Manufacturing cum Evaluation of Environmentally Benign Composites

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Abstract : Composites are the combination of matrix and reinforcement material which give better mechanical and physical properties than their individual counterparts. The project develops technology to manufacture sustainable composite materials that are eco-friendly with an additional focus on economy. Taking this into account the work focuses on preparation of green composite by combining two elements to make them resistant in wet environments and then testing its properties. The mixture used was metal scrap and epoxy resin as the matrix binder. The metal scrap was taken in the form of waste chips generated due to milling and turning. Epoxy is used since it offers medium viscosity and eventually superior mechanical properties for lamination applications. Further, the manufactured composites were tested for properties like tensile strength, bending and moisture. Results indicate the manufactured green composites have varying tensile and bending strengths depending upon the types of combinations used. Ultimately the manufactured green composites were better in terms of strength, lighter in weight, lower in cost and also mainly environmental friendly. The large-scale production and actual usage in practical application of the same can be next step towards sustainable manufacturing and environmental friendly products.

***Keywords:* composites, metal-scraps, epoxy, resin, eco-friendly.**

I. Introduction

Owing to remarkable advancements in product design, the conventional materials cannot adequately satisfy the growing demand on product capabilities and performance. This dictates the necessity of composite materials which provide the required properties in much greater way than that by conventional materials. Composites are combination of two or more materials when they combined gives a better property than those of their individual components used alone [1]. The two materials are commonly termed as reinforcements and matrix. The individual components do not blend into each other and remain distinct when they are mixed. In this project, we use metal-scrap as a reinforcement material along with a binding agent matrix mostly being resins. The reinforcements are tough, durable and stiffer than the matrix. Thus, providing superior strength and stiffness to the composites formed. In general, green composites consist of some eco-friendly or natural materials, or should be sustainable from manufacturing and usage point-of-view, or even sufficient in recycling towards their end of shelf-life [2-5]. Uses of composites have been increased due to their specific properties and lightweight than commercially used materials. Advantages such as corrosion resistance, electrical insulation, easy processability at relatively less energy requirement in tooling and assembly costs, higher stiffness and strength, fatigue resistance and lower weight than metals have made polymer composite widely acceptable in structural applications.
The so-called advanced composites have replaced metals because of their excellent mechanical properties and low density giving them high specific strength and stiffness. At present the majority of the fibers and resins are derived from petroleum feed stocks and do not degrade for several decades under normal environmental conditions. Thus, there is a huge interest generated in increasing green composites using fully sustainable, biodegradable, environment friendly and annually renewable fibers and resins, particularly those derived from plants. Many composite materials are used in aircraft industries as wings, rotors, tail, and propellers and in automobile industries too [6-7]. Apart from using natural fibers for producing composites, we can also produce composites from industrial wastes that still have a decent mass which could be well utilized to get the desired strength [8]. One such waste is metal chips generated while machining which is treated as waste for industries calling it as machining scrap.
The metal chips that are generated from machining process of different sizes and shapes could be made uniform to particular physical size and then could be used as a reinforcement material for metal scrap composite. Metal scrap composites produced from machining chips are new types of composites. These composites are not used commercially and are yet not accepted across the globe. Hence there needs to be work done and study the properties of these composites too.
At present the various types of composites present in the market also have some merits and demerits, like a composite with high strength may be very expensive for the industry or a composite which is very cost-effective may not be having the desired mechanical properties in it. Therefore, there is a necessity to produce composites which are optimum in both cost and property, so that they can be used in mass production and thus can make their existence in every corner of the world. With this perspective, this paper discusses the manufacturing and mechanical testing of green composites particularly by using metal scrap as reinforcement material and resin as matrix.

II. EXPERIMENTAL WORK

2.1 Mould Preparation

The initial step in preparation of composite is the design and preparation of mould cavity. Since the ultimate green composites were to be economical, extra focus was also given through implementing low cost manufacturing techniques. Hence cheaper but valuable mould preparation was given prime consideration. Thus, GI sheet was used as initial raw material for mould. The sheet was bent in such a way so as to form a tray like structure with dimensions 180x200x10 mm (see fig.1a and b). This enabled for getting a composite moulding of around 178x198x7 mm dimensions (see fig. 1c) from which later the experimental test specimens were cut.

Fig 1(a). Mould layout

Fig 1(b). Mould with composite under curing

Fig 1(c). Manufactured composite

2.2 Metal-Scrap Preparation

Taking into account the metal-scrap composites, scrap metal chips generated after the machining operation of drilling and turning were used (see fig. 2a). Since the composites were to be tested experimentally, uniformity of material is necessary. Hence considering this, long metal chips ranging between 2 cm – 3 cm were only selected. Further the chips which were longer than 3 cm were cut down manually so as to get uniformity within size limits. Further to avoid variation in properties of composites due to rusting phenomenon of chips, the chips were instantly collected after machining operation.

Fig 2(a). Metal scrap in form of chips

2.3 Matrix Material Preparation

The matrix material too plays a vital role in composites as it binds the fibres together and provides the required strength. The thermosetting resin, with commercial name as "HSC 7660" from "THE HINDUSTHAN SPECIALITY CHEMICALS LTD", was used as matrix material. It was available in a combo pack of epoxy resin and hardener (HSC 8210) that gives high strength adhesive bonding [8]. Selection of it was done because of its good mechanical properties and it is available in liquid state and can be well used in combination with hardener. Further it has slow reactive low viscosity epoxy system for hand lay-up application and cure at normal ambient temperatures. The matrix material thus consisted of resin and hardener mixed in 100:10 ratios.

2.4 Preparation of composites

A vellum paper is applied to the inner surface of the mould since the resin is directly poured in the mould cavity, which gets stuck in the mould and removal of the same becomes difficult. Hence a thin layer of oil is applied uniformly over the paper, as it creates a film between the resin and the paper and thus aids in easy removal of the composite. To avoid the concentration difference in quantity of resin poured throughout the mould, the mould is placed on a flat surface. If its placed in an inclined surface the resin will flow down and more of it will be concentrated at the lower side. Now the mould was filled with resin and metal-scrap in layers form for the formation of composites.
For composites, the resin was poured in the mould to form first layer at bottom. By placing the desired metal-scrap, the second layer was formed above it and was then again followed by resin over it to form the third layer. Only three layers are used so as to form intermediate by metal-chips and the peripheral ones by resin. In order to ensure proper bonding between metal-scrap and resin, a lid in the form of flat plate of about 500gms was placed over the mould. The mould was then kept at normal atmospheric conditions to cure for a period of approximately 24hrs. Thus, by the above mentioned process metal-scrap composite moulding was prepared. Total twelve different variants of composites were prepared by changing the composition as given in Table 1 [12]. From the mouldings desired shaped specimens in the shape of rectangle was cut by using hand-held disc grinder carefully and safely (see fig. 3a). These specimens were then subjected to various mechanical testing.

Table 1
Composite variants manufactured for experimental testing

Tensile Testing		Flexural Testing	
Variant no.	Reinforcing materials	Variant no.	Reinforcing materials
1	40% T	7	40% T
2	50% T	8	50% T
3	60% T	9	60% T
4	40% M	10	40% M
5	50% M	11	50% M
6	60% M	12	60% M

T = Turning Chips, M = Milling Chips

First the tray was filled with chips to its fullest. After that weight of the chips was checked. Based on the weight, the chips were divided into three types. First was 40% of the weight of the chips, Second was 50% of the weight of the chips and Third was 60% of the weight of the chips.

Fig 3(a). Actual cut specimen variant of manufactured composite

2.5 Mechanical Property Testing

For any given composite, the mechanical properties are most important from application point-of-view and thus its testing becomes necessary. In this project, tensile and bending strength were given importance as they are important mechanical properties desired for majority of applications. Thus, for measuring the same, the standard setup of universal testing machine available in lab was used. The specimens were cut to standard sizes as discussed in previous section and were tested for the strengths according to the ASTM testing standards.

III. RESULTS AND DISCUSSIONS

The variation of tensile and flexural strength for various composite variants is shown in (Fig. 4 and Fig. 5). It is observed that different variants have quite varying levels of tensile and flexural strengths. This variation is dependent on the types of combinations incorporated.

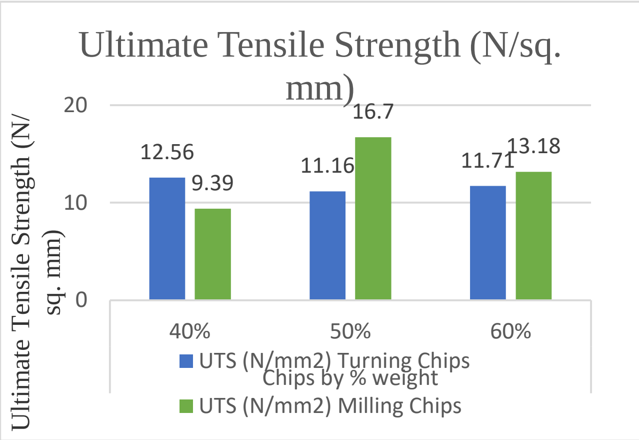

Fig. 4. Tensile strength for various composite variants

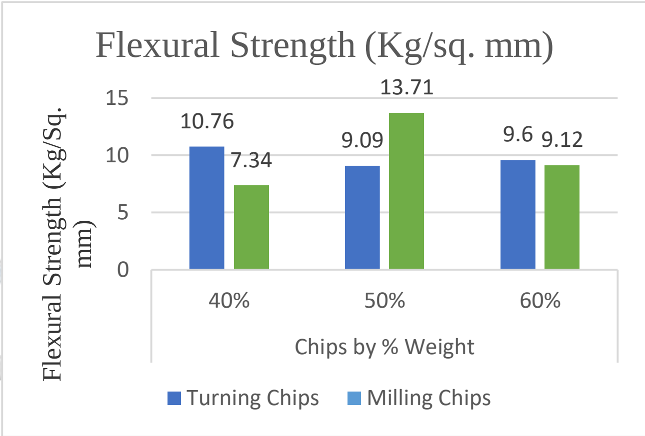

Fig. 5. Flexural strength for various composite variants

Considering composites made by using 40% turning chips (variant no. 1) the tensile results showed better strength than that of 40% milling chips (variant no. 4) whereas for 50% turning chips (variant no. 2) the strength was less as compared to the 50% milling chips (variant no. 5) and for 60% turning chips (variant no. 3) the strength was less as compared to the 60% milling chips (variant no. 6).

Considering composites made by using 40% turning chips (variant no. 7) the flexural results showed better strength than that of 40% milling chips (variant no. 10) whereas for 50% turning chips (variant no. 8) the strength was less as compared to the 50% milling chips (variant no. 11) and for 60% turning chips (variant no. 9) the strength was almost equal as compared to the 60% milling chips (variant no. 12).

In moisture absorption test, the sample was placed in water at room temperature. After every 24 hours, the sample was removed and weighed.

We can find this variation in strengths because we know that the chips are formed due to metal shearing process during machining and are also subjected to thermal stresses in the same process on account of high cutting temperature. Thus, the mechanical and thermal stresses degrade the properties of the chips through subjecting it to indirect heat treatment further causing a reduction in their strength through metallurgical changes. Thus, the composites manufactured from such metallurgically altered material obviously leads to its poor strength characteristics. However, its worth appreciable that the metal-scrap composites are still better with milling chips than turning chips and should be efficiently used for suitable applications having higher tensile load bearing capacities on a mass scale. Metal-scrap composite also can still find suitable applications, even though on limited basis, as its strength is appreciably better in certain aspects. Thus, manufacturing of green composites and their incorporation in practical applications should be primarily given due consideration on account of its economic as well as environmental view-points driven towards sustainably.

IV. CONCLUSIONS

The experimental investigation leads to the following conclusions.

- All the manufactured green-composite variants, had varying tensile and flexural strengths.
- From tensile test results, we can conclude that composites made from milling chips showed more strength as compared to the turning chips.
- From flexural test results, we can conclude that the composites made from both turning and milling chips are of equal strength.
- Metal-scrap composites, even though having lower strength, still have wide scope of applications on account of its better properties as well as due to potential for waste scrap utilization in an alternate useful manner.
- Green-composites are economic as well as environmental friendly and thus need to be utilized in applications.

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