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FEA WAS USED TO DESIGN AND ANALYZE THE EXHAUST VALVE OF AN IC ENGINE.

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ABSTRACT

In order to manage the flow of intake fresh charge and exhaust flue gases in the engine, intake and exhaust valves are utilised alternately. They open and close using the Valve gear mechanism, which seals the working space inside the cylinder against the manifold. Because the pressure inside the combustion chamber presses the valve against the seat, closing the chamber and preventing leaks, exhaust valves work effectively in engines. However, during this cycle, exhaust valves are exposed to high temperatures and pressures, reducing the engine's life and performance. Using Finite Element Analysis, the goal of this project is to design an exhaust valve for a four-stroke diesel engine using a suitable material and three distinct fillet radii. Aluminium 7068 alloy, Silicon carbide reinforced Zirmanium di-boride, and Carbon fibre composite material have all been investigated for the exhaust valve. We compare the stress, strain, and total deformation values of conventional exhaust valves to the improved exhaust valve design, which demonstrates a significant shift in stress, strain, and total deformation of the composite material.

Key words: Engine, FEA, Aluminium 7068, Silicon carbide, Carbon fiber

1. INTRODUCTION

An exhaust valve is considered an essential component of an Internal Combustion Engine because it offers a channel for the exhaust gases created after the fuel is burned in the combustion chamber to be ejected. The valve train mechanism is utilised to open and close the exhaust valve, which seals the working space inside the cylinder against the manifolds [26].

Fig.1. Exhaust valve model

The exhaust valve is often composed of steel valve material (steel alloy) to reduce weight and improve thermal conductivity. Steel alloy valves, on the other hand, have reduced strength and a high coefficient of thermal expansion, making them unsuitable for high-temperature use. To solve the difficulties, aluminium 7068 alloy, silicon carbide reinforced zirconium diboride, and carbon fibre composite materials are employed as alternatives to steel alloy valves.

1.2 ENGINE VALVES

The intake and exhaust valves' functions are to seal the cylinder during combustion while enabling new fuel/air to enter and combustion products to exit. Valve movement is normally regulated by mechanical connection to camshafts, and they are also the most critical limitation to flow in an engine. The most common form of valve used in engines is the poppet valve, and the closer the camshafts are to the valve stems, the more mechanical efficiency.

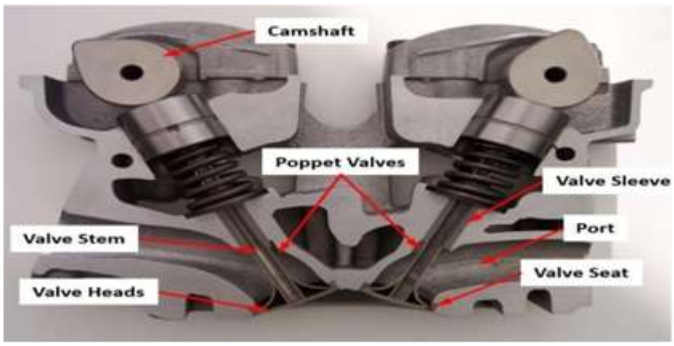

Fig.2. Engine head arrangement

1.2.1 Intake valve

An intake valve regulates the quantity of working fluid that enters an engine's cylinder. Because of the varied valve timing, one intake valve was fully opened while the other was only partially opened.

1.2.2 Exhaust valve

A cylinder head's exhaust valve is a mechanical component. Its role is to open and shut, allowing exhaust gas, or the byproducts of a burnt combustion, to exit the combustion chamber so that fresh air may be introduced to restart the combustion cycle. The camshaft is responsible for opening and shutting the exhaust valve.

2. LITERATURE SURVEY

The extensive literature survey will help to understand the concepts, the theorems and the different factors that influence that the engine performance. Before starting our work, we had viewed many research papers which indicates that for a product design based industries machine drawing is a skillful task as many factors are associated with it such as design calculations and dimensioning, design and analysis, cost efficient material selection etc.

Amitkumar.et.al., [1] in this paper discuss the manual design calculation of the exhaust valve was done based on EN9 materials and the design achieved as a safe design for the cylinder in this article, according to the Compression Ignition engine specs and dimensions.

Dinesh Kumar. V.et.al., [2] this research establishes a conceptual framework for a better understanding of the material behaviour of intake and exhaust valves in internal combustion engines using finite-element modelling. As per the experimental analysis the exhaust valve directional heat flux, total heat flux, the thermal error is perfectly better compared to other compositions.

Fred Starr.et.al., [3] in this paper he concludes Even though side-valve combustion chambers limited power production, designers took steps practically from the outset to keep exhaust valves from getting too hot.

Fuqiang Lai.et.al., [4] in the present paper the To isolate the action of each section of the cylinder head and determine instantaneous boundary conditions, the valve was separated into various zones. Each zone's average boundary conditions are computed during one engine cycle and then utilised in the Finite Element Method model.

In contrast to hydraulic systems utilised in other equipment, a mechanical loading system was chosen in this research for its advantages in economic efficiency and machine maintenance. Fuqiang Lai.et.al., [5]

Kakarapalli. Divya Teja.et.al., [6] have taken a poppet valve and updated the design of the poppet valve in this thesis, and they have used Catia v5 software for design and Ansys programme for analysis in this project. For this study, they looked at three materials: al2o3, carbon epoxy, and technetium. When they compared the data from the original model, they discovered that stress (6.69E+10), strain (0.20893), and total deformation (0.013013) were all lower.

According to Karan Soni.et.al., [7], the findings obtained through numerical analysis for the material Aluminum EN52 imply that the valve design may be modified to minimise weight without altering acceptable stress and deformation values.

Kuldeep Shakya.et.al., [8] in this analysis concludes, the thermal simulating of the poppet valve and its function in the thermal conditions of the engine. They have used Solid work software for design.

LucjanWitek.et.al., [9] in this paper he made two valves as per the design. The first valve having the maximum stress resulting from the non-uniform temperature field has a value of 12.7MPa. The thermal stress in the fracture area of the valve equals 1.58 Mpa only.

Mahfoudh ceredoun.et.al., [10] from this paper the conclusions are drawn as follows. Compared to the solid valve, the highest temperature of the Hollow Stem & sodium-filled V was decreased from 745 °C to 590 °C.

According to Mamta.R. Zade.et.al., [11], the findings obtained from static structural analysis imply that the optimal value of fillet radius of 14 mm displays safe results and is chosen for future research. In comparison to allowed stresses, the findings for the specified valve radius demonstrate a significant improvement.

The 3D model of a poppet valve was created in this work by

Mani Kumar et.al., [12], and the materials utilised for this design were Aluminium Nitride, Silicon Nitride, and Stainless Steel. The greatest heat flux was recorded in steel (0.48813 W/mm2) for intake valve and stainless steel (0.64196 W/mm2) for exhaust valve in this investigation. Based on the foregoing findings, it was determined that stainless steel is the ideal material for intake and exhaust valves.

Mark. P Gorton.et.al. [13] In this study, finds that a novel piston design, built of carbon-carbon Refractory-composite material, has been created that addresses a number of the shortcomings of aluminium pistons. When compared to aluminium, carbon-carbon material has a higher carbon content.

In this study, Muhammad Imran Khana.et.al., [14], the exhaust valves were examined and found to be characteristic of the nickel-based superalloy Inconel-751. Overheating most likely caused the valves to fail. Lack of tappet clearance is one probable cause of overheating, which leads in light sitting and carbon buildup on the seating face.

The experimental results of the peak cylinder pressure of JME and JOE15 in this article are slightly greater than those of diesel, and comparable results are achieved using simulated circumstances, according to Potru Girish.et.al., [15]. In both experimental and simulated situations, the maximum heat release rate of JME and JOE15 is lower than that of diesel fuel.

Rajkumar. N. et.al., [16] in this analysis he concludes the model is done on three different alloy materials (CrSi, CrMo, CrNiMn) for the exhaust valve. The steady-state thermal analysis also was done on the same materials. The results showed that in Static testing the results are the same for all the three materials. But in static thermal load testing, CrNiMn alloy shows the best results and it is suitable for best performance.

Seshagiri Rao. B. et.al., [17] in this paper they conclude that the results as follows: for EN 52 -- Cast iron, Phosphor Bronze.

The maximum temperature of the exhaust valve is found near the stem of the valve, according to Shojaefard. M. H.et.al., [18]. The maximum temperature of the exhaust valve for the specified boundary conditions is around 700C. According to Snehal S.Gawale.et.al., [19], poor fillet radius selection causes exhaust valve failure. According to Snehal S.Gawale.et.al., [20], the failure rate of the exhaust valve is greater than that of the inlet valve. Using a proper fillet radius and optimization based on finite element analysis, stress concentration on the valve may be decreased in this suggested work.

Sowjanya. G.et.al., [21] in this paper they conducted transient thermal analysis at closing and opening conditions using Bimetal and Single metal for the valve. We have also conducted thermal analysis.

Tagaram Laxman.et.al., [22] in this paper they used forged iron steel for their design. And they have considered that the result of the diesel and blended fuels (Diesel+100% grain alcohol, Diesel+15% Ethanol, Diesel+25% Ethanol) on the valve is studied by mathematical correlations to calculate thermal hundreds created throughout the combustion.

In this study, Uma Rani. R.et.al. [23] sought to construct automotive engine valves utilising HEA's, i.e. high entropy alloys, as opposed to standard valves built of nimonic alloys. By comparing both alloys, they concluded that the high entropy alloy is more efficient than the nimonic 80A. Only one element is used in the convection alloy, with minor elements added in minuscule amounts.

In this article, Yu. Z. W. et al. [24] constructed four different valves out of the same heat resistant steel. Cracks started at the tapered plane's junction for valves No. 1 and No. 2. The most common cause of failure on exhaust valve No. 3 is burn through. The failing valves' plate material has comparable metallurgical properties.

In this research, Yuane Wu.et.al. [25] conclude that carbon fibre reinforced polyimide composites were produced employing a hot press technique. The resultant composites had a storage modulus that remained almost unaltered in the temperature range of 50–500 °C, as well as above 500 °C. Furthermore, the neutron permeability of the PI-1 composite was 0.962, and the macroscopic absorption cross-section was 0.192 cm, implying that it has high neutron shielding properties [26-27].

3. SPECIFICATION OF THE PROBLEM

The exhaust valves fail due to axial stresses due to gas pressure, cyclic stress due to spring load and stress due to inertial forces. The designing of the exhaust valve has an impact on valve plate. The improper selection of fillet radius while designing the valve, causes premature failure. The material used to design an exhaust valve should have high coefficient of thermal expansion, less wear and fatigue strength. "To design the valve using modelling and structural analysis by selecting optimal fillet radius for which stresses are reduced and suggesting the best alternative material by finite element analysis, so that valve can resist specified operating circumstances," says the problem description.

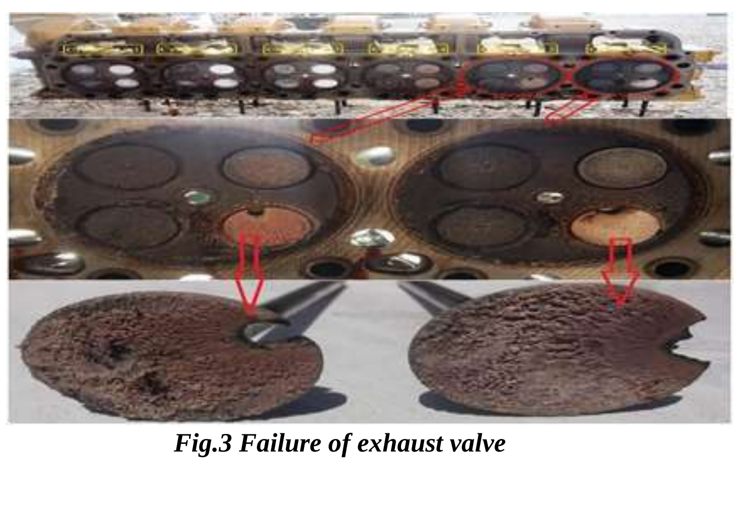

Fig.3 Failure of exhaust valve

4. RESULTS AND DISCUSSION

4.1 STATIC STRUCTURAL ANALYSIS OF EXHAUST VALVE DESIGN

ANALYSIS PLATFORM - ANSYS 15.0

The flagship mechanical engineering software package, ANSYS Mechanical Enterprise, employs finite element analysis (FEA) for structure analysis via the ANSYS Mechanical interface. It covers a wide range of applications and includes everything you need to get started, from geometry preparation through optimization and all in between. In fields like offshore hydrodynamics and layered composite materials, you may use Mechanical Enterprise to simulate sophisticated materials, complicated environmental loadings, and industry-specific needs.

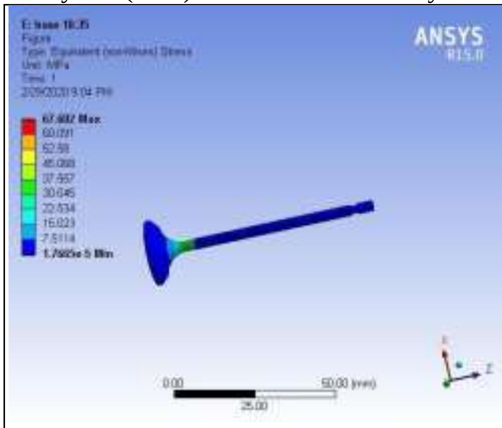

Fig. 3 (A) Von-mises stress for valve of fillet radius 10.35 mm

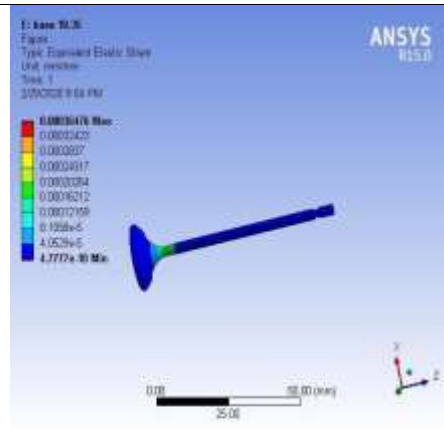

Fig. 3 (B) Elastic strain for valve of fillet radius 10.35 mm

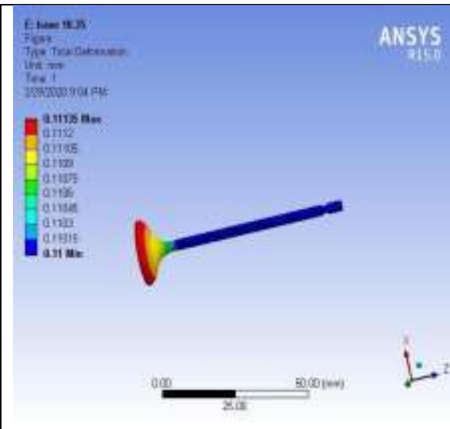

Fig. 3 (C) Total deformation for valve of fillet radius 10.35 mm

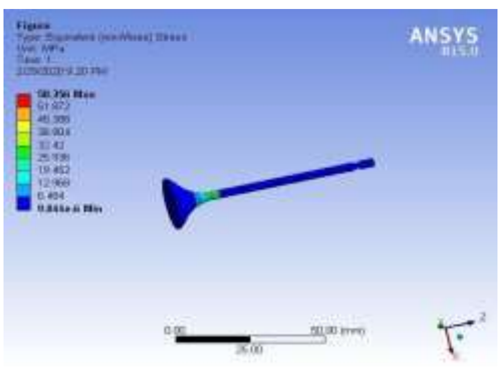

Fig. 4 (A) Von-mises stress for valve of fillet radius 12.5 mm

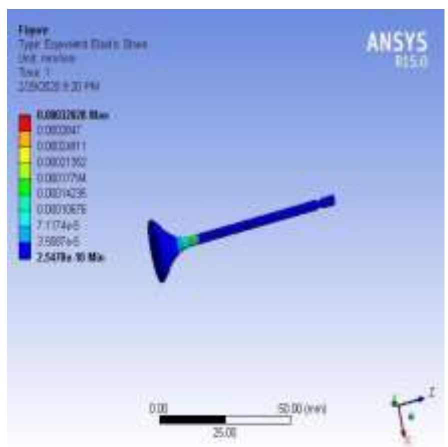

Fig. 4 (B) Elastic strain for valve of fillet radius 12.5 mm

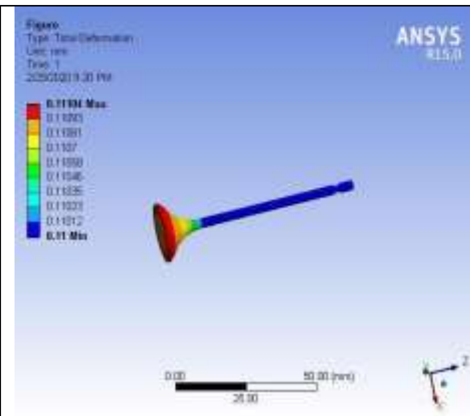

Fig. 4 (C) Total deformation for valve of fillet radius 12.5 mm

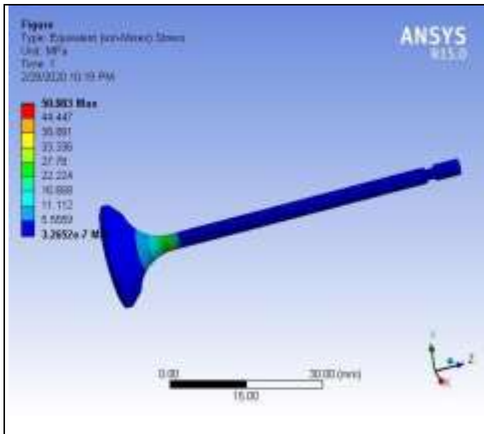

Fig. 5 (A) Von-mises stress for valve of fillet radius 13.5 mm

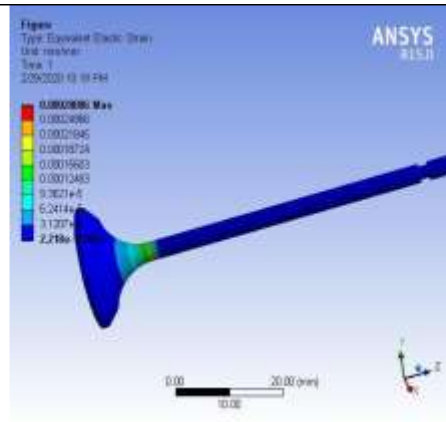

Fig. 5 (B) Elastic strain for a valve with a 13.5 mm fillet radius

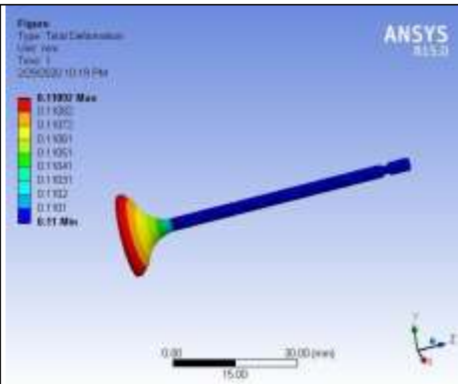

Fig. 5 (C) Total deformation for valve of fillet radius 13.5 mm

Table.1 Von-mises stress, strain and deformation comparison

S. No	FILLET RADIUS (mm)	LOAD APPLIED (N)	MAX STRESS (Mpa)	MAX STRAIN	MAX DEFORMATION (mm)
1	10.35 (Current)	247.48	67.02	0.00036476	0.1135
2	12.5 (Optimized)	247.48	58.356	0.00032028	0.1104
3	13.5 (Optimized)	247.48	50.003	0.00028086	0.11092

From the above data we could observe that the stress value is least for the fillet radius 13.5 mm. Hereby we conclude that the fillet radius 13.5 mm is suitable for exhaust valve design, for longer life of the valve. The fillet radius 13.5 mm is chosen to carry out further design and analysis of the exhaust valve using different composite materials to choose the best composite material.

The composite materials selected are

- Aluminium 7068 Alloy
- Silicon carbide reinforced Zirconium diboride composite
- Carbon fiber composite

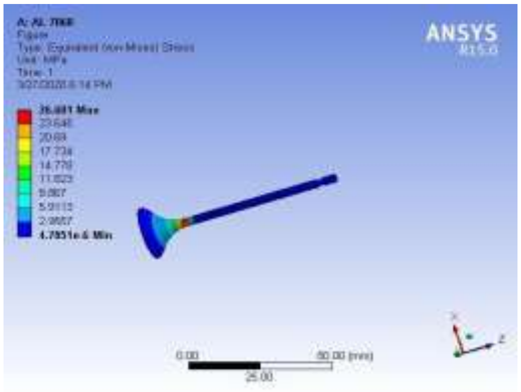

Fig. 7 (A) Von-misses stress of Al-7068

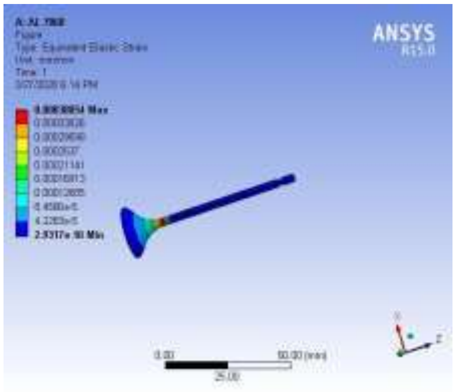

Fig. 7 (B) Elastic Strain of Al-7068

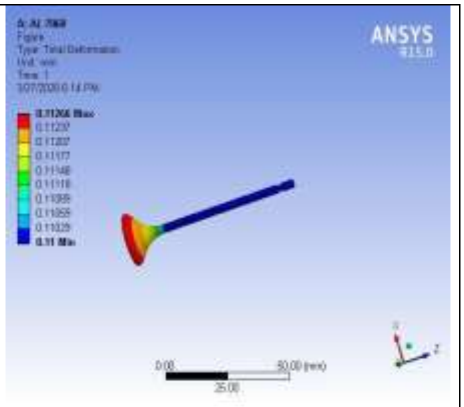

Fig. 7 (C) Total deformation of Al-7068

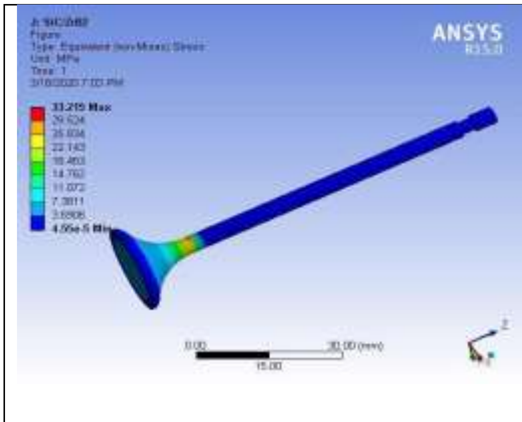

Fig. 8 (A) Von-misses stress of SiC ZrB2

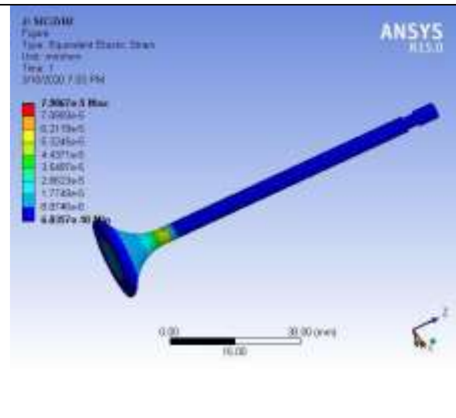

Fig. 8 (B) Elastic Strain of SiC ZrB2

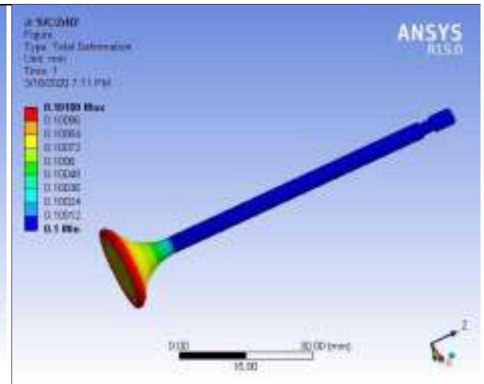

Fig. 8 (C) Total deformation of SiC ZrB2

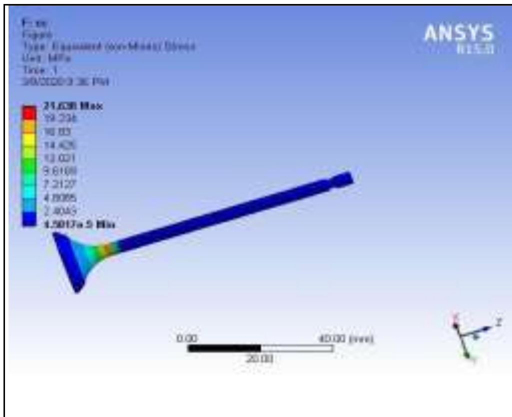

Fig. 9 (A) Von-misses stress of CFC

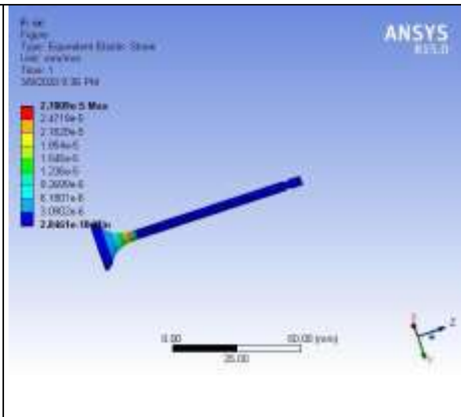

Fig. 9 (B) Elastic Strain of CFC

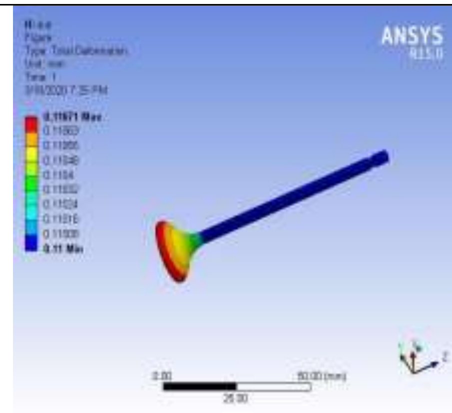

Fig. 9 (C) Total deformation of CFC

Table.2 Comparison of stress values

S. NO	MATERIAL	LOAD APPLIED (N)	MAX STRESS (Mpa)	MAX STRAIN	MAX DEFORMATION (mm)
1	Al-7068 alloy	248.47	26.601	0.00038054	0.11266
2	SiC ZrB2	248.47	33.215	0.00007986	0.10108
3	Carbon fiber composite	248.47	21.837	0.00003293	0.11071

Table.3 Percentage of reduction in stress (%)

S. No	MATERIAL	PERCENTAGE OF REDUCTION IN STRESS (%)
1	Aluminium 7068 alloy	46.8
2	Silicon carbide reinforced Zirconium diboride	33.5
3	Carbon fiber composite	56.3

5. CONCLUSION

1. The Automobile industries are requiring less weight and high tensile materials in these days, so we have gone with alternative materials for automobile parts.
2. 2. An internal combustion engines exhaust valve for further alteration which is light in weight and improve performance of the engine.
3. Exhaust valve design with 12.5-mm & 13.5-mm fillet radius along with three composite materials.
4. Exhaust valve which is having 13.5 mm fillet radius gives a good result when applying the load by analysing the 13.5 mm fillet radius design with different composite materials (Aluminium 7068 alloy, Silicon carbide reinforced Zirconium diboride & Carbon fiber composite), Carbon reinforced carbon gives the result as well.
5. The stress developed in the carbon fiber exhaust valve is least when compared with 21- 4N exhaust valve material.
6. The overall reduction in stress is 56.3 % for Carbon-Carbon fiber. Hereby we conclude that Carbon fiber composite will be the best alternative for exhaust valve of an internal combustion engine.

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