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Weight Reduction of Air Filter Assembly Using the Composite Material

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Abstract— ***Air filtering systems are inevitable part of a controlled volume vessel and its vitality increases with increasing on-board time. However, using bulking CF filters adds to add weight of vessel which further decreases the efficiency of the air filter. For the present work, composite material made from E-glass, silenka with honeycomb structure is chosen. The study involves the generation of the 3D model on Solid- works and then performing the analysis on the model using ANSYS 2019R1 software. A new composite material using honeycomb structure of E-glass, Silenka laminate is generated which is effective in cost saving as well as delivers good results against stresses. The composite laminate was successfully implemented on to the 3D model generated with weight reduction approach, the 45.86% of the dead -weight is reduced which would be very effective to raise the efficiency of the submarine and other industrial plant.With comparative strength approach, 55.78% increment in the tensile strength is achieved in computational analysis, impact test shows 2.28%, 25.90% and -82.13% change (for respective maximum values) in Max. deformation (mm), Equivalent Stress and Equivalent Elastic Strain during impact test as compared to Stainless steel using ansys.***

Keywords- composite material,weight reduction,airfilter, solidworks,ansys.

I. INTRODUCTION

While a submarine is deployed at the front or during the times of patrolling, the uninterrupted and substantial supply of breathable air is vital for support of life of the crew members. Its shortage may lead to many ailments, dizziness and sometimes may prove fatal for the occupants. Apart from this, it is necessary to remove the volatile components, liberated by other materials and components, from the atmosphere of the submarine [1]. Hence, an air filter is an important part of the air purification system which runs around the clock to supply a conditioned and purified air in the chamber which is optimum for human consumption. It ensures that the level of contamination should be 'as low as reasonablypracticable' (ALARP) .

An air filter is the heart of any filtration system, which generally filters using the chemistry of activated carbon in many forms such as activated carbon sphere (ACS), multisorb abek, non-chromium grade carbon, nuclear grade carbon and catalytic carbon [2].In most of the air filters, cross flow (CF) method is adopted against dead-end filtration process, to reduce the power consumption as there is not much back pressure in the former case. Depending upon the direction and volume of the air flow CF filters may be of many sizes and designs [3].

As the filter has to deal with high air pressure with a high runtime during the entire drive, it has to be sturdily built to bear all the stress generated [4]. For this reason, CF filters are generally built of steel. But it further adds to the dead weight on the board which is a point of concern[5].

In the past few years, various composite materials had been employed instead of traditional materials which have exponentially reduced the weight on the ship vessels and submarines with similar stress variation graphs [6]. Hence, the present study further elaborates this study of using composites which has remain unprecedented to be employed in the case of CF air filter.

II. LITERATURE REVIEW

Rubino et. al (2020) has reviewed fiber reinforced composites for their marine applications in comparative study for generated stresses and degradation due to environmental factors. Although,authors have witnessed the predominant usage of polymer composites as a replacement to metals in various marine systems during last few decades yet latter still dominants, subjected to limits in design norms, data and model requirements. However, composites have been proved better for offshore applications due to lower density, better mechanical properties and ocean environment resistance. In marine machines which face higher fatigue loads such asturbines, extensively uses composite material, nevertheless, with a scope of investigation for newer materials that would suits the machine design and its requirement in a better way.

Fekih L.B et. al (2021), have investigated and characterized the mechanical bending of E-glass laminates subjected to high bending loads. Although, the study focused epoxy glass applications in PCBs used in electronic components yet the results depicts linear elastic behaviour of the material with comparative results from FEA analysis which makes the study relevant to the present work. The models were designed and fabricated to support the uniaxial and biaxial bending tests of the E-glass composite and the results were used to identify the lamina properties in contrast to simulated structural data.

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Barsotti B et al (2020) presented a comprehensive report on various recent developments in composite materials for strength from limit states and design approach. In the study, the failure mode criterion and limit states of inter and intra-ply composites with detailed assessment procedures were presented. The authors havecome out with a number of recommendations and solutions to reinforce concurrent design processes and scantling assessment approaches,which are now under practice at shipyards, to have much effective and design oriented limit state approach.

Tawfik B. E. et al (2016) studied the suitability of composite materials in context of hatch cover replacement used in marine vessels. The study has been completed using two approaches under Finite Element Analysis (FEA), namely weight reduction and strengthening approach. Authors claimed to save 44.32% weight with one while reinforced 150% strength to withstand load needed for safer navigation with other approach, along with reduction in reduction in maintenance costs of the vessel.

III. PROBLEM FORMULATION

For a thorough literature survey, it is reckon air filtering systems are inevitable part of a controlled volume vessel and its vitality increases with increasing on-board time. However, using bulking CF filters adds to add weight of vessel which further decreases the efficiency of the air filter.Thus, there is a need to eliminate the inessential weight of filters by shifting on to contemporary better solutions for a material. For present work, composite material made from E-glass, silenka with honeycomb structure is chosen. The study involves the generation of the 3D model on Solidworks and then performing the analysis on the model using ANSYS software. The following objectives are set:

1. To find the percentage weight reduction by employing composite material
2. To find the percentage change in maximum stress generated after employing composite materials.

PRESENT WORK

The present work involves the study of application of composite material to manufacture CF filter that is used in submarines in air filtration system. For the specific study, CF filter is selected as it is the most common type that is used in submarines and other controlled volume vessels. E-glass, Silenka with honeycomb structure is chosen as a replacement to traditional stainless steel (SS) body of the filter after comparing the isometric properties. Fig. 1. and Fig. 2. shows the polar properties of E-glass, Silenka and honeycomb structure respectively.The polar properties ofthe laminate is shown in Fig .3.

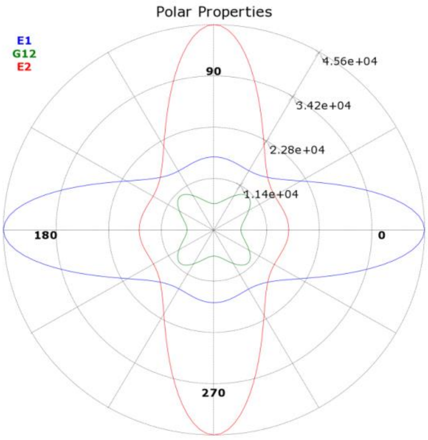

Fig. 1. Polar properties of E-glass ,Silenka.

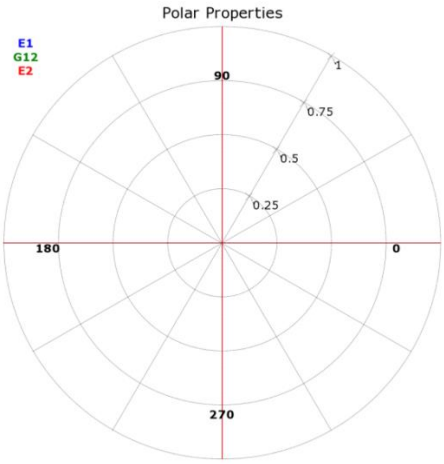

Fig. 2. Polar properties of Honeycomb.

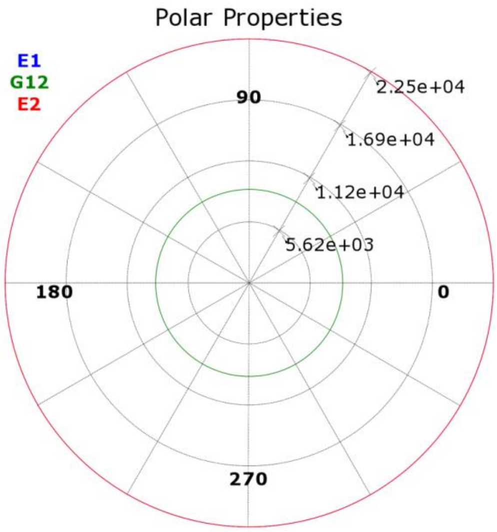

Fig. 3. Polar properties of laminate.

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Fig. 4 shows the designed model used for the analysis and Fig. 5 show the assembly of cartridge. The design being used in the present work constitutes of two cartridges which further contains ACS . Fig. 6 shows the boundary conditions which are employed for analysis. As CF filter is not a load carrying member in the vessel, so the only expected load is its self-weight which is implemented during the analysis. The actual analysis setup is shown in figure.

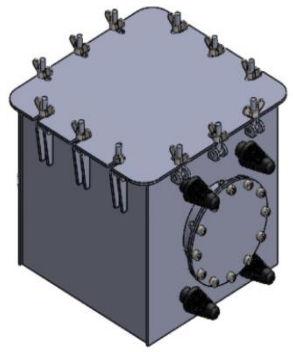

Fig. 4. Designed 3D model of CF filter on solidworks.

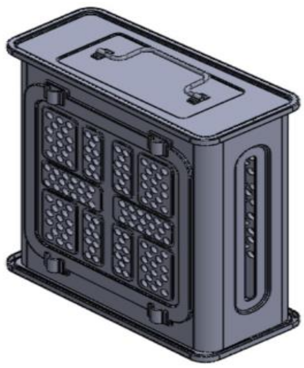

Fig. 5. Designed 3D Model of cartridge on solidworks.

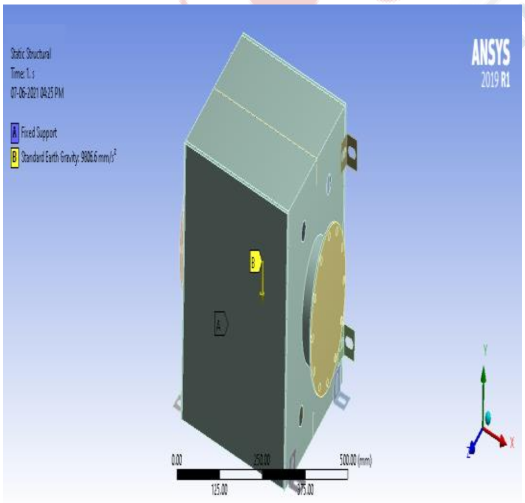

Fig. 6. Boundary conditions shows self-weighing due to gravity at the centre and supports are fixed.

Approaches used to analyse the present work

Two approaches viz. weight reduction approach and equivalent strength approach by ansys has been used to access the application of designed composite on the CF air filter assembly. In the first approach, the standard material SS has been replaced with composite of same thickness and the result has been analysed with same boundary conditions. While in the latter case, the thickness of the composite is increase to match with the SS structure and the analysed is performed on that Modal.

IV. RESULTS AND DISCUSSION

The design was analysed once using standard SS material and then using new composite material.

A. Analysis of CF filter with SS material

The total mass of the assembly was found to be 23.9 kg. Only acceleration due to gravity has been taken as input parameter while total deformation, equivalent strain and equivalent stress are taken as output parameters. The following results were obtained.

Table 1: Maximum and Average values of output parameters

	Max. deformation (mm)	Equi.Strain (mm/mm)	Equi. Stress (Mpa)
Max.	4.7 E-02	9.825 E-06	9.405 E-02
Avg.	2.081 E-03	2.092 E-07	1.901 E-03

However the analysis have shown that the net volume of the filter has remained unaltered. Figure 8a-8c shows the analysis report for total deformation, equivalent elastic strain and equivalent elastic stress respectively for CFK filter with SS material and the graphical variations of all these output parameters are show in Fig.(7A-7C). It can be seen that all the three parameters varies linearly with time and attains maximum values which are mentioned in table 1.

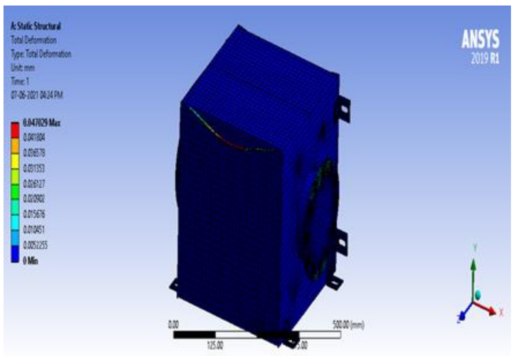

Fig. 7a. Total deformation.

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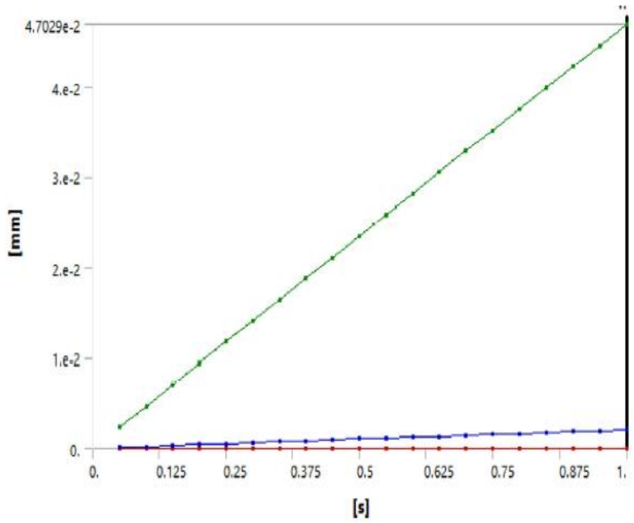

Fig. 7A. Graph for total deformation vs time.

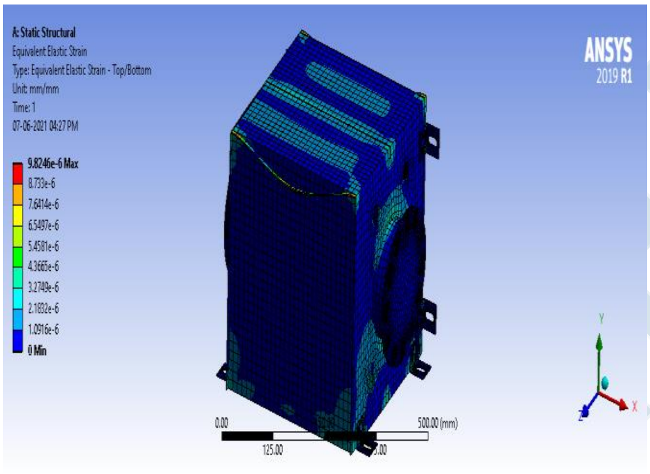

Fig. 7b. Equivalent elastic strain.

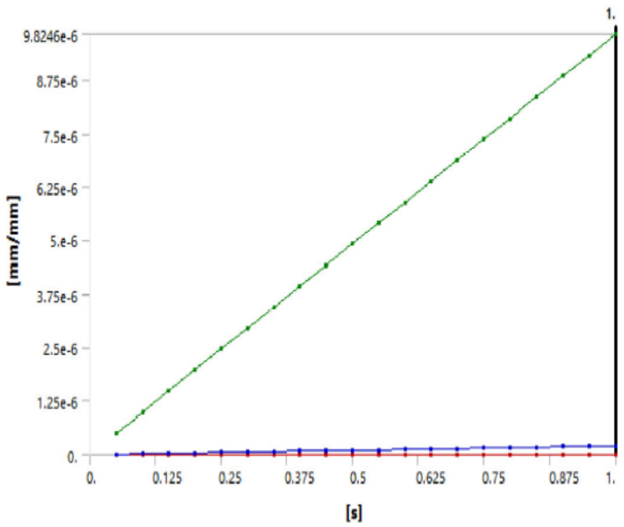

Fig. 7B. Graph for equivalent elastic strain vs time.

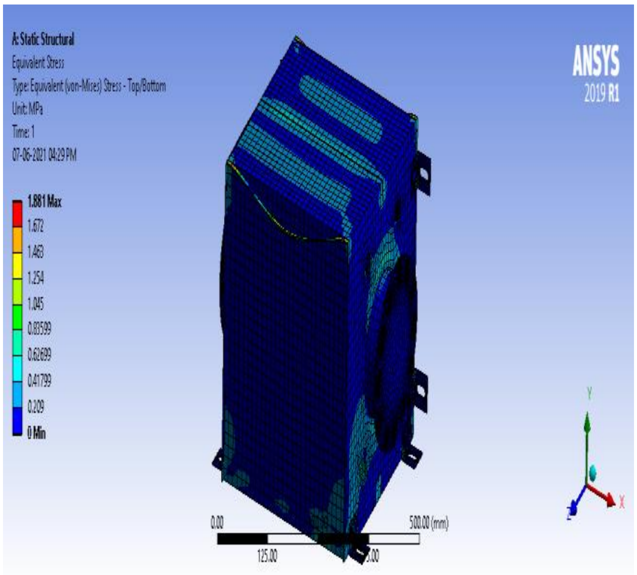

Fig. 7c. Equivalent elastic stress.

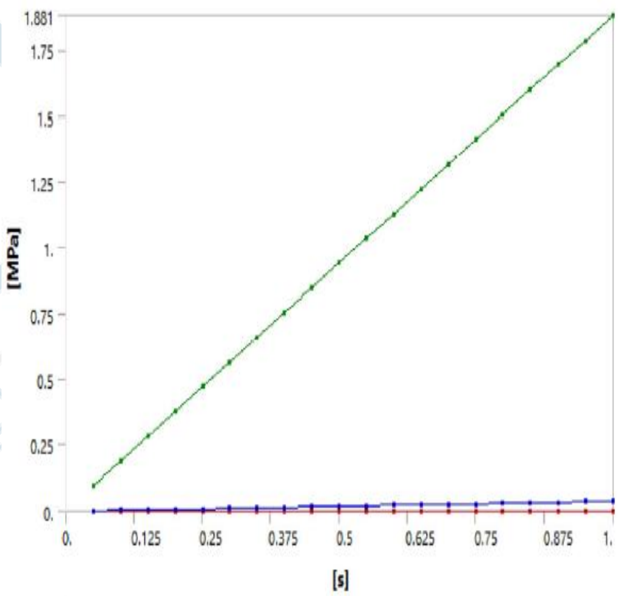

Fig. 7C. Graph for equivalent stress vs time.

B. Analysis of CF filter with Composite

B.1. Weight reduction approach:

In this case the material of the model is replaced with E-glass composite. It is found that the final weight of the assembly falls at 12.95 kg only with a weight reduction of about 45.86%. Also, the analysis has shown that the model has performed better in the case of equivalent strain and equivalent stress parameter, nevertheless, it falls short at deformation parameter which is due to the flexibility imported to the model due to composite properties. Table 2 shows the results for weight reduction approach analysis.

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Table 2: Maximum and Average values of output parameters with weight reduction approach on composite

	Max. deformation (mm)	Equi.Strain (mm/mm)	Equi. Stress (Mpa)
Max.	4.7 E-02	9.825 E-06	9.405 E-02
Avg.	2.081 E-03	2.092 E-07	1.901 E-03

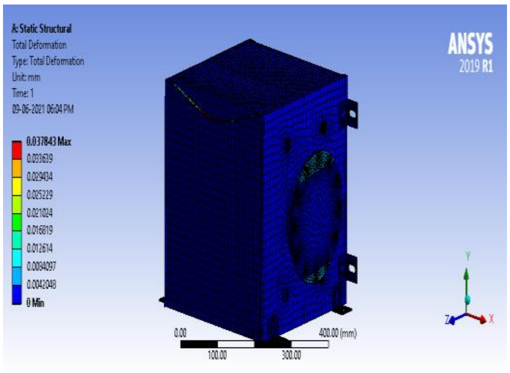

Fig. 8a. Total deformation in case of weight reduction approach with composite.

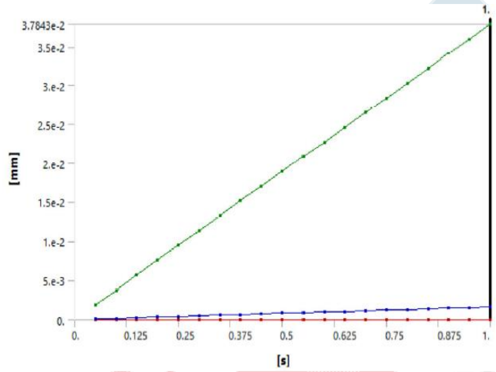

Fig. 8A. Graph for total deformation vs time.

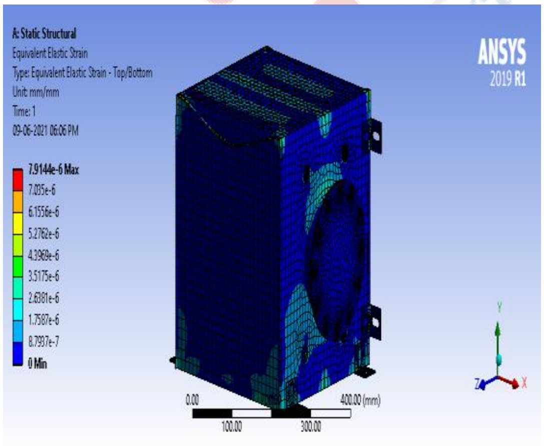

Fig. 8b. Equivalent elastic strainin case of weight reduction approach with composite.

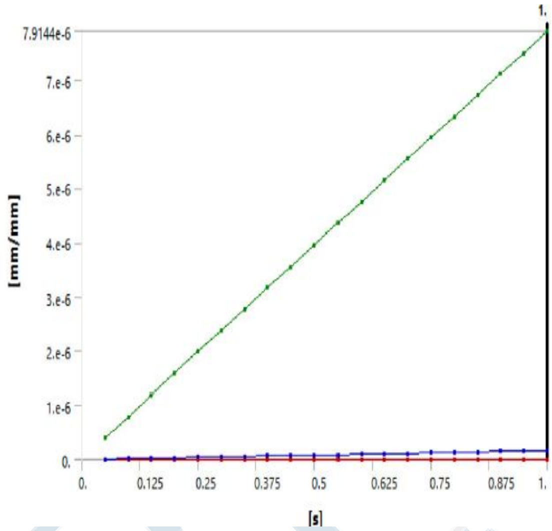

Fig.8B. Graph for equivalent elastic strain vs time.

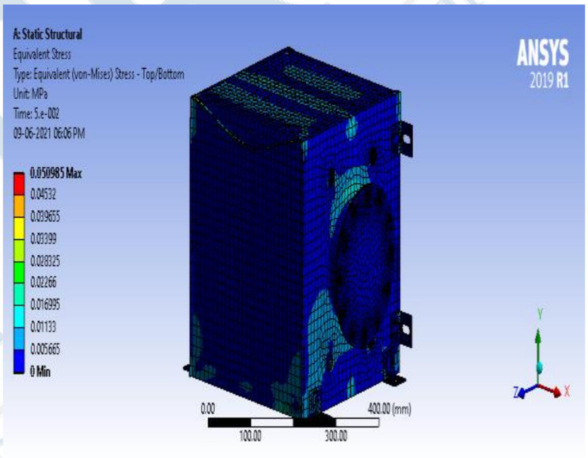

Fig. 8c. Equivalent elastic stressin case of weight reduction approach with composite.

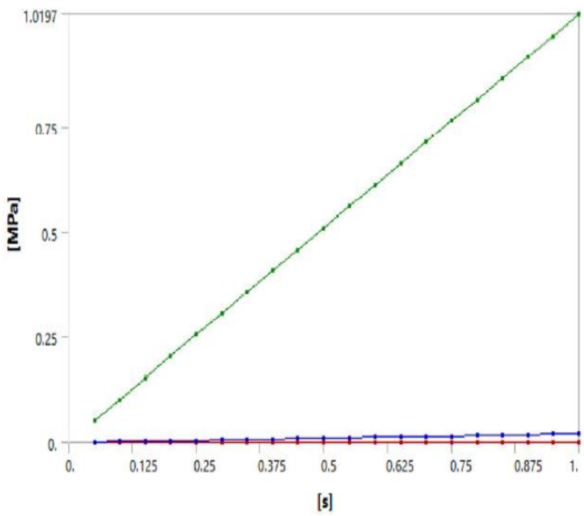

Fig. 8C. Graph for equivalent stress vs time.

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It can be seen in the analysis images and graphs that the induced stresses are less than the prior case with SS and the results vary linearly with time.

B.2. Comparative strength approach:

In this case the strength of the composite is increased either by providing thickness to the laminate or by providing trusses and ribs on inner races using ansys software. The mass obtained is 25.9 kg with all other boundary conditions similar to other experiments. Table 3 shows the results with respect to total deformation, EE strain and Equivalent stress.

Table 3: Maximum and Average values of output parameters with comparative strength approach on composite (Air filter E glass laminate 4mm)

	Max. deformation (mm)	Equi. Strain (mm/mm)	Equi. Stress (Mpa)
Max.	1.011 E-02	6.397 E-06	4.158 E-02
Avg.	1.0619 E-03	1.579 E-07	9.888 E-04

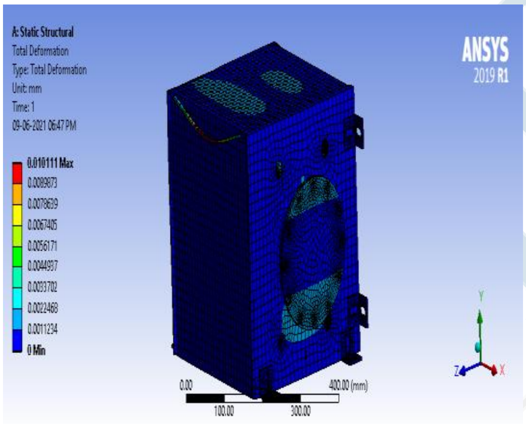

Fig. 9a. Total deformation in case of comparative strength approach with composite.

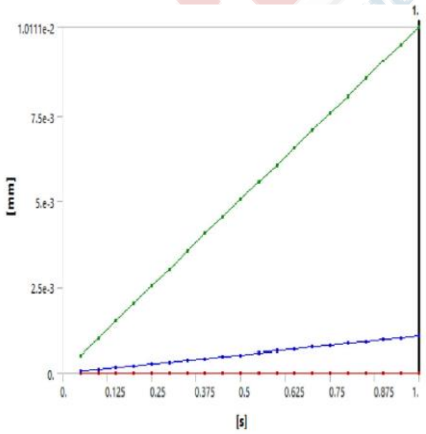

Fig. 9A. Graph for total deformation vs time.

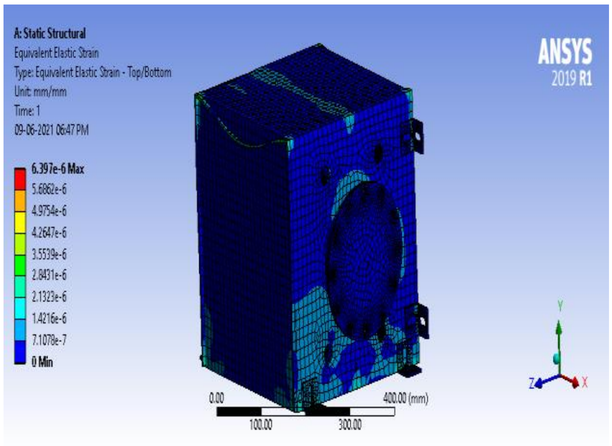

Fig.9b. Equivalent elastic strain in case of comparative strength approach with composite.

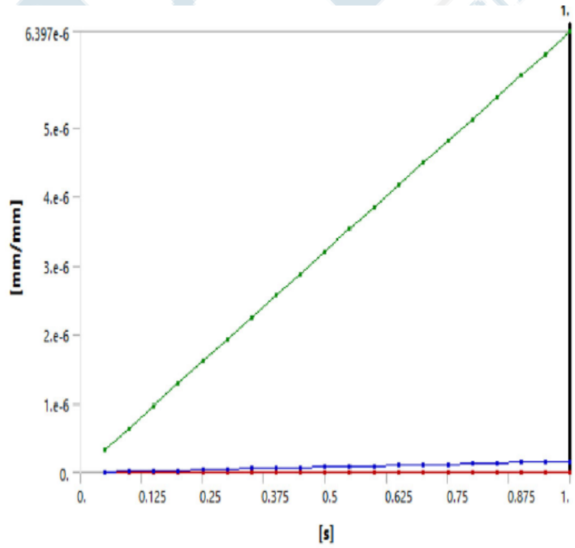

Fig.9B. Graph for equivalent elastic strain vs time.

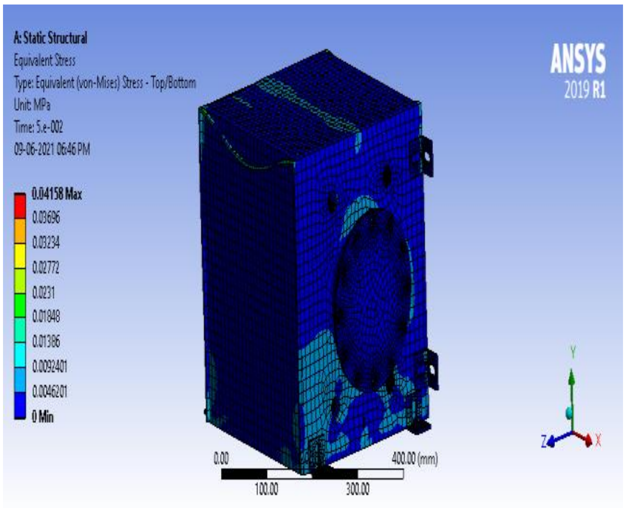

Fig.9c. Equivalent elastic stress in case of comparative strength approach with composite.

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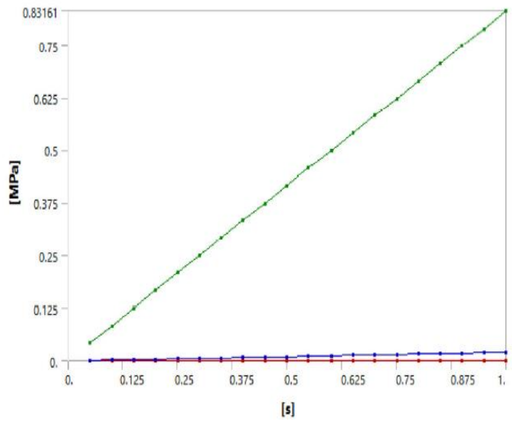

Fig. 9C. Graph for equivalent stress vs time.

It can be seen from table 3 that using comparative strength approach the model with composite material has performed far better than the tradition material and a tensile strength increment of 55.78% has been witnessed.

C. IMPACT TEST

To test the resilience of the design and laminate impact test with a velocity of 10 mm/s was performed on the model. The boundary condition of the modal are same are shown as below:

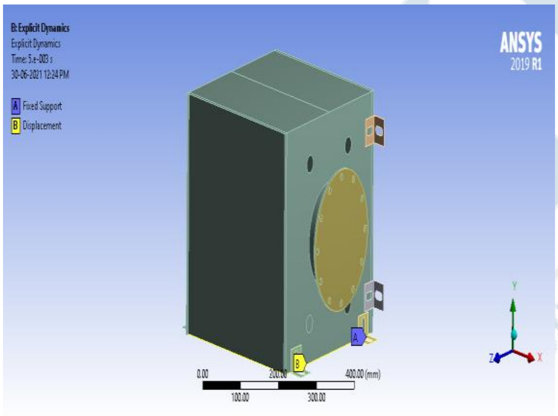

Fig. 10. Boundary condition for the impact test.

Table 4 shows the impact test results with total deformation, Equivalent Elastic strain and Equivalent stress. Figure 11a-11c shows the analysis result with respect to all three output parameters.

Table 4. Impact test results for SS material

	Max. deformation (mm)	Equi. Stress (Mpa)	Equi. Strain (mm/mm)
Max.	9.66E-03	1.189	6.21E-06
Avg.	7.43E-04	6.77E-02	5.38E-07

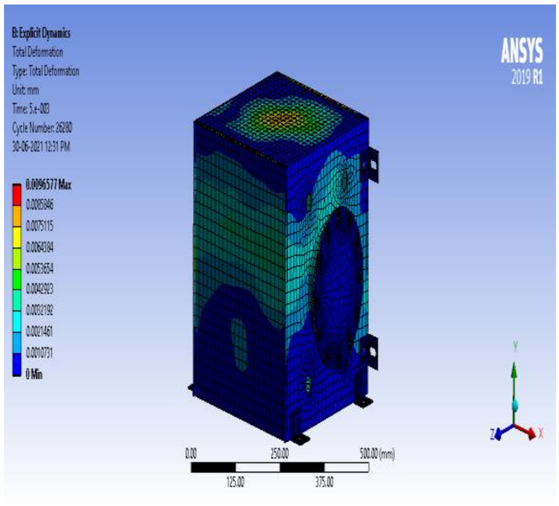

Fig. 11a. Total deformatiomnin case of impact test with SS material.

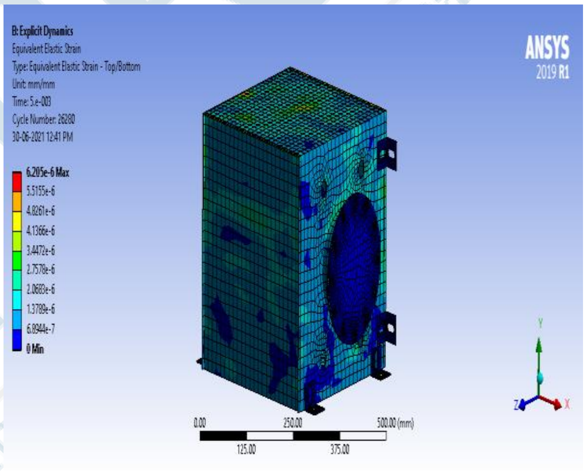

Fig. 11b. Equivalent elastic strain in case of impact test with SS material.

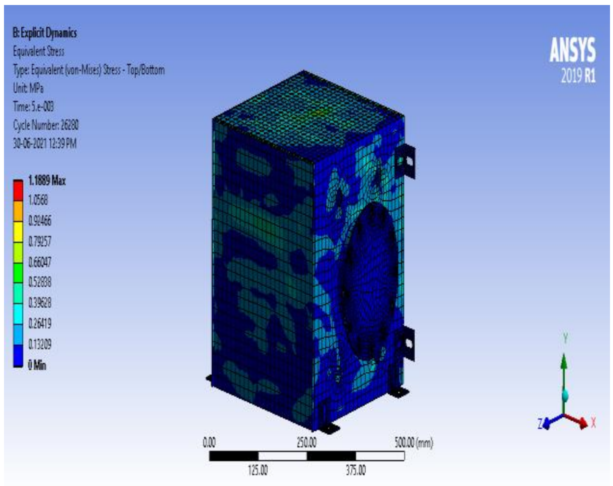

Fig. 11c. Equivalent elastic stress in case of impact test with SS material.

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Results with E-Glass,silenka with Honeycomb laminate assembly

Table 5 shows the result after application of laminate with same boundary conditions in case of the impact test. Further figure 12a-12c shows the analysis results with respect to output parameters.

Table 5. Impact test result for composite material

	Max. deformation (mm)	Equi. Stress (Mpa)	Equi. Strain (mm/mm)
Max.	9.44E-03	0.881	1.13E-05
Avg.	7.35E-04	8.28E-02	9.83E-07

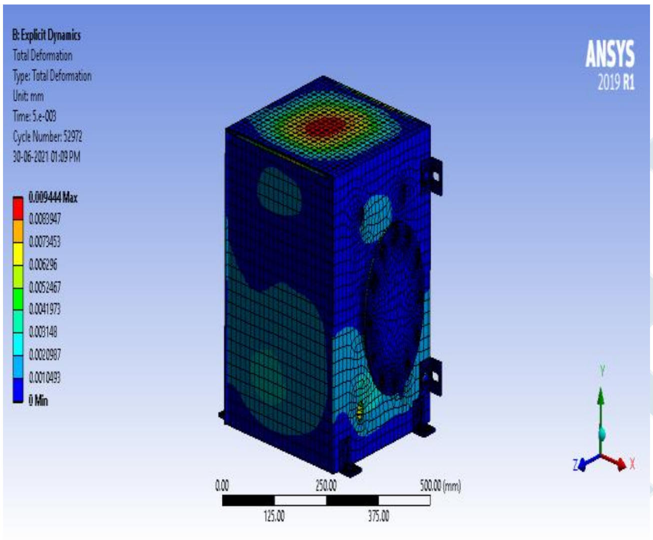

Fig. 12a. Total deformation in case of impact test with composite.

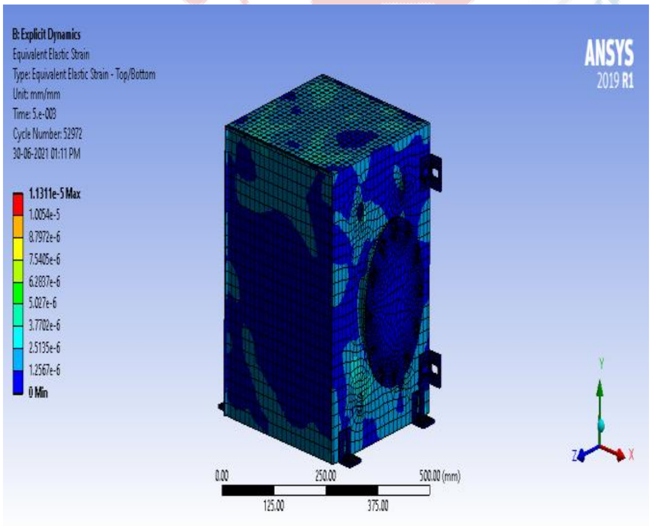

Fig. 12b. Equivalent elastic strain in case of impact test with composite.

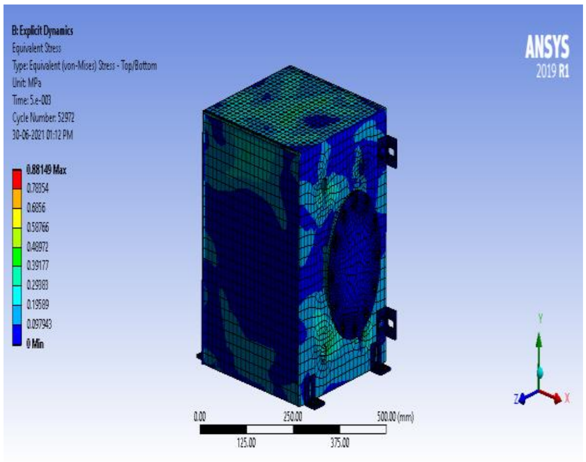

Fig. 12c. Equivalent elastic stress in case of impact test with composite.

V. CONCLUSION

1. A new composite material of E-glass, Silenka using Honeycomb Structure is generated on Ansys which is effective in cost saving as well as delivers good results against structural performance.
2. Using ansys software the composite laminate was successfully implemented on to the 3D model generated on Solidworks .With weight reduction approach, the 45.86% of the dead -weight is reduced which would be very effective.With comparative strength approach, 55.78% increment in the tensile strength is achieved in computational analysis using ansys software.
3. Impact test shows 2.28%, 25.90% and -82.13% change (for respective maximum values) in Max. deformation (mm), Equivalent Stress (Mpa) and Equivalent Elastic Strain (mm/mm) during impact test as compared to SS using ansys software.

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