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Design, Analysis And Manufacturing Of Race Car Exhaust System

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Abstract:

Exhaust Systems for the vehicle are the most crucial system required in the transmission which follow IC Engine trend. Concerning race car, the exhaust systems determine the performance along with the treatment of Exhaust gases. Mufflers, catalytic converters and resonators make up the system complete for treatment of exhaust gases. Exhaust gases norms getting strict all over the world makes the topic more interesting and important for the innovation and development. In this paper the exhaust system is designed using Volumetric Theory followed by Acoustic Theory specifically the free flow absorptive muffler. In order to optimize the engine performance and the Sound limit, the free flow muffler is designed with minimum back pressure. Further modelled using design software Creo Parametric1.0 and simulation carried by software Ansys (Fluent) and tested by Matlab validates the model. Thermal stress analysis carried in Ansys gives safe results. Mathematically modelled the design and verified with the Simulation results are presented in the paper. Confining to the rule book of GKDC Season6 the acoustic limit of 100dB is achieved that further validates the Vehicle with Technical Inspection OK report.

Keywords : *Exhaust system , noise reduction , emission ,*

mufflers , efficiency of engine.

1 INTRODUCTION

Go-Kart is a type of open, four - wheeled vehicle. Go-kart vary widely in speed and some can reach speeds exceeding 260kmph while recreation go-karts intended for the general public may be limited to lower speed. **American Art Ingels** is generally accepted as a father of karting. It has generally low capacity engine (in our event it is restricted to 150cc) and suspension is mandatory for go-karts. Go karts have specific systems as transmission, steering, brakes of which our area of focus is transmission system which is further divided into power train, intake and exhaust system. With our main concern of reducing exhaust noise and emissions the project is directed.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 converter through a pipe. Due to partial combustion the gases entering the catalytic converter consist of a mixture of CO, HC and NOx which are harmful to environment. Gases first enter one of the ceramic blocks of a three - way catalytic converter 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 are less toxic containing mixture of CO_2, N_2, H_2O (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. Depending on the configuration and working principle 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. 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.

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Along with the main purpose 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 GOKART 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 best suitable. Targeted transmission loss for the muffler is 98db. With the calculations based on volume theory of muffler with respect to engine (BAJAJ PULSOR 150CC old model) used in the vehicle the design is formulated and cad models are designed in modelling software Catia and Creo Parametric1.0 and analysis performed in CFD (fluent) along with the analytical techniques.Further with the experimental validation with the manufactured model system is installed in kart which is then tested for performance of vehicle.

2. LITERATURE REVIEW

A. **Shital Shah, Saisankara narayana K, Kalyankumar S. Hatti, Prof. D. G.Thombare et al (2016)** suggested that 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. This paper deals with a practical approach to design, develop and test muffler particularly reactive muffler for exhaust system, which will give advantages over the conventional method with shorten product development cycle time and validation. This paper also emphasis on how modern CAE tools could be leveraged for optimizing the overall system design balancing conflicting requirements like Noise & Back pressure.

B. **Jayashri P. Chaudhari, Amol B. Kakade et al (2016)** Absorptive mufflers use sound absorbing materials to attenuate sound waves. It is widely used in HVAC duct systems. Typical absorptive mufflers are configured in a parallel baffle arrangement. The motivation behind why we go for absorptive muffler is; in daily life the air pollution causes physical sick impacts to the individuals furthermore the earth. The main contribution of the air pollution is automobiles discharging the gases like CO2, unburned hydrocarbons and so forth, in order to avoid such gases by introducing this absorptive muffler. It is fitted to the exhaust pipe of the engine; Sound delivered submerged is less hearable than it produced in atmosphere. The objective of this work is to obtain a muffler with optimal acoustic performance in relation to its size or volume, as well as a reduction in the counter pressure to the flow of gases, i.e. while at the same time reducing the noise, it also minimizes

3. SELECTION OF MUFFLER TYPE FOR THE SYSTEM

GO-KARTS use four stroke and 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 13.5bhp at 8500rpm, 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 with out baffles is selected for the exhaust system of GO-KART.

4. COMPONENETS OF EXHAUST SYSTEM

Absorptive mufflers consist of shell that is the outer cover of the expansion chamber, the packing porous material and the perforated tube creating the hollow cavity duct in the chamber. The packing material is fixed inside the gap between perforated tube and external shell.

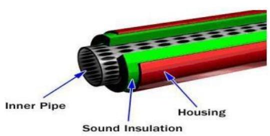

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Fig1. Absorptive type muffler

4.1. *Housing(shell)*: 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 With the strength capacities and availability criteria Mild steel and Stainless steel-304 (2 mm thickness)is selected for the manufacturing of the component.

4.2. *Porous material:* There are three types of porous materials used in exhaust muffler. They are as following:

- Glass wool
- Ceramic wool
- 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 where as ceramic wool lasts longer. Also Glass wools maximum service temperature is less than 500°C and much less than that of ceramic wool which is about 950°C.

4.3. *Perforated steel tube:* Perforation on the sheet allows the sound waves to reach the absorbing material. This tube is manufactured of the same material as that of housing shell.SS304 is used in the perforated

5. DESIGN OF MUFFLER

5.1. *Design of housing of muffler*

***A.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 the absorbing material at the greater surface area reducing the sound intensity at the outlet of the muffler.

Generalized equation can be given as:

$$V_m = F * V_s$$

Where,

Vm=Volume of muffler, Vs =Swept Volume of engine, F=Factor (multiple of swept volume)

Factor to be multiplied to swept volume of engine is to be selected from 10 to 24. Selection is based on the space availability to accommodate the muffler. Since exhaust system is the last part of the transmission department which has to be adjusted with respect to the space and structure of rest of the components of the systems in the vehicle.

Step1: Input Data:

Bore (D): 57mm
Stroke (L): 56.4mm
No. of cylinders : 1
Engine Power : 13.5bhp Max.
RPM : 8500rpm

Step2: Volume of Muffler

Swept volume of engine, Vs=143.9cc

Assuming the values of factor, below iterations were carried out:

Iteration1 : Factor20, Vm=2878.0cc
Iteration2 : Factor16, Vm=2302.4cc
Iteration3 : Factor12,

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Vm=1726.8cc

Depending on the space availability we proceed with design models having expansion factors 16 and 12 for further analysis. Expansion chambers can be of varied shapes, we select a combination of frustum and cylinder. This is to utilize the maximum available space with optimum results concerned with volume based design followed by Acoustic Design.

Step3: Internal configuration
Assuming total length of muffler to be 0.3m, based on space available.

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Length of frustum: 01m and length of cylinder:0.2m

$$V_m = \pi R^2 0.2 + \frac{\pi * 0.1[R^2 + r^2 + rR]}{3} \quad (1)$$

Iteration1: Vm=
2302.4cc R=0.0544m

Iteration2:
Vm=1726.8cc
R=0.0468m

B Acoustic Theory*:* As confirming to the rule book of "Go Kart Design Challenge Season-6" the acoustical performance is to be considered in the design of expansion chamber. Given that sound decibel level not to be exceeded than 100dB. From the Study of literature through BAJAJ PULSAR 150cc engines specifications and visiting company's service stations, we could get the information of engines exhaust decibel level of about 105-110 db.The targeted transmission loss is from 5 to10dB. Using the two Iterations from Volume Theory we calculate transmission loss for the two chambers.Transmission loss (TL) is defined as difference between power incident on a duct acoustic device and that transmitted downstream into an anechoic termination. TL is independent of source and presumes an anechoic termination at the downstream end.

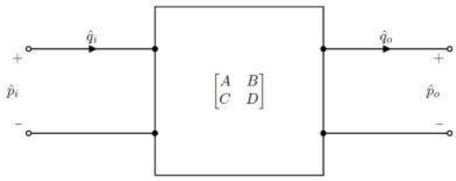

Fig. 1 Four Pole matrix for expansion chamber

$$\begin{pmatrix} P_i \\ q_i \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} P_o \\ q_o \end{pmatrix} \quad (2)$$

Where,
P_i, P_o are sound Pressures at input and output q_i ,q_o are volume velocities at input and output A , B , C and D are complex numbers

$$TL = 10\text{Log}_{10}\left[\frac{1}{4}\left|A + B\frac{S}{\rho c} + C\frac{\rho c}{S} + D\right|^2\right] \quad (3)$$

Where,
S is area of cross section at inlet and outlet
P is media density C is sound velocity

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{pmatrix} \cos kL & j\frac{\rho c}{S_2}\sin kL \\ j\frac{S_2}{\rho c}\sin kL & \cos kL \end{pmatrix} \quad (4)$$

Substituting in the above equation we get ,

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$$TL = 10\mathrm{Log}_{10}\left[\frac{1}{4}\left|\cos kL + j\frac{\rho c}{S_2}\sin kL\frac{S}{\rho c} + j\frac{S_2}{\rho c}\sin kL\frac{\rho c}{S} + \cos kL\right|^2\right] \quad (5)$$

Where,
h= ratio of area of cross section

$$h = \frac{S_1}{S_2}$$

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l= length of chamber k = wave number

$k = \frac{w}{c}$

w = sound energy density c = speed of sound

(7)

(6)

Assuming the section a the inlet of the muffler as 22mm inner diameter and 1inch Outer Diameter pipe connected to the expansion chamber the following iteration are for Cylindrical part of muffler,we apply the acoustic theory to get the transmission loss as below:

Iteration 1:Dimensions are as follows

Diameter = 0.10886m, Length =
0.3m S1=615.7521mm2,
S2=9307.36mm2, H = 0.06615
w=109200, c=520 at 400◦C,k=210
Therefore, TL=9.3086dB

Iteration 2: Dimensions are as follows

Diameter: 0.09369m, Length:0.3m
S1=615.7521mm2,
S2=6894.08mm2, H=0.08931
w=109200, c=520at400◦C, k=210
Therefore, TL=7.4431dB

Iteration 1 gives better transmission loss than that of iteration 2 according to Acoustical analytical performance which also satisfies the volume theory of design. Hence Iteration 1 is finalized with the dimensions of cylinder of length 300mm and diameter 110mm.The Cad Model is designed in designing software Creo Parametric1.0 and is represented as:

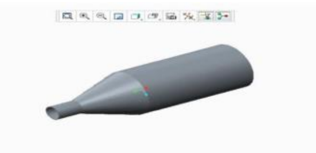

Fig. 2 CAD model of Muffler

C.*Design of Perforated Tubes*

Perforated tube is the stainless steel perforated plate of material same as that of housing rolled to form a cylindrical tube. This tube is fixed inside the expansion chamber concentric with it. The perforations in the plate are circular holes. These holes are to be drilled or punched in the plate. Diameter of the perforation is given by the empirical relation as:

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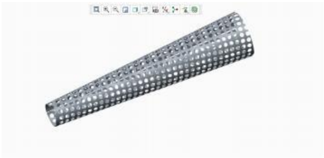
Fig. 3 CAD model of perforated tube

$$d1 = \frac{1.29}{\sqrt{N}} \quad (8)$$

Where, d1 is diameter of perforation N is Maximum Frequency in RPM Input : Maximum RPM =9000, d1 =13mm

Smaller diameter of the tube is 35mm and larger diameter of tube is 65mm length same as that of housing 300mm with thickness of 2mm.Calculating number of holes in the plate 300mm*100mm. Number of holes in the plate is 330. Cad Model of the Perforated Tube with design dimensions is given below:

Surface Area of Plain sheet is, Dimension = 300mm*110mm
Surface area = 33000mm2 Area of perforation of holes is,
Area of holes = (area of one hole)*(no. of holes) Area of holes (Theoretical) = 15981.6
Area of perforation = 0.478
According to the theoretical calculations the diameter of the hole in the perforated sheet is13mm.But while manufacturing the available standard diameters of the hole are 5mm and 6mm, among which we have selected the larger diameter that is 6mm.By selecting this diameter, we have increased the number of hole by keeping the area of perforation of holes same as that of theoretical value.
Calculation for number of holes (Practical):
Area of holes(theoretical) = Area of holes (Practical) 15918.6 = (π*3^2)*No of holes
Therefore, Number of holes = 563.

D. Porous Material (Ceramic Wool): Ceramic wool is selected material for the muffler which is to be fixed between housing of expansion chamber and the perforated tube. Average thickness of ceramic wool is determined by:

$$t = \frac{D - d}{2} \quad (9)$$

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Where,
t=thickness of glass wool
D= cylinder diameter of expansion chamber Cd =maximum diameter of perforated tube Therefore ,t=22.5mm

E. Exhaust Pipe: Exhaust pipe is the connection between exhaust port of the engine and the muffler. The literature study from the research papers as well as the industrial design in formation from the service stations directs the diameter of the exhaust pipe to be equal or just greater than the exhaust port diameter of the engine. The length of the pipe is decided by volume theory for exhaust pipe and deciding the mounting points of muffler from the engine. Since the engine mounting of karts can be side mount or the rear mount, our vehicle has side mounted engine.Diameter of pipe:
ID: 28mm, OD: 32mm, Length of pipe: 630mm
The cad model is prepared using Creo Parametric 1.0 and viewed as below:

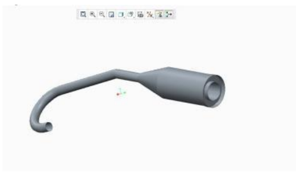

Fig. 4 Cad model of exhaust system

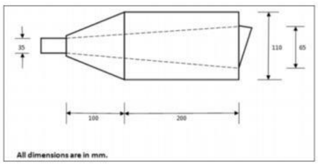

Fig. 5 2D of Muffler model

6. ANALYSIS OF CAD MODEL

The model is analysed using Ansys simulation software for Computational Fluid Dynamics and Thermal Analysis.

6.1. *Pressure Distribution:*

Here the model is judged for back pressure in the system. Software used is Ansys R15.We can perform 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.
Input Boundary Conditions:
a) Inlet pressure: 2 bar (gauge)
b) Outlet pressure: 1.01325 bar (absolute)

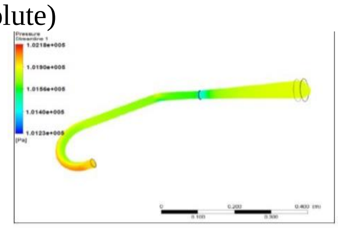

Fig. 6 Pressure distribution

Results:
Maximum Pressure: 1.0218 bar Minimum Pressure: 1.0123 bar
Since the pressure in the system is greater than atmospheric pressure through the muffler there won’t

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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 back firing. This gives the less back pressure as compared to the previous model hence safer.

6.2. *Temperature Distribution*

Software:
Ansys
Solver:
Fluent
Analysis: Temperature Distribution
This is carried out to get the temperatures at the different points throughout the system which can also be used in variant thermal analysis. Input Boundary Conditions:
a) Temperature at inlet of system: 650◦C
b) Temperature at outlet: 25◦C

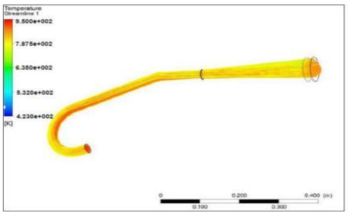

Fig 8: Temperature Distribution

Results:
Maximum
Temperature: 650◦C
Minimum
Temperature: 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.

6.3. *Velocity Distribution*

This model is verified through velocity distribution also which will give the flow characteristics clearly through the pipe as well as the muffler.
Analysis: Velocity
distribution Software:
Ansys
Solver: Fluent
From the input of pressure and temperature the velocity contour can be plotted as shown below:

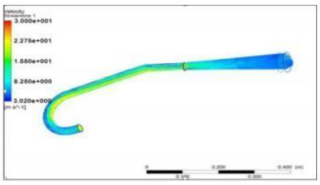

Fig. 9: Velocity Distribution

Results:
Maximum Velocity:
30.00 m/s Minimum
Velocity: 3.02 m/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 portion after muffler too. As Maximum velocity is
30.00 m/s the flue gases moves through the duct faster and does not cause back pressure and chances

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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.

6.4.1.Deformation

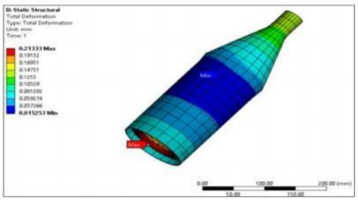

Fig. 10: Deformation

Results:
Maximum Deformation : 0.2133mm
The deformation can be as viewed maximum at the exhaust pipe. Since the deformation is with in limits and does not hinder working of any other component of the system the system is said to be safe in terms of deflection. This result is also further analysed analytically with Finite Element Analysis (Dynamic Analysis).

4.6.2.Stress (von misses)

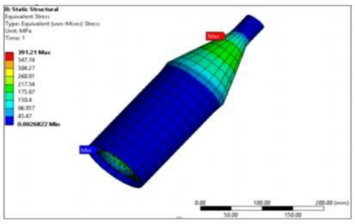

Fig. 11: Von Misses Stress

Results:
Maximum Stress
:167.28MPa Tensile
Strength (yield) :
215MPa
The factor of safety of the design from above analysis is 1.285
From the above analyses the components are observed to be safe and hence are finalized for manufacturing .The system is also analysed analytically as the finite element Analysis and mathematically modelled.

7. MATHEMATICAL MODELLING OF EXHAUST SYSTEM

The system is classified under semi-definite system also called as unrestrained or degenerative systems. These systems are based on the considerations that they are not attached to any stationary frame. Simple example can be Railway Wagons.
To calculate displacements of engine and exhaust due to force from engine: Numerical values required:
m1:35kg , m2:1.5kg
k1: stiffness of engine mounts, k2:stiffness of exhaust pipe, k3: stiffness of muffler mounts F10 = force by engine, F20 = 0N
We know,

$$T = F_O * r \quad (10)$$

Where,
Torque ,T=253Nm, Radius, r=5.5inch ,
F0=1811.0236N Force is given by,

$$F=F_0e^{iwt} \quad (11)$$

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Where,
Forcing
Frequency, W
= 942.47rad/s

Stiffness Constant (k):
For engine mounts: Number
of mounts=6 For Mount1and
2, Length=3.5inch
k1=k2=7266.325N/mm

For Mount 3 and 4,
Length = 4.8inch K3 = k4
= 2817.05N/mm

For Mount 5 and 6,
Length = 6.0inch
K5=k6=1442.33N/mm

Equivalent Stiffness , Keq=23051.42N/mm

For muffler mounts: Number
of mounts=2 ForMount1and2,
Length=2.0inch
k1=k2 =40882.96N/mm

Equivalent Stiffness

K_{eq}=81765.8N/mm Exhaust

Pipe: K_{pipe} =58.816N/mm

Now, $m_{11} = m_1$ =35kg, $m_{12} = m_{21}$ = 0kg, $m_{22} = m_2$ =1.5kg
Also, $k_{11}=k_1+k_2$=2.311*107N/m, k_{12}=-58816N/m, $k_{22}=k_3+k_2$=8.182462*107N/m

Impedance can be
calculated as:

$$Z_{rs(iw)} = -w^2 m_{rs} + iwc_{rs} + k_{rs} \qquad (12)$$

Z_{11} = -79.7873*105, Z_{12} = -58816, Z_{22} = 5.073588*107
The displacement is
given by: Engine:

$$X_{1(iw)} = \frac{F_{10}Z_{22(iw)} - Z_{12(iw)}F_{20}}{Z_{11(iw)}Z_{22(iw)} - Z^2_{12(iw)}}$$

$$X_{1(iw)} = 0.2268 \text{ mm}$$

Muffler:

$$X_{2(iw)} = \frac{-F_{10}Z_{12(iw)} - Z_{11(iw)}F_{20}}{Z_{11(iw)}Z_{22(iw)} - Z^2_{12(iw)}}$$

$$X_{1(iw)} = 1.35*10^{-3} \text{ mm}$$

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The displacement of Engine is 1.325mm and that of muffler is 1.35*10-3mm. these deformations do not disturb the system and are in safe limits. The model is mathematically represented and the results are obtained in the form of deformations. Also these deformation results are same as the analysis performed in Ansys (Static Structural).

8. MANUFACTURING OF MUFFLER

Material selection for manufacturing of exhaust components is already discussed in the previous chapter. Similar to the design procedure manufacturing of the system is segmented into two parts that is the manufacturing of muffler and the manufacturing of exhaust pipe. The procedure followed is as stated below.

8.1. Manufacturing of Muffler: Muffler constitutes of three components which are manufactured individually and then assembled as the complete product .It involves the manufacturing of housing, perforated tube and the glass wool insertion into the assembled product them.

8.1.1. Housing of Expansion chamber:

Material used : SS304Sheet
Dimensions of Raw material :
500mm*500mm Dimension of
Processed Material : 400mm*255mm
Dimensions of Finished component:
Length:300mm,Diameter:max-110mm,min-35mm according to the shape
Manufacturing Processes: Cutting, Folding to form cylinder and fastening to join the metal sheets.

8.1.2. Perforated tube:

Material used:SS303Sheet
Dimensions of Raw material :
500mm*500mm Dimension of
Processed Material : 400mm*115mm
Dimensions of Finished component:
Length : 300mm,Diameter:35mm
Manufacturing Processes: Cutting, Punching, Folding to form cylinder and fastening to join the metal sheets.

8.1.3. Ceramic Wool:

Material used: Corning Glass Wool
The material is filled into the gap between the housing and the perforated tube after assembling the two.The ends of the housing are fastened and closed keeping the inlet and outlet pipes with the diameter of 22mm open to further connect it with exhaust pipe.
The assembled muffler with glass wool and perforated tube inside the housing is viewed as below:

Fig. 12: Manufactured muffler

8.2. Manufacturing of Exhaust Pipe :

Material : MS409L Dimensions of finished product : 630mm.
Manufacturing Process : Cutting , Bending , welding. The pipe is bent in with the angle of 180◦ to

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obtain the required dimensions. It is then welded with the flange so that it can be further fastened to engines exhaust port.These two components muffler and the exhaust pipe are joined by welding and connected to the engine and muffler mounts to record the observations for testing of the components.

9. ACOUSTICAL TESTING OF EXHAUST SYSTEM

Testing of manufactured system is conducted in terms of acoustics . The Sound waves after firing the engine are recorded in the . wav file format and this inputs provided to the programming software MATLAB with the valid set of codes. The sound file is judged for Sound Power level , Sound Pressure level, Wave Number and Sound Energy.
Following are the Codes for the Testing of Sound file:

9.1. ***Sound Power*** **:** Here key function used to obtain power of sound wave is pwelch (). This function provides power of Sound File Stored with an extension.wav. The signal file is first sampled based on length of the signal which then yields power.

Code for Sound power is
as follows: S = audio
read('muffler.wav');
{y,fs} = audio
read('muffler.wav'); Pxx
= pwelch(y);
Disp(Pxx)

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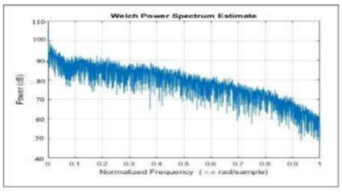

Fig. 14: Power Spectrum for Sound power

Fig.13:Power Spectrum for Sound power

9.2. ***Sound Pressure :*** Sound Pressure Level Code also follows the same basic program for audio file (.wav) using function audio read() and further analysed for pressure level using function SPL(). The audio file is first sampled discretely which is worked for Sound Pressure Level Function SPL. Plot for SPL is generated as SPL (dB) against time(sec). Code for sound pressure level is given as:

Fig.15: Sound pressure code and result

Fig.14:Sound pressure code and result

9.3. ***Sound Energy:*** Sound energy of the audio file is obtained using function abs() which is then modified with Length of samples to get Average Sound Energy. Code for sound energy is given as:

Fig. 16: Sound energy code and results

Fig.15: Sound energy code and results

10. RESULTS AND CONCLUSIONS

1. Exhaust System for GOKART is designed successfully based on two theories and analysed 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 modelled using FEA (Vibrations) for the entire Exhaust System.
4. Manufactured System is implemented for use in GO-KART vehicle for GKDC Season6 event with completion of testing. The system satisfies the requirement of sound limit with in 98dB as tested results give 84dB 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.

11. ACKNOWLEDGEMENT

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