Material Selection of the Frame of the Hybrid Agricultural Sprayer

Jasveer Kaur, Rythm Jain, Prakriti Saini, Komal, and V. K. Chawla

Abstract Selection of a suitable material is of prime importance in designing and fabrication of the hybrid agricultural sprayer. Material plays an important role as it affects factors such as function, mechanical properties, quality, manufacturability, endurance, performance and cost of the hybrid agricultural sprayer. In this research paper, the solid modelling of hybrid agricultural sprayer has been done on SolidWorks and suitable material is selected by comparing static structural analysis of aluminium, mild steel, stainless steel, epoxy carbon and epoxy E-glass UD-based frames on ANSYS workbench and properties such as density and yield strength. The deformation, equivalent stress and equivalent strain, obtained through analysis on ANSYS workbench, and other properties such as density and yield strength cost are compared for aluminium, mild steel, stainless steel, epoxy carbon and epoxy E-glass UD-based frames to determine the suitable material for the frame of the hybrid agricultural sprayer. Thus, by comparing aluminium, mild steel, stainless steel, epoxy carbon and epoxy E-glass UD-based frames, this research paper determines the appropriate material for the frame of the hybrid agricultural sprayer.

Keywords Agriculture sprayer · ANSYS workbench · Hybrid SolidWorks · Solar energy · Wind energy

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P. Joshi et al. (eds.), *Advances in Engineering Design*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-981-33-4684-0_67

1 Introduction

To reap good yields, effective spraying of a number of chemicals is necessary in agricultural field. Adequate spraying of such chemicals can only be accomplished by use of a reliable and efficient sprayer. The performance of the sprayer to a huge extent is influenced by the material of the frame of the agricultural sprayer. Material plays an important role as it affects factors such as function, mechanical properties, quality, manufacturability, endurance, performance and cost of the hybrid agricultural sprayer. Therefore, selection of a suitable material is of prime importance in designing and fabrication of the hybrid agricultural sprayer.

Agricultural sprayer plays an important role in agricultural field, and the performance of the agricultural sprayer depends upon material of frame of agricultural sprayer. Early different types of agricultural sprayer used by the farmer such as backpack type sprayer, fossil fuel type sprayer, mechanical type sprayer and electrical type sprayer in which frame of such agricultural sprayer is made up by mild steel; hence, many analysis is done on different agricultural equipment by using different software such as SolidWorks, CATIA and ANSYS. Simulation is considered to be one of the best procedures to analyse and anticipate the performance of any system or component scrupulously without practically developing it in actual [1–4].

The paper by Karthik et al. [5] deals with the design and development of the solarized agro-based sprayer for rural application. A paper was proposed by Rajashekar et al. [6], and the aim of this paper was to design a three-row agricultural weeder in CATIA, to perform simulation at the frame of agricultural weeder on ANSYS, to calculate functional efficiency on loamy soil, clay soil and sandy soil and to reduce the cost of weeder in order to develop a low-cost weeder for small-scale farmer. The frame of the weeder was made up of mild steel which made its cost economical but increased the weight as well as power required to move the weeder. The paper by Bhanutej et al. [7] deals with the design and modelling of the agricultural sprayer. In this paper, the analysis of the sprayer was carried out to predict the stresses and deformation induced in the components of the sprayer. This paper suggested the use of the polyethylene as the frame material, but it is difficult to bond and flammable characteristics negated its lightweight characteristic Then an agricultural growth nourishing implementor is developed by Sujay et al. [8], and in this paper, solid modelling of model is done on CATIA V5 R20 modelling software, and different components of implementor are done on ANSYS. Also result is obtained by comparing theoretical result with ANSYS result. In the paper by Bhatkar et al. [9], an adjustable manually push operated pesticide spraying machine was proposed. The design and analysis of the machine were carried out to predict the stresses and deformation.

Ghumadwar and Banker [10] proposed a paper in which designing of three-stage low-cost crop cutter machine is done on Creo drawing software. Also in this research paper, in order to analyse force on rolling cutter blade of the crop cutter, a static and dynamic analysis is done on rolling cutter blade by importing crop cutter modelling from Creo in ANSYS workbench 14 software. The mild steel was used as a material for the frame. Meghana et al. [11] performed impact analysis on bumper and car frame using different materials such as aluminium, stainless steel, structural steel and carbon epoxy. An impact analysis is performed using ANSYS workbench, and result is generated by comparing different materials such as aluminium, stainless steel, structural steel and carbon epoxy on deformation, stress-strain and weight basis. This paper suggested the use of aluminium, stainless steel, structural steel and carbon epoxy as material for the frame of the sprayer.

In order to analyse different components of agricultural sprayer for rose farming, a paper is proposed by Pramodh et al. [4]. In this research paper, an ANSYS workbench is used to analyse deformation, equivalent stress and equipment strain acting on different components of sprayer such as kart wheel, pulley and sprayer head due to application of tension and compression force on these components of the agricultural sprayer. Sagar et al. [12] proposed a paper which deals with design, analysis and fabrication of trolley type agrochemical sprayer. In this paper, UNIGRAPHICS software is used to perform geometric modelling, and then this geometric model is imported in the ANSYS workbench in order to study deformation, equivalent stress, equivalent elastic stain and type of material used for different components of the pesticide sprayer.

Later on, Saheb and Babu [3] developed a low weight agricultural robot. In this paper, carbon fibre is used as a material for frame of robot which analysis on ANSYS workbench and designing of robot done on CATIA V5 software. In the paper, by Subrahmanyam et al. [13], a grass cutting and water spraying rover was proposed. It is a four-wheeled device designed to go around fields, smartly irrigating the lands and trimming the grass. Apart from structural analysis of frame of robot, other components of agricultural robot are also analysed on ANSYS workbench. Pramod and Jithinmon [14] developed an agricultural robot which works on dual prismatic-revolute (PR). This paper also involved kinematic, static and dynamic analysis of the robot in ANSYS workbench which is used to determine the dimensions of dual arm. Also, in this research paper, C17 mild steel material is used for analysis, and to determine thickness of flange, static analysis is performed.

It is clearly evident from the literature review that tremendous amount of work has been done on the agricultural sprayer in the past. Most of the work has been done by considering mild steel as the material for the frame. But mild steel has heavyweight and is susceptible to corrosion. Consequently, greater power is required to impart motion to the agricultural sprayer. All of these disadvantages outweigh its advantage of being economical. In order to overcome the aforementioned research gap, this paper proposes to find a suitable material for the agricultural sprayer.

2 Methodology

This paper provides incite to design and simulate a hybrid agricultural sprayer. In research paper, suitable material for the frame of the hybrid agricultural sprayer is selected by comparing the deformation, equivalent stress and equivalent elastic strain, obtained through analysis on ANSYS workbench, and other properties such as

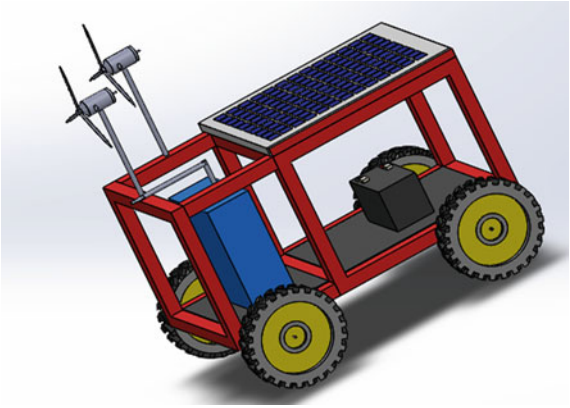

Fig. 1 Agricultural sprayer model

density and yield strength cost for aluminium, mild steel, stainless steel, epoxy carbon and epoxy E-glass UD-based frames. The designing of the model has been carried out on SolidWorks as shown in Fig. 1, and static structural analysis of aluminium, mild steel, stainless steel, epoxy carbon and epoxy E-glass UD-based frames has been carried out on ANSYS workbench. Then the frames based on materials such as structural steel, aluminium alloy, mild steel, epoxy carbon and epoxy E-glass UD are compared to choose the optimum material for the frame of the sprayer, on the basis of their equivalent elastic strain, equivalent stress, deformation, density, Poisson's ratio, tensile yield strength, tensile ultimate strength, weight and cost.

3 Structural Analysis

Structural analysis was done on the hybrid agricultural sprayer to find out the suitable material for frame of the agricultural sprayer. For this purpose, five materials were chosen and were analysed using the ANSYS software.

Static structural analysis was done initially on the following five materials:

1. Stainless steel
2. Mild steel
3. Epoxy carbon
4. Epoxy E-glass UD
5. Aluminium alloy

For the structural analysis of the geometry after the mesh generation process, backside of the frame was fixed, and the force of 400 N was applied in the negative Z-axis direction.

The results were generated for the following:

1. Deformation of the frame,
2. Stress on the frame,

3. Strain in the frame,

The deformation, stress and strain result obtained by static structural analysis of stainless steel is shown in Fig. 2, Fig. 3 and Fig. 4, respectively.

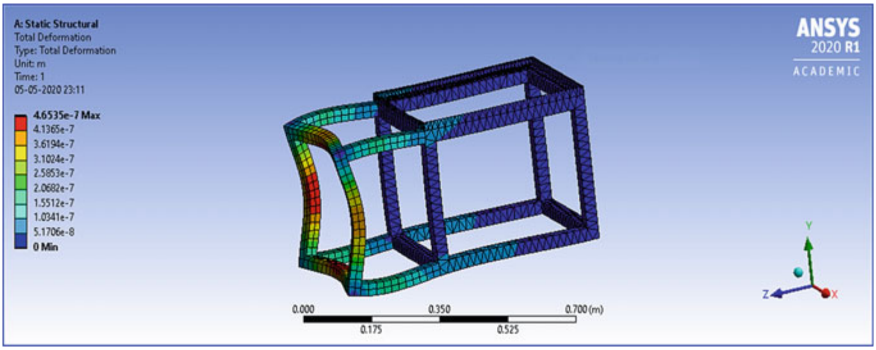

Fig. 2 Deformation of stainless steel

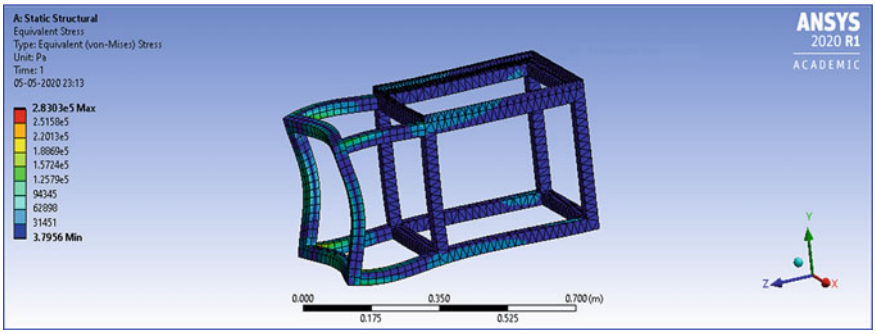

Fig. 3 Stress of stainless steel

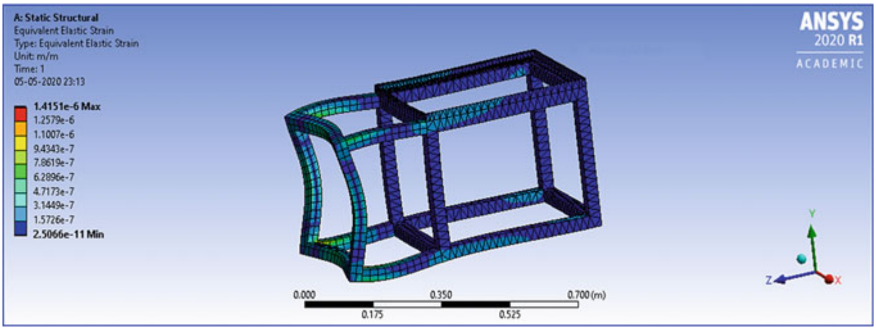

Fig. 4 Strain of stainless steel

The deformation, stress and strain result obtained by static structural analysis of mild steel is shown in Fig. 5, Fig. 6 and Fig. 7, respectively.

The deformation, stress and strain result obtained by static structural analysis of epoxy carbon is shown in Figs. 8, 9 and 10, respectively.

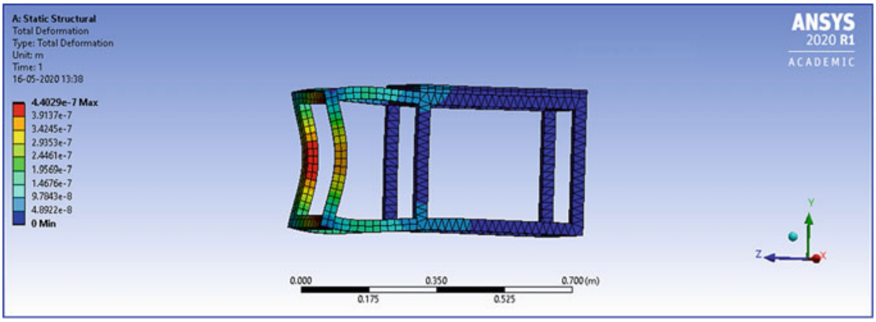

Fig. 5 Deformation of mild steel

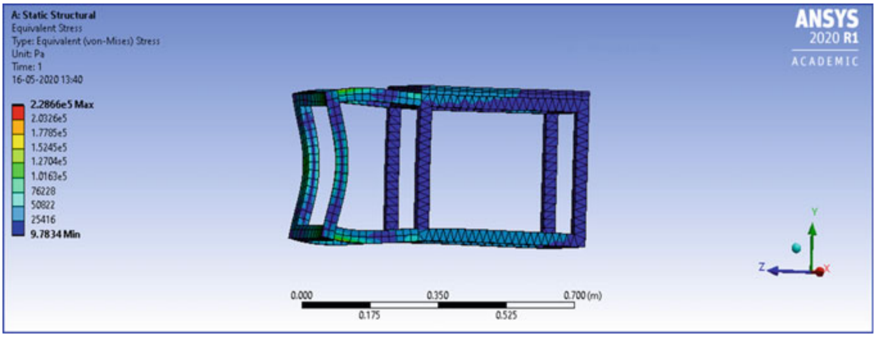

Fig. 6 Stress of mild steel

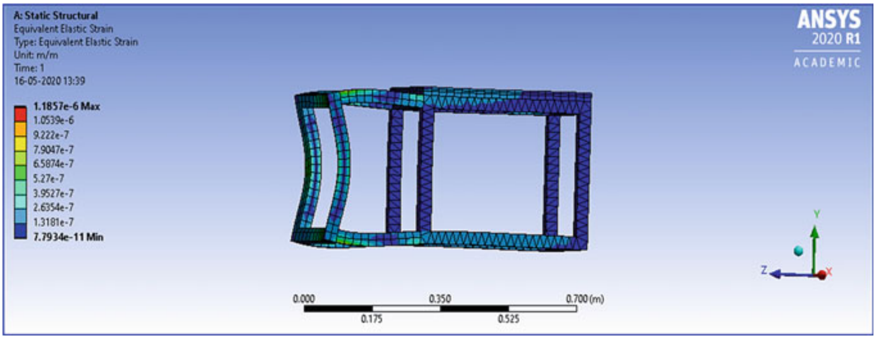

Fig. 7 Strain of mild steel

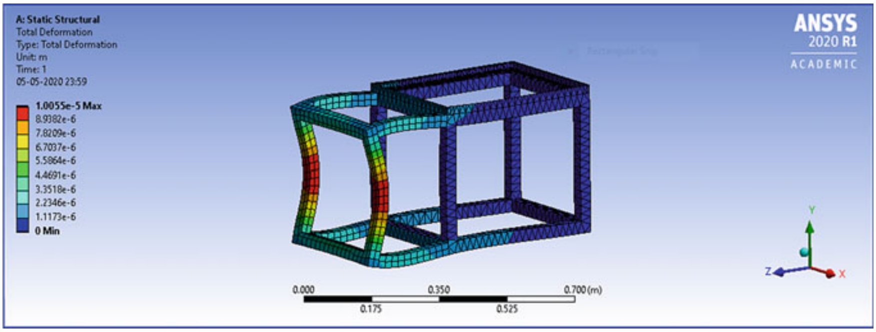

Fig. 8 Deformation of epoxy carbon

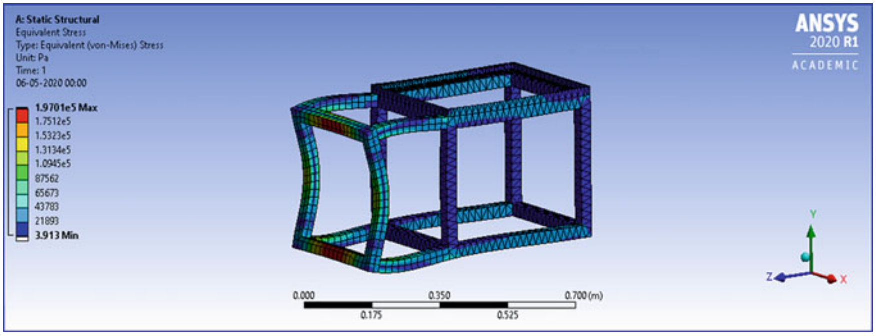

Fig. 9 Stress of epoxy carbon

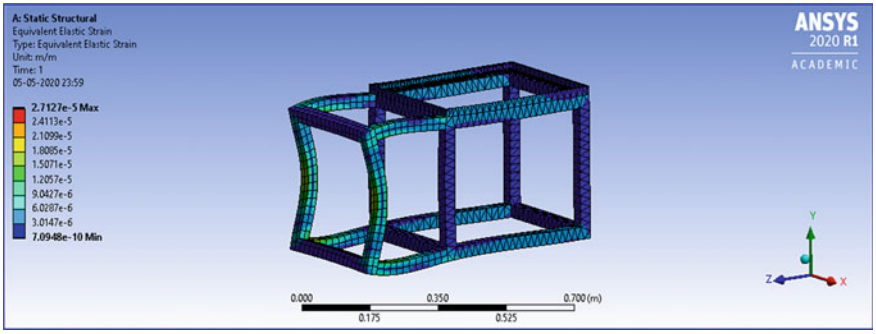

Fig. 10 Strain of epoxy carbon

The deformation, stress and strain result obtained by static structural analysis of epoxy E-glass UD is shown in Figs. 11, 12 and 13, respectively.

The deformation, stress and strain result obtained by static structural analysis of aluminium is shown in Figs. 14, 15 and 16, respectively.

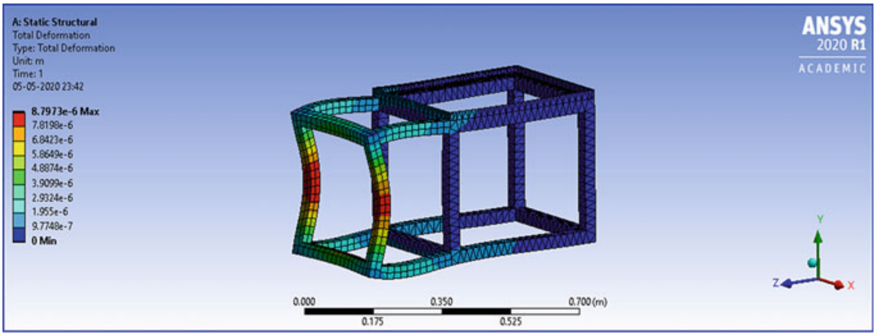

Fig. 11 Deformation of epoxy E-glass UD

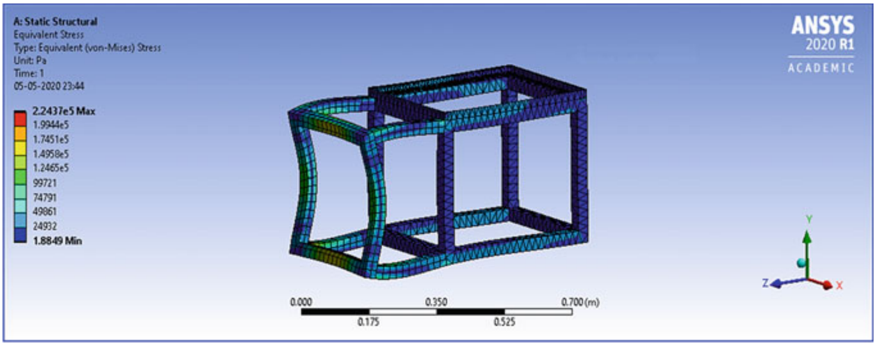

Fig. 12 Stress of epoxy E-glass UD

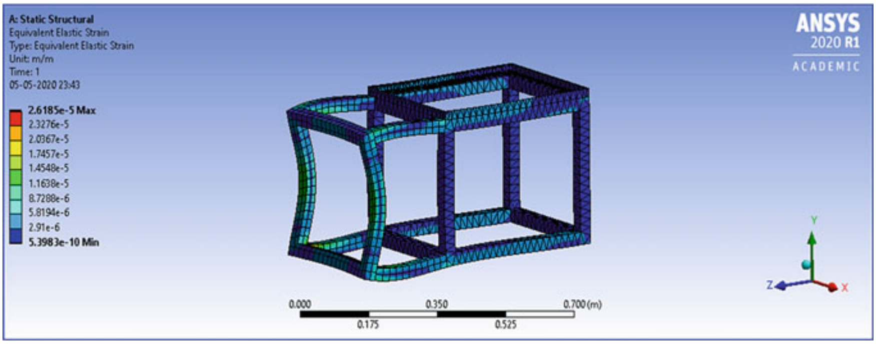

Fig. 13 Strain of epoxy E-glass UD

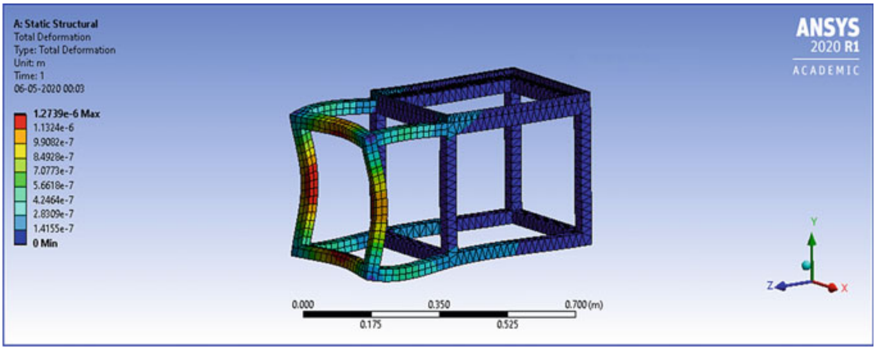

Fig. 14 Deformation of aluminium

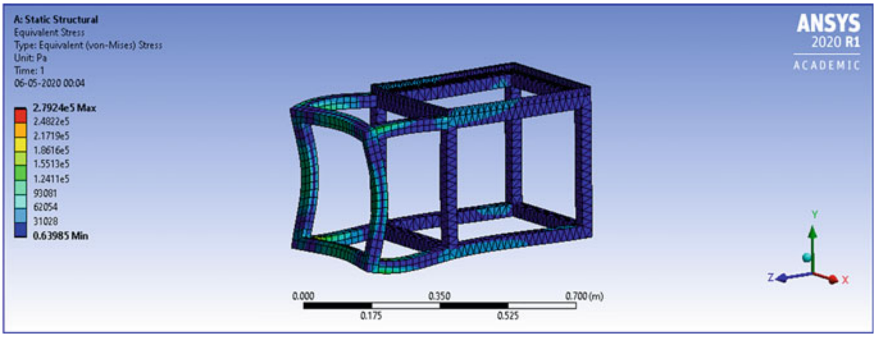

Fig. 15 Stress of aluminium

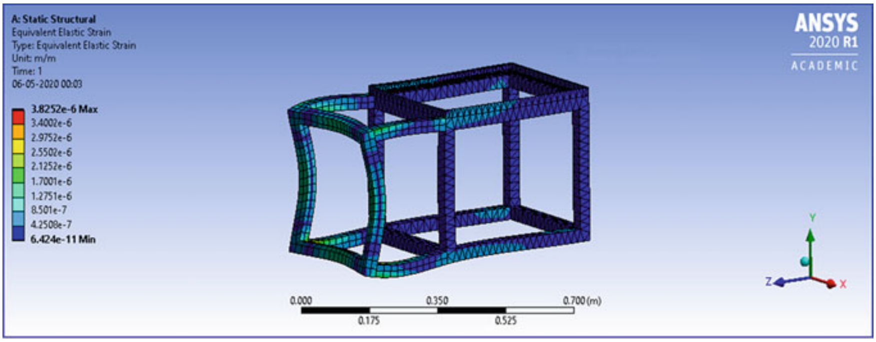

Fig. 16 Strain of aluminium

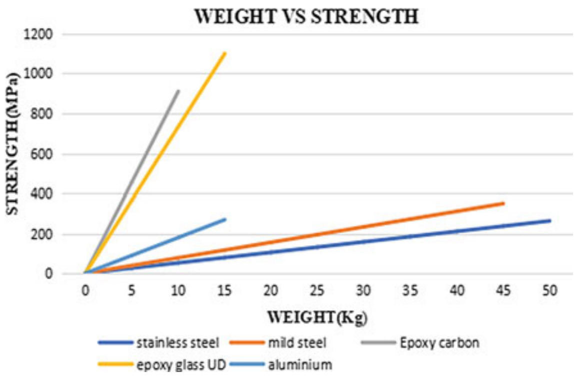

Fig. 17 Weight versus strength

4 Result and Discussion

The graph of weight of sprayer versus the yield strength of material is plotted above as shown in Fig. 17. From the graph, it has been concluded that aluminium alloy is offering strength value very close to mild steel and its weight is very close to that of epoxy carbon. Therefore, aluminium alloy has been chosen as the most suitable material for the frame of the hybrid agricultural sprayer. The below graph in Fig. 18 depicts the relation between the cost and strength of different materials. Here, we can easily conclude that the cost of the material epoxy E-glass UD is the highest making it less economical to use in the fabrication of hybrid agricultural sprayer. This graph also corroborates to the statement made earlier that the best material to use for this hybrid agricultural sprayer is aluminium alloy.

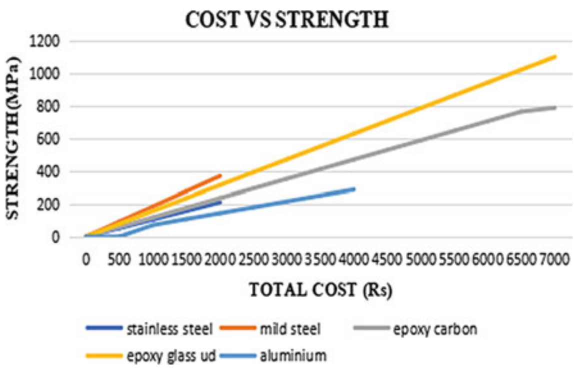

Fig. 18 Cost versus strength

5 Conclusion

The comparison of different materials for frame is shown in Table 1, and from this table, it is observed that mild steel offers minimum deformation of $4.4029e^{-7}$m, stress of $2.2866e^{5}$ Pa and strain of $1.1857e^{-6}$ for the same load applied. However, it weighs 45 kg. Epoxy carbon offers minimum weight of 8.67 kg. However, it is costly as compared with other materials and might have availability issues in the market. Aluminium alloy gives deformation of $1.2739e^{-6}$ m, stress of $2.7924e^{5}$ Pa and strain of $3.8252e^{-6}$ that are very close to mild steel. Also, it weighs 15.604 kg and will be easily available in the market. Therefore, it is concluded that for the optimization of the material of the frame of hybrid agricultural sprayer, an aluminium alloy is chosen. Subsequently, this sprayer opens up the scope for improvements and augmentations:

1. Various other alloys and materials can be explored to serve as the frame material of the agricultural sprayer.
2. Dynamic analysis of these sprayers can be carried out to study the motion of the agricultural sprayer and to study the impact of forces.
3. The analysis of the frame can also be carried out by considering forces acting on the sides of the frame in case of impact as well as forces acting due to the weight of the components of the sprayer acting in downward direction.

Table 1 Comparison between different materials

		Stainless steel	Mild steel	Epoxy carbon	Epoxy E-glass UD	Aluminium
Deformation (m)	Minimum value	0	0	0	0	0
	Maximum value	$4.6535e^{-7}$	$4.4029e^{-7}$	$1.0055e^{-5}$	$8.7973e^{-6}$	$1.2739e^{-6}$
Equivalent stress (Pa)	Minimum value	3.7956	9.7834	3.913	1.8849	0.63985
	Maximum value	$2.8303e^{5}$	$2.2866e^{5}$	$1.9701e^{5}$	$2.2437e^{5}$	$2.7924e^{5}$
Equivalent elastic strain	Minimum value	$2.5066e^{-11}$	$7.7934e^{-11}$	$7.0948e^{-10}$	$5.3983e^{-10}$	$6.424e^{-11}$
	Maximum value	$1.4151e^{-6}$	$1.1857e^{-6}$	$2.7127e^{-5}$	$2.6185e^{-5}$	$3.8252e^{-6}$
Density (kg/m^2)		7850	7800	1600	2000	2770
Poisson’s ratio		0.3	0.3	0.27	0.3	0.33
Tensile yield strength (MPa)		250	370	805	1100	280
Tensile ultimate strength (MPa)		460	400	1717	4800	310
Weight (kg)		47.5	45	8.675	11.645	15.604
Cost per kg		50	42	788	600	250

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