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Design & Manufacturing of exhaust system for GO- KART

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Abstract-**A muffler is a device for reducing the amount of noise emitted by the exhaust of an internal combustion engine. This noise is reduced as the transmission loss (TL) inside the muffler increases. Different components are present in the muffler for transmission loss like perforated tubes, absorption materials etc. by which noise is reduced.[1] Exhaust noise from engines is one of component noise pollution to the environment. Exhaust systems are developed to attenuate noise meeting required db (a) levels and sound quality, emissions based on environment norms. Hence this has become an important area of research and development. Most of the advances in theory of acoustic filters and exhaust mufflers have been developed in last two decades. Mufflers are important part of engine system and commonly used in exhaust system to minimize sound transmissions caused by exhaust gases.[2] With the simulations for analysis and based on results from CAE Software Tools (ANSYS R16.2) and CFD (FLUENT 10), the design is manufactured into a prototype.[3] The complete system is modeled mathematically for analytical results. The work carried out will be used by the students participating within the STALLION KARTING project for year 2022-23 and carried out for the progress of the team. A theoretical concept has been demonstrated on the Energy recovery system Le the MGU-H that can be implemented that has many positive points.[4]**

Keywords **– Muffler, Designed muffler, Back Pressure, CAE, CFD, FEA, Energy Recovery.**

I. INTRODUCTION

The exhaust system of an automobile consists of manifold, catalytic convertor and muffler connected with the tail pipe. Hot gases along with the sound waves are generated at the exhaust stroke are sent to the exhaust manifold through exhaust valve. Sound waves along with exhaust gases pass from exhaust manifold to catalytic convertor through a pipe. Due to partial combustion the gases entering the catalytic convertor consist of a mixture of CO, HC and NOx which are harmful to the environment.[1] Gases first enter one of the ceramic blocks of a three-way catalytic convertor and heat it up causing catalyst to react with toxic gases which further continues in the next ceramic block. The exhaust gases coming out of the CATCON (Catalytic Convertor) are less toxic containing mixture of CO2, N2, H2O (vapour). These gases are now less toxic sound waves which are then passed into the muffler. Muffler is an expansion chamber where sound waves can be absorbed or cancelled or both together.[3] Depending on the configuration and working principal mufflers are classified into reactive, absorptive and reactive absorptive type of muffling chambers. In reactive mufflers the principle of destructive interference is used while in absorptive mufflers the sound waves are absorbed by the insulating material which then converts incident sound energy into heat. Various insulators can be used as according to the requirement of the system.[5] Approaching towards more efficient sound cancellation additional component in the expansion chamber can be equipped called as Helmholtz resonator. Finally, the exhaust gases consisting of less harmful gases along with considerably low sound waves move out of tail pipe into the atmosphere. Along with the main purpose of the exhaust system serves it is to be well tested for the performance of the vehicle with parameters such as back pressure or back fire. Depending upon the requirement of GO KART and the rules bonded the exhaust system is designed with the components including exhaust pipe, muffler and tail pipe. According to the requirement of the vehicle with the study and analytical results absorptive type of muffler is found most suitable. Targeted transmission loss for the muffler is 98 db.[6]

II. LITERATURE REVIEW

Industrial noise sources are divided into two categories with specific characteristics. Category - I cover sources that produce mainly low frequency noise and can tolerate relatively high pressure drops. Engines, rotary screw compressors, rotary positive blowers and reciprocating compressors are types of these sources. The nature of these machines is to generate low frequency noise and have pressure volume relationships that are quite tolerant of systempressure drop; such machines are perfectly suited for reactive mufflers. Category - II covers sources that produce mainly high frequency noise and have performance is very sensitive for system pressure losses. These sources are always moving or compressing the fluid with spinning blades. For examples, includes turbines, centrifugal fans, etc. This kind of equipment is best treated with absorptive muffler for both low and high temperature applications.

III. GO-KARTSEXPERIMENTAL SETUP

Use four stroke or two stroke internal combustion engines, air cooled or water cooled engines for their operations. According to specifications confining to the rule book, Bajaj Pulsar 150 Engine is selected for the Kart Power Train. The maximum engine power 13.5 bhp at 8500 rpm, the types of mufflers are judged from Absorptive type, Reactive Type and Combined Absorptive and Reactive Type of mufflers. Absorptive muffler gives less back pressure reducing the chances of back firing in engines and used for low capacity low power engines without baffles is selected for the exhaust system of GO-KART.

IV. MATERIAL SELECTION FOR COMPONENTS

1) Housing (shell):2 Shell performs the function of external cover which has to be high in strength structurally and thermal strength to withstand high temperature of about 300-C to 500 C. Material that can be used for manufacturing the shell to satisfy function requirements are Mild steel and Stainless steel. Any of the two material and specified grades of these materials can be used. With the strength capacities and availability criteria Mild steel and Stainless steel-303 (1.5mm thickness) is selected for the manufacturing of the component.
Properties of SS 303 are:

1. Physical Properties:
   a. Density (p): 8 g/cc
   b. Tensile Strength (yield): 415 MPa
   c. Modulus of Elasticity (E): 200 GPa
   d. Poisson's ratio (v): 0.29
2. Thermal Properties:
   a. Thermal Conductivity: 16.2 W/mK at 100-C
   b. Melting Point: 1400-1455 C

2) Porous Material:1 There are three types of porous materials used in exhaust muffler. They are as Following:

a. Glass wool
b. Ceramic wool
c. Steel Wool

Glass wool: Glass wool is preferable porous medium because it is relatively in active chemically, relatively non hygroscopic, its fibres are strong and elastic, making in bulk a resilient mass that will retain its characteristics; and the fibres can be made in an almost unlimited range of sizes. A wide range of permeability is there for obtainable that is absolutely essential for latitude in the design of flow meters. In addition, the wool is inexpensive and easy to procure.

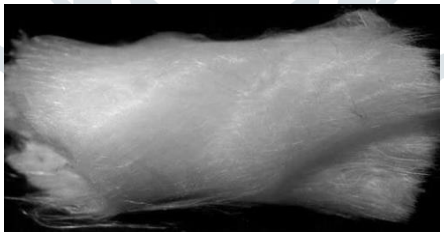

Figure 1 : - Corning Glass Wool

Ceramic wool: Ceramic fibre is a lightweight insulating product. It has low thermal mass which means that it does not retain heat, low thermal conductivity and is an extremely effective insulation material. Its high thermal shock resistance makes it suitable for applications where traditional refractories cannot be used. So called Refractory Ceramic Fibre is made from high purity alumina-silicate materials. Ceramic fibre is produced by melting these products in an electric arc furnace, a stream is poured and cooled to form the fibre strands from which the ceramic fibre products are produced.

Figure 2 : - Ceramic Wool

Steel wool: Steel wool, also known as iron wood, wire wool, steel wire or wire sponge, is a bundle of very fine and flexible sharp-edged steel filaments. It was described as a new production 1896. It is used as an abrasive in finishing and repair work for polishing wood or metal objects, cleaning household cookware, cleaning windows and sanding surfaces. Steel wool is made from low-carbon steel in a process similar to broaching, where a heavy steel wire is pulled through a toothed die that remove thin, wire shavings.

Figure 3 : - Steel Wool

From the above three materials ceramic wool is chosen for manufacturing as it has more life than the glass wool. Glass wool has a tendency to deteriorate under prolonged exposure to heat whereas ceramic wool lasts longer. And also, Glass wools maximum service temperature is less than 500° C and is much less than that of ceramic wool which is about 950 C.

Properties of ceramic wool fiber are:

1. Physical Properties:
    a. Porosity(a): sum
    b. Permeability(u): 2.39*10* m/s
    c. Moisture Absorption: less than 0.2%byVolume d. Density(p):23kg/m
    d. PackagingDensity:250kg/m³
2. Thermal Properties:
    a. Thermalconductivity:0.09W/mKat400 °C
    b. SpecificHeatCapacity:1000J/kgK
3. Perforated Sheet Tube:

Perforation on the sheet allows the sound wave to reach the absorbing material. This tube is manufactured of the same material as that of housing shell. SS 303 is used in the perforated tube with the same properties.

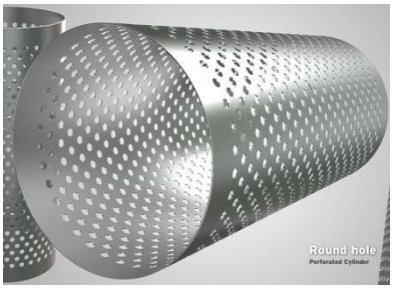

Figure 4 :- Perforated Steel Sheet

These are the component material selected such that they fulfil the functional requirement of the system.

V. DESIGN OF EXHAUST SYSTEM

V.1 Design of housing of muffler

Designing the muffler for Go-Kart or any of the automobile can be achieved by various theories. In this project we have focused on the volume-based theory for the expansion chamber followed by Acoustical theory and then verified with the thermal and fluid pressure computational analysis. With these additional structural mathematical modelling also helps in finalizing the model of muffler and the components in the system. With the volume theory the design is initiated and iterations are carried out which are then filtered by acoustical theory designing procedure.

V.2 Volume Theory:

Volume of expansion chamber has to the multiple of swept volume of engine. This will ensure the expansion of flue gases in the chamber reducing its pressure and sound waves are absorbed by absorbing material at the greater surface area reducing the sound intensity at the outlet of the muffler.

VI. ANALYSIS OF DESIGNED MODEL

Analysing the model with software is the best way to judge the design flaws and re-designing the models to make the required corrections which satisfy all the functional requirements of the system. Various analyzing software are used to analyze the muffler model such as Ansys Fluent, Hyper mesh.

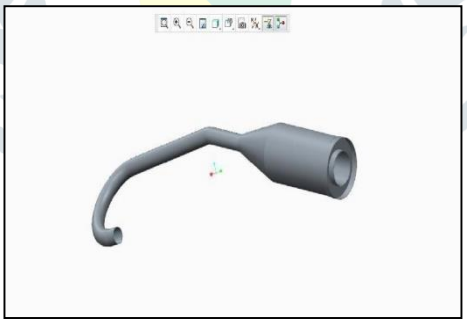

Figure 5 : - Cad Model of Exhaust Assembly

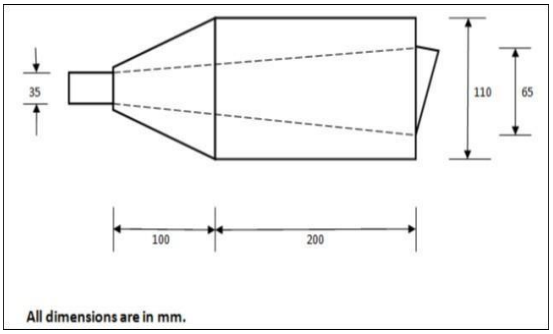

Figure 6 : -Section view of the muffler

VII. COMPUTATIONAL FLUID DYNAMICS

1.Pressure Distribution:

Here the model is judged for back pressure in the system. Software used is Ansys R15. We camper form various analyses using different solvers. Since the pressure distribution is to be determined, the available suitable solver is Fluent. From the information studied the pressure at the exhaust port is known and the corresponding input parameters are provided for the analysis. Pressure distribution usually is to be judged through the exhaust pipe.5

Input Boundary Condition:

Inletpressure:2 bar (gauge)

OutletPressure:1.01325 bar (absolute)

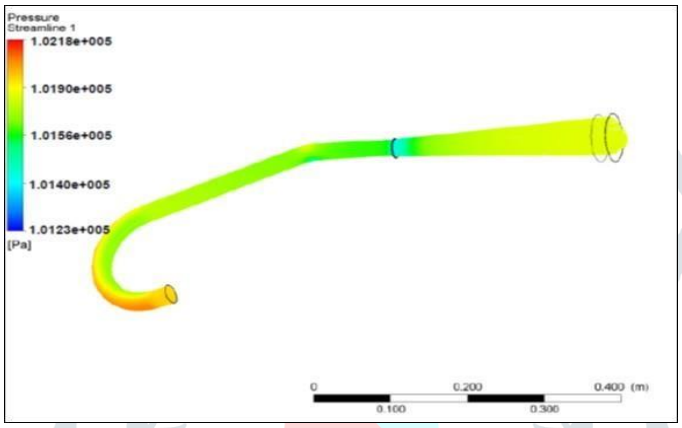

Figure 7 :Pressure Distribution Result

Result:

Maximum Pressure: 1.0218 bar

MinimumPressure:1.0123bar

Since the pressure in the system is greater than atmospheric pressure through the muffler there won't be back force acting in the exhaust pipe. At the end section after the muffler the pressure is lower than atmospheric pressure by 125 pa which can create back pressure in the muffler. Since muffler is the expansion chamber with greater diameter than that of the pipe it causes the back pressure gages to expand. Hence it is unaffecting the performance of engine without causing any backfiring. This gives the less back pressure as compared to the previous model hence safer.

2.Temperature:

Software: Ansys
Solver: Fluent
Analysis: Temperature Distribution
This is carried out to get the temperature at the different point through out the system w hich can also be used invariant thermal analysis.

Input Boundary Conditions:

a) Temperature at inlet of system: 650°C
b) Temperature at outlet: 25°c

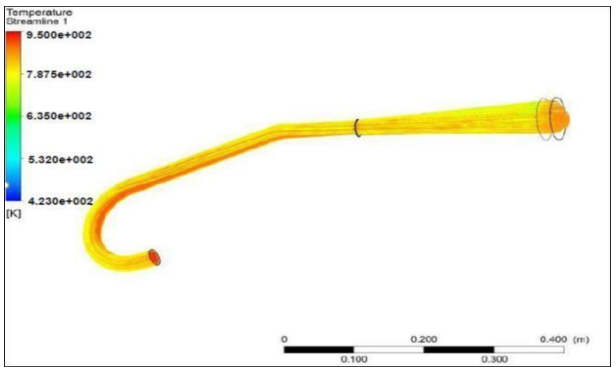

Figure 8 : -Temperature Distribution Results of model

Results:

Maximum Temperature: 650°C

MinimumTemperature:423°C

The results from the temperature streamline are also used for the thermal analysis of the system which gives the deformation of the muffler thermally. Here the heat dissipation is observed is more as compared to the earlier model giving better results thermally.

3.Velocity Distribution:

This model is verified through velocity distributional so which will give the flow characteristics clearly through the pipe as well as the muffler.

Analysis: Velocity distribution

Software: Ansys

Solver: Fluent

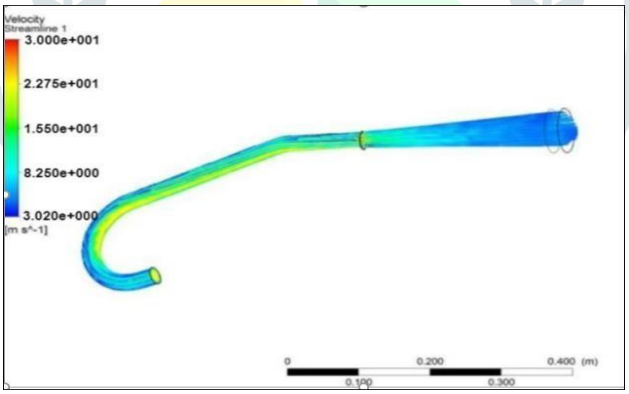

Figure 9 : - Velocity Distribution Results

Results:

Maximum Velocity: 30.00 m/s

Minimum Velocity: 3.02m/s

Velocity distribution helps in understanding the flow of flue gases through the duct.The velocity reduces in muffler as the flue gases expand and the energy is the absorbed by Glass wool. Hence reducing the speed in the portional to muffler too. As Maximum velocity is 30.00m/s the flue gases moves through the duct faster and does not cause back pressure and chances of back firing of engine is reduced.

From the above illustrations of analysis the model is safe through Computational Fluid Dynamics in all three analyses of pressure, temperature and velocity distribution streamlines. These resulted are self satisfying and few of the results are used as the input data in the further analysis.

Thermal Analysis:

Thermal analysis gives the deformation and stress induced in the model due to temperature of the system. Since the temperature distribution is known from CFD analysis, the transient flow analysis with varying temperatures in the system can be judged for deformation.

Analysis: Transient Thermal Analysis (Static structural) Software: Ansys R18

Solver: Thermal Input Data:

Temperature at inlet of Pipe: 650-C Temperature at inlet of Muffler: 355-C

Temperature at outlet: 25-C Film Coefficient: 970.84W/mK

VIII. RESULT AND DISCUSSION

Analysis Results

The designed model was analyzed for CFD, Static Structural and FEA using both Software Simulations and analytically. Mathematical modeling including FEA for Exhaust System is performed and the behavior of the system is predicted.

1. CFD (Computational Fluid Dynamics)

Maximum:1.021bar

Minimum:1.012 bar

2. Temperature

Maximum:650°C

Minimum:361°C

3. Velocity

Maximum: 36.87 m/s

Minimum:0.0027m/s

4. Static Structural (Thermal)

Maximum Displacement: 1.339 mm

Maximum Stress (Von Misses): 325.1 MPa

Factor of Safety: 1.276

IX. CONCLUSION

1. Exhaust System for GO KART is designed successfully based on two theories and analyzed for its performances using CAE tools which is then manufactured selecting best material and design.

2. Analysis performed includes Thermal, Structural and Acoustical tools optimizing variables confirming to the objectives from Rule Book of GKDC.

3. The system is mathematically modeled using FEA (Vibrations) for the entire Exhaust System.

4. Manufactured System is implemented for use in GO KART vehicle for GKDC Season event for year 2018-19 with completion of testing. The system satisfies the requirement of sound limit within 98 dB as tested results give 84 dB as emitting Sound Level from tail pipe of exhaust.

5. This system model has also cleared Technical Inspection in events GKDC event represented by STALLION KARTING.

6. Study of Energy recovery system is more efficient than the Naturally aspirated engine.

7. Adoption of ERS may permit Regenerative braking and engine downsizing as a means of improving efficiency and hence reducing fuel consumption and CO, emissions.

8. The ERS has major areas of development in power density, life, simplicity, effectiveness and first and foremost the cost of the device.

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