heat transfer and proposed best suitable results to
reduce hot spots in the exhaust sub-system.

Satish G. Kandlikar et al. [3] study the effect of roughness on heat transfer by experimentation method. Under the study they kept the value of Reynolds number much below i.e. 2300 with single phase flow in channel with small hydraulic diameter. For changing the roughness of inside surface of tube acid etching method was employed during experimentation. They used two stainless steel tubes of 1.032 cm and 0.62 cm of inner diameter which acid treated to provide three different effective roughness values for each tube. The Reynolds number range for the test was 500-2600 for 1.032 cm tube and 900-3000 for 0.62 cm tube. The effective roughness (e/D) for 1.067 cm diameter tube is 0.0025, 0.00178 and 0.00281 and for 0.62 cm diameter tube is 0.00355, 0.0029 and 0.00161. From the experimentation found that the effect of varying roughness from 0.00178 to 0.00225 on heat transfer of 1.067 cm tube was insignificant but for 0.62 cm diameter tube roughness plays significant role. From that it found the tubes of small diameter i.e. less than 0.62 cm is more effective with increasing the effective roughness factor. From that it is clear if tube diameter increases then for same roughness value as that of small tube it gives the low heat transfer rate; hence as tube diameter increases roughness value also have to increases to maintain the effectiveness of tube for heat transfer rate.

Antony luki A et al. (2016) [4] investigated that augmented surface has been achieved with dimples strategically located in a pattern along the tube of a concentric tube heat exchanger with the increased area on the tube side. Here investigation dimpled tube is used. From theoretical calculation the overall heat transfer coefficient is increased and also effectiveness of the dimpled tube with concentric tube heat exchanger is increased 8% compare to plain tube concentric tube heat exchanger. From theoretical results shows that dimpled tube heat exchanger gives better performance. Hence they suggest the dimpled tube is used in concentric tube heat exchanger in various applications will give high heat transfer.

ZeynepParlar et al. (2013)[5] studied a reactive perforated muffler numerically and experimentally.The transmission loss for the muffler was analyzed using NASTRAN, ANSYS and COMSOL software. For experimental results he used FFT analyzer, pressure microphones, power amplifiers and sound source. He found that the results obtained by numerical analyses and experimentally were having an error of around 20%. So, prior to prototype manufacturing the muffler design should be verified numerically,(ZeynepParlar,

RifatYilmaz, et al 2013)[6] Bin Zou, Yaqian Hu, Zhien Liu, Fuwu Yan and Chao Wang [2] in their research paper "The Impact of Temperature Effect on Exhaust Manifold Thermal Modal Analysis" discussed the impact of temperature effect on exhaust manifold modal analysis by mapping temperature field from the CFD software and then heat conduction process is analyzed in FEM software with the temperature field boundary conditions. At last, the modal analysis that considers temperature effect is done. The frequency and vibration mode between cold modal and thermal modals are compared.The result shows that temperature has a great influence on the manifold mode and it is very valuableto product design.

Chinaruk Thianpong et al. (2009) [7] Experimentally investigated the friction and compound heat transfer behavior in a dimple tube fitted with twisted tape swirl generator using air as a working fluid. The effect of the pitch and twisted ratio on the average heat transfer coefficient and the pressure loss are determined in a circular tube with the fully developed flow for the Reynolds no. in the range of 12000-44000. The experiment is conducted for 2 different dimple tubes with different pitch ratios of dimple surfaces. The Results obtained reveal that both heat transfer coefficient and friction factor in the dimple tube fitted with twisted tape, are higher than those in dimple tube acting alone and plain tube.

Dr. S. Rajadurai et al., [8] this paper deals, to evaluate the durability of exhaust system components by CAE Simulation. Finite element simulation are carried out and the results are explained for the typical exhaust system components considering the durability loads such as engine vibration loading, proving ground road loads. The durability issues associated with the exhaust system components such as muffler-pipe system, brackets and hanger designs are analyzed.

Johan Wall Karlskrona, [9] describes the Low vibration levels are a critical objective in automobile exhaust system design. It is therefore important for design engineers to be able to predict, describe and assess the dynamics of various system design proposals during product development.

Yang Yun Hong, Cao Zhan-Yi, **Lianzhen Song & Yu Hai Xia [10**]: The aim of this paper is to find a new material composition for exhaust manifold in first automotive works (FAV) to meet reduced pollutant emission and high efficiency. The repeated heating/cooling test was performed under cyclic heating at various maximum heating temperature (Tmax) ranging from 8000 C to 9000 C and minimum temperature of 2000 C was maintained. 4.7% Si - 1.1% Mo Nodular Cast Iron was used as a specimen. Thermal fatigue cracking behaviour was inspected by use of optical microscope, scanning electron microscope and energy dispersive spectroscope. It was found that cracking always initiates at the bigger surface of specimen and showed cross shape budding. The reasonable working temperature of high SiMo Nodular Cast Iron is not more than 8400 C

Dr. L. Suresh Kumar [11]: This paper showcases the various factors to be considered while designing an optimal engine to satisfy the increasing performance demand and to reduce the weight. It was observed from design consideration that engine power could be maximized at high speed if gases can be lead from piston chamber to exhaust manifold smoothly and heat radiation into surrounding can be reduced by coating exhaust header with ceramics. FEA consideration show that if stresses and deflections obtained in various analyses are under the design limit of the material used then the design can be considered as a safe

R. Raguram [12] carried out an effective study of the analysis and failure of silencer and silencer mounting brackets. The study is carried out on Ashok Leyland passenger busses. The study depicts the common causes of silencer failures.

P. Srinivas et.al [13] performed Design and Analysis of an Automobile Exhaust Muffler. Dynamic modal analyses were carried out to determine the mode shapes, stresses and deformations of exhaust muffler using CAE analysis.The muffler geometry was checked for its Pressure drop,Temperature drop and Velocity distribution and based on the study it was concluded that Double expansion chamber gives better results as compared to single

expansion chamber.

S. Rajadurai et.al [14] provided an extensive study for the materials used for the automotive exhaust systems

Mr. N. Vasconcellos et.al [15] performed Structural Analysis of an Exhaust System for Heavy Trucks. A finite element model was generated including the complete vehicle and the exhaust system. The results obtained assured the structural integrity of the exhaust system and contribute to a better understanding of this system behavior and its structural strength.

Mr.AmitMahadeoAsabe et.al [16] Postulated the design and modification of silencer in order to reduce the vibration. The experimental analysis was carried out with the help of FFT analyzer to evaluate the natural frequency and to distinguish it from the working frequency to avoid resonating condition.

Patekar [17] theoretically modeled the exhaust silencer of a two wheeler using Finite Element Method and experimentally validated using Fast Fourier Transform analyzer. It was noticed that thedynamic performance could be increased with increasing thickness of various parts

METHODOLOGY

1) Mathematical Method

In order to analyze the problem, the empirical procedure in the Engineering domain can be applied for seeking a outcome. The study over the topic done in the past has offered formulae derived by the researchers in the particular field. Application of the significant mathematical rule to the problem at hand can lend a reliable solution for finding the best alternative. Usually, the formulae in the field of Applied Mechanics or Structures can be useful for finding a numerical value for specifying the quantum of the unit or direction for the result. By using those formulae one can compute the temperature drop over the length of silencer body and on the basis of that inlet and outlet temperature difference it is easy to calculate overall heat transfer coefficient.

2) Analytical Method

Analytical methods refer to procedures and techniques for diagnosing data collected while conducting an evaluation. There are two main types of analytical methods include quantitative and qualitative methods. Quantitative methods consist of arithmetical techniques for analyzing data, and qualitative methods analyze data, such as notes from interviews and observations, that cannot easily be concise in numerical terms. Popular quantitative methods used in evaluation include, but are limited to, analysis of variance, factor analysis and linear regression. Quantitative methods make data simpler to diagnose and summarize, and qualitative approaches are subject to changing interpretations. Many evaluations, especially in education and the social sciences, merge qualitative and quantitative techniques. Typically, arithmetical tools are engaged like ANOVA, DOE or other process control or parameter optimization techniques whereas, the software Minitab is utilized for working on these tools.

3) Computational approach

Computational approach presents for the assessment of the given problem. One of the key features of the work is the search for ease and robustness in all steps of the modeling, in order to contest the proposed method with industrial practices and constraints. The proposed technique utilizes software in the domain of FEA (Finite Element Analysis) for analyzing the effects of the deviation in the values of the design parameters influencing the response parameter. For current case, appropriate CAE software in the structural domain like Ansys Nastran / Radio SS or similar solver would be deployed.

4) Experimental set up

With the help of experimental set-up one can diagnose the data in a real time situation or verify the actual outcomes obtained by other methods. This method is easier to visualize and comprehend but is more challenging in terms of manipulation of the input data for finding the sensitivity associated with the result. Also, it is expensive and time

consuming to build a prototype and later engage the testing equipments for the purpose. For proposed study, for reasons of confidentiality, the Sponsoring Company would only provide experimental and validation data generated at its end. This data can be used for assessment with the Analytical approach or the Mathematical dealing offered to the thesis work. Of the above, the computational approach using CAE software would be administered for this planned work. Physical experimentation methodology would be deployed for verification of results.

EXPERIMENTATION

The two-wheeler recognized for proposed study being a modern variant introduced by a top OEM in this segment, the experimentation would be carried out over the silencer of a `live' vehicle. For the existing silencer, the readings for temperature would be recorded at various chosen locations over the complete length of the silencer. These results would be compared with the benchmark analysis done using the `existing' i.e. current geometry for the silencer. A good consensus of the outcome would be a precursor for alignment of readings over the `modified' geometry to be suggested later for summit the objectives.

CONCLUSION

To have more life span of silencer thermal stress concentration due to localised heating has to be minimized. to avoid localised heating. there is need of uniform distribution of heat throughout the silenser. Comparison of the result determined by `analysis' i.e. the methodology /computational approach with the physical (laboratory) experimentation would be a good pointer to authenticate the thermal analysis and hence design , said to be validated if the geometry of the silencer yields a result that displays a good competition within the analysis and the physical experimentation.

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