DESIGN ANALYSIS OF EXHAUST MANIFOLD IN DIFFERENT METALS ON SOLIDWORKS

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ABSTRACT

The target of this research is to design, implement and then perform experimental comparison a EXHAUST MANIFOLD under various metals such as Stainless Steel 304, Aluminium 6063, Cast Iron. In automotive engineering, an exhaust manifold collects the exhaust gases from multiple cylinders into one pipe. Exhaust manifolds are generally simple cast iron or stainless steel units which collect engine exhaust gas from multiple cylinders and deliver it to the exhaust pipe. Normally, ferrous alloys are used in the manufacturing of exhaust system. These include carbon steel, stainless steel, alloy steels and cast iron. The purpose of adding alloying elements is to help in solid solution strengthening of ferrite, improve the corrosion resistance and other characteristics and the cause the precipitation of alloy carbides. Mild carbon steel was extensively used for the manufacturing of exhaust systems for a considerable period of time. Although mild steel has the properties to withstand exhaust temperature it has very poor corrosion resistance. High exposure to road salt and exhaust condensate can terribly shorten the life span of a mild steel based exhaust system. Also, over the years higher demands in power and environmental safety have seen the demise of mild steel from exhaust systems. Nowadays mild steel is employed in applications where the environment is non-corrosive. Stainless steel has replaced mild steel in exhaust systems today. The ferrous alloying element used here is chromium. The minimum amount of chromium in stainless steel is 10.5%. When stainless steel is heated, chromium forms a protective layer of chromium oxide over the stainless steel surface and delays further oxidation process. The reason why I am choosing the ides because to identify which material is suited to reduce the back pressure. The operations which I have done are 2D design, 3D design, evaluation, simulation. As I mentioned earlier, I gave the detailed report of material properties, simulation , evaluation and orthographic view. Atlast I concluded, I chosen Aluminium 6063 is the suitable material due to the reduction of back pressure when compared to other metals which is used in this project.

KEYWORDS. - *2D Drafting – 3D Designing – Evaluation – Simulation – Resulting.*

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1. INTRODUCTION

To achieve reliable models both theoretical and experimental modal analysis should be performed so that finite element and test model can be compared and successfully improved. Free-free boundary condition is recommended for this model. At an early stage of product development process the boundary conditions that exhaust system will have under operation are not always known. By using free-free boundary condition it is still possible to develop FE models of exhaust system or part of it, which corresponds well with measurements [1]. It is found out that approximately 70 % pressure drop can be reduced if length of exhaust pipe at starting reduced by 50 mm and restriction to the flow in D chamber is removed. It can be seen that first 3 iterations show slight increase in the pressure drop across the exhaust system which will result in to increased work for the two wheeler engine to overcome the resistance by exhaust system. In iteration 4 design pressure drop across the exhaust system drop down by 12.3 KPa and it is observed to be 5 KPa which reduces the required work by the engine to force exhaust gases out of the system drastically [2]. In particular, attention has been focused on a production multivalve spark-ignition engine during the intake phase. To this purpose, a numerical and an experimental investigation were carried out to evaluate the influence of novel intake valves opening strategies on the system permeability and on the incylinder flow field, highlighting their effectiveness and their advantages with respect to the standard (symmetric) valves opening configurations. As concerns the numerical analysis, an immersed boundary approach for a cell-centred finite volume solver was adopted to simulate efficiently the flow field using Cartesian grids. For the 20 experimental investigation, the fluid dynamic efficiency of the intake system was analysed at a steady flow rig in terms of flow coefficients. The comparison of numerical and experimental data displayed a good agreement. Specifically, the mean percentage difference between measured and numerical flow coefficients was equal to 4.6% despite the very complex three-dimensional flow and the large size geometry [3]. The distributions of the pressure and mass flow rates of all cases are evaluated. We determine that adding a baffle in the inlet manifold significantly improves the uniformity of the mass flow rate of an individual channel. The variation of the mass flow rate decreases from 39% to 2% or less. Adding a baffle below the inlet air stream and a porous baffle on top of the channel engenders a highly uniform mass flow rate and pressure[4]. The CFD simulation software can be used in designing and simulations of the automobile exhaust system. Apart from that, it can also be used to design any other parts in automobile applications to simulate the flow in real condition. The simulations give valuable information regarding the velocity field, pressure field, density field and temperature field of the exhaust muffler. This is important because save time and many in the production process through the identification of eventual problems before the exhaust muffler is build[5]. The present study is focused on the comparison between the estimated lives obtained through the von Mises, the ASME code, the Sonsino-Grubisic, the Kandil-Brown-Miller, and the Fatemi-Socie multiaxial damage assessment criteria. These predictions have been also compared with the experimental life available in literature of an actual commercial exhaust manifold, very similar to the simulacrum analyzed in this work in terms of geometrical features and loading conditions. A numerical code developed by the authors, named FAST-Life and implementing the analytical expressions constituting the proposed criteria, has been used to perform life predictions. The aim of the code is to process the stress-strain data computed by simulations according to the different damage models used, giving as output the number of cycles corresponding to each area analyzed, after the required constitutive material parameters have been specified [6]. Present research work is devoted to the evaluation of different models of exhaust manifold for the purpose of reducing exhaust emissions from a four cylinder SI engine. It has been presented that the research methodology depending on three-dimensional model of airflow in the outlet systems with the application of standard numeric methods. The model may be the basis for performing changes in geometry of outlet system concerning minimizing the flow losses and shaping the field of velocity. The model enables of calculations of outlet system of internal combustion engines on the stage of its construction [7]. Exhaust manifold selection is a tricky thing where we need to have narrow pipes as possible with least back pressure. If wider pipes are selected, no doubt that there will be low backpressure, but will be losing power because there will be no good exhaust flow. So recommendation is that, if engine power band lies somewhere around 2000-3000 rpm, narrow pipes are good, whereas if it lies somewhere around 6000rpm, wider pipes lead to better performance [8]. In this study, two different manifold designs which were commonly used in automotive industry were numerically analyzed in terms of flowing material and manifold types. In the numerical analyses, pressure, velocity and temperature changes were explored and compared through the manifold at different points. Following conclusions can be drawn from this study, • Lower pressure and velocity were obtained at gasoline fluid compared to the other two fuels due to characteristics of gasoline fuel. For type A of manifold, • While the velocity increases towards the exhaust outlet, the pressure decreases to atmospheric pressure, • Pressure and velocity values of type A exhaust were higher than those of type B, • For all fuels, high pressure values of type A were obtained, and this improves the performance and efficiency of the engine [9]. The following conclusions can be drawn from the study: • The four failures investigated resulted from one or more of the following: local stress raisers, operations outside design temperatures and/or reduced creep strength as a result of poor fabrication. • Creep life calculations with an end life utilization lower than 1.0 (as per EN code), or design calculations based on a maximum allowable primary stress (as per ASME code), is not a guarantee for low risk of creep failure during the boiler service life. All four investigated cases failed prematurely (for different reasons) even though the design life could be considered “safe”. This leads to the conclusion that life calculations based on hoop stress and design temperature alone is not necessarily conservative. • Using Weld Strength Reduction Factors (in combination with hoop stress) when designing a safe component creep life is not a guarantee for low risk of creep failure during the boiler service life [10]. In this present work I designed a EXHAUST MANIFOLD in Stainless Steel grade 304, Cast iron, Aluminium 6063. Here I done the 3D modeling, simulation, comparing the mechanical properties and has been properties of Al 6063 is satisfied.

2. SELECTION OF MATERIAL

6063 is an aluminium alloy, with magnesium and silicon as the alloying elements. The standard controlling its composition is maintained by The Aluminum Association. It has generally good mechanical properties and is heat treatable and weldable. T5 temper 6063 has an ultimate tensile strength of at least 140 MPa (20,000 psi) in thicknesses up to 13 millimetres (0.5 in), and 130 MPa (19,000 psi) from 13 mm (0.5 in) thick, and yield strength of at least 97 MPa

(14,000 psi) up to 13 millimeters (0.5 in) and 90 MPa (13,000 psi) from13 to 25 mm (0.5 to 1 in). It has elongation of 8%.

2.1 Material Composition

NAME OF THE STAINLESS STEEL	CAST IRON	SS 304	Al 6063
MATERIAL COMPOSITION			
NAME OF THE METAL	**CONTAINMENT IN PERCENTAGES**		
Carbon	4.50%	0.08%	-
Manganese	0.269%	2%	0.10%
Sulphur	0.150%	0.030%	-
Phosphorus	0.158%	0.045%	-
Chromium	-	18%	0.10%
Nickel	-	0.10%	-
Nitrogen	-	8%	-
Iron	Balance	Balance	0.35%
Silicon	2.63%	-	0.2%
Magnesium	0.0016%	-	0.45%
Copper	-	-	0.10%
Zinc	-	-	0.10%
Titanium	-	-	0.10%
Other	-	-	0.05%

Table-1: Material composition of Stainless Steel 304, 316, 347

3. DESIGN PROCEDURE

3.1 To Draw The 3D Modeling Of MARINE PROPELLER:

- ❖ Front Plane – Rectangle – Draw the rectangle – Make coincident the top line of the rectangle and midpoint of the axis.
- ❖ Sketch – Smart dimensions – Give the value (146.05mm) to first half of the top line rectangle – Height (63.50mm) – Total length (387.35mm).
- ❖ Sketch – Rectangle – Centre rectangle – Line – Centerline – Make the center rectangle and line to meet each other.
- ❖ Smart Dimension – Give the value of side face (38.10) and top face (31.75mm).
- ❖ Sketch – Fillet – Give the value of 6.35mm and select all the corner points of the rectangle.
- ❖ Smart dimension – Give the centre distance value 27.31mm.

- Select the rectangle – Sketch – Linear sketch pattern – Count of rectangle (2) – Spacing (146.05) – Click OK.
- Sketch – Oval – Height (114.68mm) – Radius (47.61mm).
- Select the oval – Linear sketch pattern – Count of oval (2) - Spacing (146.05) – Click OK.
- Sketch – Trim entities – Trim the bottom surface of the oval.
- Right plane – View orientation – Normal To – Circle (38.10mm) – Centre distance (63.50) – Click OK.
- Right plane – Features – Reference geometry – New plane - Count of plane (2) - Spacing (146.05) – Click OK.
- Draw the circle on plane1 (50.80mm) and plane2 (57.15%) – Click OK.
- Click Isometric View.
- Features – Boundary Boss/Bass – Select the rectangle and circle - Offset distance 1.10mm – Click OK.
- Features – Boundary Boss/Bass – Select the round edge – Normal to profile – Select all the circles – Select edge in box – Select Align with other geometry.
- Repeat the last three steps again.

- Select the edge circle – Extruded Boss/Base – Give the offset distance (137.16mm)
- Select the base – Features – Extruded Bose/Base – Blind – Thickness (10mm).
- Features – Shell – Select the necessary part to get hole – Shell outward.
- Insert – Features – Select the base and exhaust design – Click OK.
- Features – Fillet – Edges of manifolds (7.50mm) and corners of the base (12.50mm).

3.2 To Simulate The 3D Modeling Of MARINE PROPELLER:

- SolidWorks Add-Ins – SolidWorks Simulation – Simulation – New study.
- Click Static – Click OK.
- Select the material which we want to test.
- Fixtures – Select the fixed part of the geometry – Click OK.
- External Loads – Pressure – Apply the maximum pressure of the material where it is needed – Reverse direction – Click OK.
- Mesh – Select the level of mesh – Give the meshing parameters – Click OK – Ensure the meshing is done.
- Run the result.

4. EXPERIMENTAL WORK

In my project experimental work is meant by designing the EXHAUST MANIFOLD in SolidWorks software. In this research I done the works like 2D drafting, 3D modeling, evaluation, taking analysis report, and then simulation. Here I include the orthographic view, mass properties, simulated diagram (Von-Mises and Displacement), mesh diagram.

4.1 ORTHOGRAPHIC VIEW:

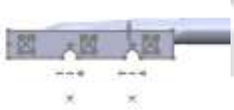

Fig-1: Front Plane of Exhaust Manifold

Fig-2: Top Plane of Exhaust Manifold

Fig-3: Left Plane of Exhaust Manifold

Fig-4: Trimetric Plane of Exhaust Manifold

4.2 MASS PROPERTIES

4.2.1 Mass Properties of Al 6063

- Density = 0.01 grams per cubic millimeter
- Mass = 3964.07 grams
- Volume = 543023.45 cubic millimeters
- Surface area = 251722.36 square millimeters
- Center of mass: (millimeters)
  X = 116.46
  Y = -16.79
  Z = -28.86

- Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
  Taken at the center of mass.

Ix = (0.99, 0.06, -0.12)	Px = 5534656.87
Iy = (-0.13, 0.46, -0.88)	Py = 89122882.92
Iz = (0.00, 0.89, 0.46)	Pz = 92243097.20

- Moments of inertia: (grams * square millimeters)
  Taken at the center of mass and aligned with the output coordinate system.

Lxx = 6941685.11	Lxy = 4706863.89	Lxz = -9668489.16
Lyx = 4706863.89	Lyy = 91308615.57	Lyz = -1831498.11
Lzx = -9668489.16	Lzy = -1831498.11	Lzz = 88650336.30

- Moments of inertia: (grams * square millimeters)
  Taken at the output coordinate system.

Ixx = 11359953.96	Ixy = -3044758.08	Ixz = -22990358.07
Iyx = -3044758.08	Iyy = 148376968.99	Iyz = 89101.63
Izx = -22990358.07	Izy = 89101.63	Izz = 143535507.15

4.2.2 Mass properties of Stainless Steel 304

- Density = 0.01 grams per cubic millimeter
- Mass = 4344.19 grams
- Volume = 543023.45 cubic millimeters
- Surface area = 251722.36 square millimeters
- Center of mass: (millimeters)
  X = 116.46
  Y = -16.79
  Z = -28.86
- Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
  Taken at the center of mass.

Ix = (0.99, 0.06, -0.12)	Px = 6065377.39
Iy = (-0.13, 0.46, -0.88)	Py = 97668912.79
Iz = (0.00, 0.89, 0.46)	Pz = 101088325.69

- Moments of inertia: (grams * square millimeters)

Taken at the center of mass and aligned with the output coordinate system.

Lxx = 7607326.15	Lxy = 5158207.01	Lxz = -10595604.56
Lyx = 5158207.01	Lyy = 100064236.24	Lyz = -2007121.21
Lzx = -10595604.56	Lzy = -2007121.21	Lzz = 97151053.48

- ❖ Moments of inertia: (grams * square millimeters)
  Taken at the output coordinate system.

Ixx = 12449264.61	Ixy = -3336721.18	Ixz = -25194912.95
Iyx = -3336721.18	Iyy = 162604897.52	Iyz = 97645.62
Izx = -25194912.95	Izy = 97645.62	Izz = 157299185.92

4.2.3 Mass properties of Al6063

- ❖ Density = 0.00 grams per cubic millimeter
- ❖ Mass = 1466.16 grams
- ❖ Volume = 543023.45 cubic millimeters
- ❖ Surface area = 251722.36 square millimeters
- ❖ Center of mass: (millimeters)
  X = 116.46
  Y = -16.79
  Z = -28.86
- ❖ Principal axes of inertia and principal moments of inertia: (grams * square millimeters)
  Taken at the center of mass.

Ix = (0.99, 0.06, -0.12)	Px = 2047064.87
Iy = (-0.13, 0.46, -0.88)	Py = 32963258.07
Iz = (0.00, 0.89, 0.46)	Pz = 34117309.92

- ❖ Moments of inertia: (grams * square millimeters)
  Taken at the center of mass and aligned with the output coordinate system.

Lxx = 2567472.58	Lxy = 1740894.86	Lxz = -3576016.54
Lyx = 1740894.86	Lyy = 33771679.73	Lyz = -677403.41
Lzx = -3576016.54	Lzy = -677403.41	Lzz = 32788480.55

- ❖ Moments of inertia: (grams * square millimeters)
  Taken at the output coordinate system.

Ixx = 4201626.81	Ixy = -1126143.40	Ixz = -8503283.12
Iyx = -1126143.40	Iyy = 54879152.91	Iyz = 32955.40
Izx = -8503283.12	Izy = 32955.40	Izz = 53088475.25

4.3 SIMULATED DIAGRAM

4.3.1 Cast Iron

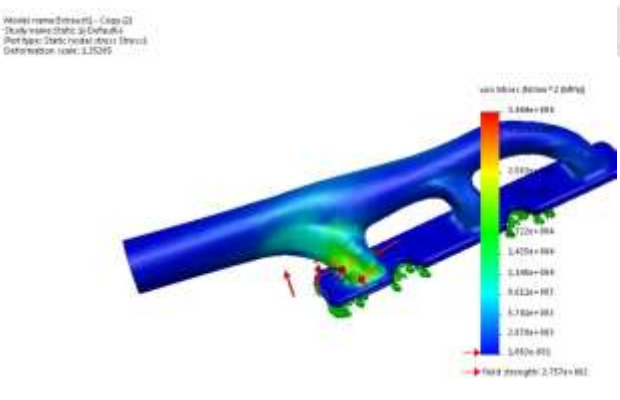

Fig-5 Von-Mises for Cast Iron

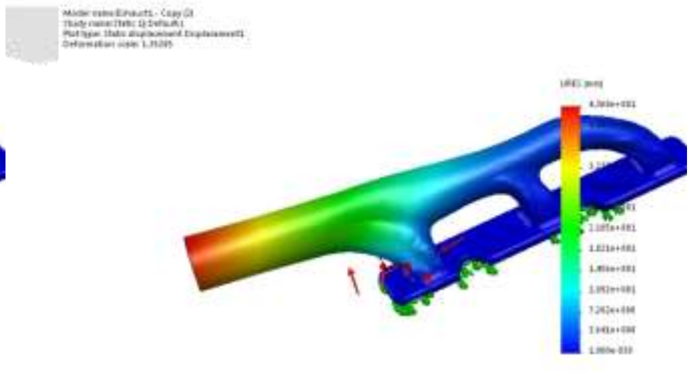

Fig-6 Displacement for Cast Iron

4.3.2 Stainless Steel 304

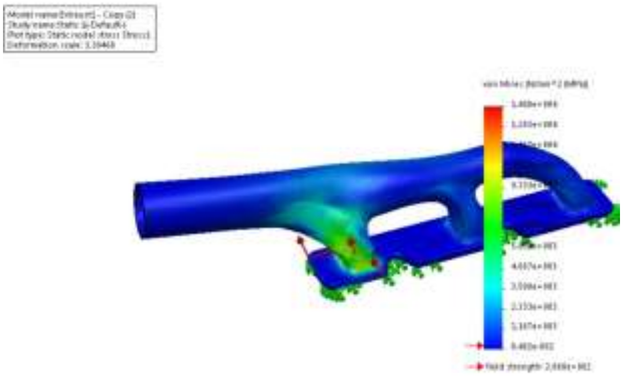
Fig-7 Von-Mises for SS304

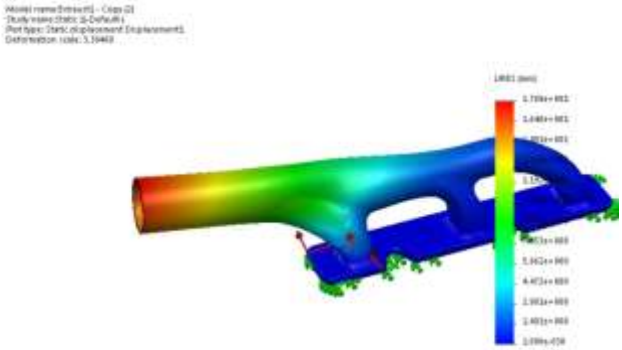
Fig-8 Displacement for SS304

4.3.3 Aluminium 6063

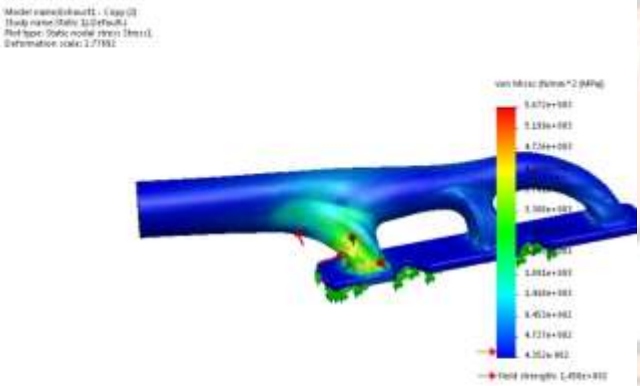
Fig-9 Von-Mises for Al6063

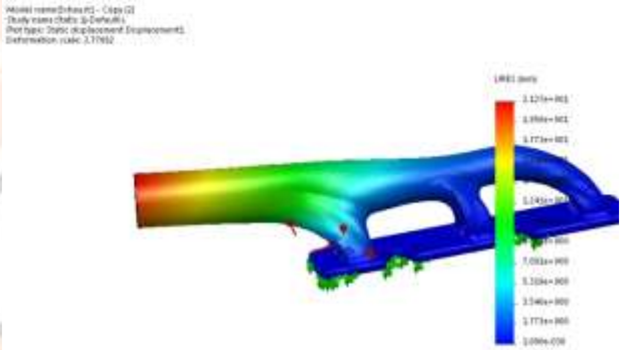
Fig-10 Displacement for Al6063

4.4 MESH DIAGRAM


Fig-11 Cast Iron


Fig-12 Stainless Steel 304

Fig-13 Aluminium 6063

5. RESULTS AND DISCUSSION

As the table concludes decreased mechanical properties of exhaust manifold. There is a step-by-step decrement in maximum pressure, elastic modulus, tensile strength, yield strength. As it shows the decreased of properties in Stainless Steel 304, Cast iron, Aluminium 6063 . Here I enclosed the comparative property table below:

Table-2: Material comparison of Cast iron, Stainless steel 304, Aluminium 6063

6. CONCLUSION

SolidWorks grades with Cast iron, Stainless steel 304, Aluminium 6063 was successfully designed via SolidWorks software. Test results revealed that grade Aluminium 6063 enhances the mechanical properties of the project. There is a decrement of mechanical properties like density, maximum pressure, elastic modulus, tensile strength, yield strength one-by-one which is shown in results and discussion chapter. So the Aluminium 6063 proves that it is suited to manufacture the exhaust manifold. Hence It is purely done by own through SolidWorks software.

Mechanical Properties	***Max. Pressure***	***Density***	***Elastic Modulus***	***Poisson's Ratio***	***Tensile Strength***	***Yield Strength***
Name of the Component						
Cast iron	40000 psi	7300 Kg/m^3	1.9 e+011	0.27 N/A	413613000 N/m^2	2.757 e+002 N/m^2
Stainless steel 304	31200 psi	8000 Kg/m^3	1.9 e+011	0.29 N/A	517017000 N/m^2	2.068 e+002 N/m^2
Aluminium 6063	14000 psi	2700 Kg/m^3	6.9 e+010	0.33 N/A	185000000 N/m^2	1.45 e+002 N/m^2

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