Aesthetic improvement of sheet molding compound (SMC) composite plate by using natural fiber reinforced polymer (NFRP) like jute fiber reinforced epoxy matrix composite coating

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Abstract. In current scenario, the use of composite materials in our lives has become very common and these are found in our furniture, transportation, education, sports, building and infrastructural system. Compared with conventional materials such as metal, plastics and woods, composite materials offer specific strength, specific stiffness and tailored material properties. Composites mainly classified as metal matrix, ceramic matrix and polymer matrix composites. Polymer matrix composites are used for low temperature applications such as automotive body panels, crashworthiness, bumpers etc. Mainly carbon, glass and aramid fibers are used as reinforcement for these applications. Nowadays, natural fibers such as flax, jute, coir, cotton etc. are also used for decorative and semi structural applications in automotive and furniture industry. Polymer matrix composites are mass produced by use of sheet molding compound (SMC) compression molding technology. SMC technology has been used in manufacturing automobile parts, electrical insulation cover applications, partition panels and many semi structural applications etc. The current trend of improving the surface appearance and mechanical properties of SMC’s can lead to even more applications such as exterior, structural parts and also decorative parts in automobile, furniture and other domestic applications. Automotive interior dashboard parts, door panel parts and other interiors need to be aesthetically appealing so that it feels pleasant to seat in the car. In this work, hand lay-up process is used for coating onto the SMC compression molded plate with jute fiber reinforced epoxy composite. Uncoated and coated SMC plates are compared by various characterization methods such as tensile, compression, hardness and surface roughness. Also visual appearance and gloss test were performed. Coated SMC plate has improved tensile strength, surface finish, gloss value and visual appearance. There is almost same compression strength and Rockwell hardness value obtained.

1. Introduction
Over past few decades composite materials, ceramics and plastics have been dominant emerging materials. The applications of composite material and the area in which they are being used are increasing day by day. Nowadays, the use of composite materials in our lives has become very common and these are found in our furniture, transportation, education, sports, building and
infrastructural system [1]. Composite materials offers advantages such as specific strength (the strength to weight ratio), specific stiffness (the stiffness to weight ratio) and tailored material (since composites are composed of two or more “phases”, they can be formulated to meet the needs of a specific application with considerable ease) over conventional materials such as metals, woods, plastics and polymers [2]. The prominent properties of fiber composites which can be utilized to manufacture complex components with lower weight and at reduced cost are high specific stiffness, specific strength, fatigue endurance, corrosion resistance, dimensional and hydro-thermal stability and desired directional properties. This is the reason why fiber reinforced composites are being used in the applications, ranging from sports goods, naval, automobiles, wind energy and bridges etc. to advanced aircraft structures. In fiber reinforced composites, polymer matrix composites (PMCs) are very popular for different types of engineering applications. They are used primarily in relatively low temperature applications. The PMCs are used in various automotive applications like crashworthiness, body panels, and bumpers and so on [3]. Despite PMCs bring advantages to many engineering applications, there are three major issues commonly criticized by the public as these are hardly to be recycled, which may cause serious environmental problems after disposal; the structures made of advanced composites may be over-strength in particular using carbon fibre reinforced polymer (CFRP) composites and there is relatively high materials cost of PMCs for domestic products. Therefore, fibres extracted from the nature have emerged in the past decades aiming at replacing traditional high strength synthetic fibres to form a new class of natural fibre reinforced polymer (NFRP) composite. The growing awareness of environmental concerns is also another element to force the engineering sectors to develop new materials from natural resources that are either reusable or renewable. Hence, natural fibres have become an attractive topic recently [4].

NFRPs have two main constituents, the polymer matrix and the organic reinforcement fiber. Polymer matrix materials used in NFRP composites can be classified into thermosets and thermoplastics. Polyurethane (PU), epoxy and polyesters are examples of thermosets and polyethylene (PE), polypropylene (PP), polystyrene (PS) and polyvinyl chloride (PVC) are examples of thermoplastics used in NFRP composites [5]. Natural fiber reinforcement materials are fibers obtained from naturally available resources such as plants, animals and minerals. Plant fibre includes jute, cotton, coir, bamboo and banana fibres which are easily available in India [6]. Basically, uses of plastics and composites in high volume vehicles are restricted to decorative or semi-structural applications. Sheet molding compound (SMC) materials are the highest performance composites in general automotive used today. Typically, SMC materials are used for grill opening panels on many car lines and closure panels (hoods, deck lids, and doors) on a few select models [7]. Sheet molding compound (SMC) is a complex composite of specialty resins (polyesters, vinyl esters, epoxy etc.) to which thickeners, inorganic fillers, fiber reinforcements, catalyst, mold release, and pigment are added. It is produced in sheet form and can be molded by compression, transfer, and thermostet injection methods. SMC enjoys a wide range of applications due to the great range in available properties. SMC can be formulated in an almost infinite number of ways affecting production cost, corrosion resistance, heat resistance, electrical properties, and flame resistance among others. The largest volume of SMC is produced by compression molding [8].

Alireza Ashori reviewed developments in the area of wood-plastic composites (WPCs) and their applications in automotive industries using plant-based fibers. The term WPCs refers to any composites that contain plant (including wood and non-wood) fibers and thermosets or thermoplastics. Currently they are very common in building, construction, furniture and automotive products. Automotive components including plant fibers are currently being used by many vehicle manufactures such as: Audi, Opel, Daimler-Chrysler, Fiat, Ford, Mercedes Benz, Peugeot, Renault, Volvo, Volkswagen and BMW [9]. Vivek Mishra et al. work describes the development and characterization of bidirectional jute fiber mat as reinforcement and epoxy resin as matrix material. Successful fabrication of the bidirectional jute fiber reinforced epoxy composite has been done by the hand lay-up technique [10]. Gon et al. discussed about Jute fiber composites. Jute fibre is a promising reinforcement for use in composites on account of its low cost, low density, high specific strength and
modulus, no health risk, easy availability, renewability and much lower energy requirement for processing. In recent years, there has been an increasing interest in finding new applications for jute fibre reinforced composites that are traditionally used for making ropes, bags, hessians, sacking, mats, and carpet. To protect environment, wood can be replaced by composite materials made from natural fibres like jute, coir, sisal etc. for making home furniture, household products and building and constructions [11]. Fan-Long Jin et al. reviewed synthesis and applications of epoxy resins. Epoxy resins have been widely used for coatings, electronic materials, adhesives, and matrices for fiber-reinforced composites because of their outstanding mechanical properties, high adhesion strength, good heat resistance, and high electrical resistance [12]. There is no any research till date available on improvement of aesthetic appearance of the SMC composite plate. In this work, jute mat as a reinforcement and epoxy resin as a matrix is used. Jute-epoxy composite coating is developed on the sheet molding compound (SMC) composite plate. Purpose of this work is to improve aesthetic appearance of the SMC composite plate and comparing jute coated and uncoated samples with different characterization methods.

2. Experimentation

2.1. Materials

Jute is available in the bidirectional woven mat form in the local market. It was used ‘as available’ (untreated) in the raw form. Cost of this mat is 60 Rs. /meter. Epoxy resin and its hardener were purchased from Atul Ltd., Valsad, Gujarat. Polyamine hardener is suitable to cure epoxy resin at ambient temperature. Base plate upon which coating is done is made up of SMC (Sheet molding compound) compression molded composite material. It is manufactured by Mahindra CIE Automotive Ltd. (Composites Division), Pune. These plates are available in 350mm x 250mm dimension. Clear gelcoat is used as outer finishing material. It was purchased from Link Composites Pvt. Ltd., Chinchwad, Pune. It is a thixotropic, quick-curing, superior phthalic anhydride and propylene glycol based unsaturated polyester resin and its hardener is methyl ethyl ketone peroxide (MEKP). Other materials includes glass plate of size 300mm x 150mm is used as mold, weight of 7 kg, Univax Superior Wax Polish, NORTON 80 Grit abrasive paper, pneumatic cutter, brush, weighing scale, chisel, hammer and micrometre screw gauge.

2.2. Coating process on SMC composite plate

Schematic diagram of coating process on SMC plate is shown in figure 1. Before coating process, surface preparation of the SMC plate is necessary to clean the surface of the plate and to get better adhesion between SMC plate and jute-epoxy composite coating. One of the surface preparation method i.e. abrasion process is done on the SMC plate. Abrasion process is done by using 80 grit sand papers. After surface preparation, wax polish was applied over the glass plate so that after completion of the process coated plate can be released from glass easily. Clear gelcoat is applied over the glass plate with brush. When clear gelcoat dries, apply properly mixed epoxy resin and hardener mixture
over it. Then, jute mat of appropriate size is kept over it and again mixture of epoxy resin and hardener is applied. Finally, SMC plate and weight were kept over the jute mat. This whole assembly is kept for curing process. Curing process completes in 24 hrs. Here in this process weight of 7 kg (approx.) is used. Sole purpose of weight is to get rid of extra resin that accumulates in the process and there won’t be any air bubble trapped on the coating. The Glass is used for acquiring good surface finish on visible side of the coating. After curing completed, weight is removed. SMC plate is released with the help of chisel and hammer. Trimming of the plate is done with the help of pneumatic cutter.

2.3. Characterization
For comparison between jute coated SMC plate and uncoated SMC plate, various characterization methods are done. Mainly mechanical testing and aesthetic testing were done. Mechanical testing such as tensile, compression, hardness and surface roughness test were done. Aesthetic testing is done on the basis of visual appearance and gloss value. Universal testing machine of Star Testing System, India (Model STS 248) was used for tensile and compression tests. Rockwell hardness tester of Saroj Engineering, India (Model RAS) is used for determination of Rockwell hardness as per ASTM D 785-03 standard. Surface roughness tester of Mitutoyo (Model SurfTest SJ400) was used. Gloss meter of Raj scientific company, Mumbai is used. Weighing scale is used for measuring weight of jute mat, resin, hardener etc. Tensile testing as per ASTM D 638, Compression testing as per ASTM D 695 and Rockwell Hardness testing as per ASTM D 785-03 standard were done. Standard specimens were prepared for these tests. Test plate of 300mm x 120mm size jute coated plate was prepared so that all the test specimens can be made by use of this plate. Table 1 describes approximate amount of materials required for coating of 100mm x 100mm of SMC plate. With the use of material requirement values obtained for 100mm x 100mm SMC plate coating, material required for 300mm x 120mm size SMC plate coating is calculated and depicted in the table 2.

| Table 1. Material requirement for coating (100mm x 100mm plate). |
|---------------------------------------------------------------|
| Natural fiber | Polymer matrix (Resin) | Ratio | Outer coating |
|----------------|------------------------|-------|---------------|
| Type           | Weight                 | Epoxy + Hardener | Fiber : Matrix | Clear gelcoat + Hardener |
| Jute           | 3gm                    | 10gm+5gm          | 1:5            | 15gm+0.2ml (approx.) |

| Table 2. Material requirement for jute coating (300mm x 120mm plate). |
|---------------------------------------------------------------|
| Natural fiber | Polymer matrix (resin) | Ratio | Outer coating |
|----------------|------------------------|-------|---------------|
| Type           | Weight                 | Epoxy + Hardener | Fiber : Matrix | Clear gelcoat + Hardener |
| Jute           | 11gm                   | 36gm + 18gm=54gm | 20:100         | 54gm + 0.8ml (approx.) |

Thickness of the developed jute-epoxy composite coating on the SMC plates is determined by taking average value of three coated SMC plate samples. Three jute-epoxy coated SMC plates of 100mm x 100mm size were made by using same amount of materials. Micrometre is used for checking thickness values at different points on the plates. Thickness before coating and thickness after coating on the SMC plates were checked and thickness of the jute-epoxy composite coating is determined.

3. Results and Discussions

3.1. Aesthetic tests

3.1.1. Visual Appearance test
Visual appearance test was performed on coated and uncoated SMC plates. Figure 2 and figure 3 shows SMC plate before coating and after coating respectively. Jute fiber gives natural appearance to
the SMC plate. All bidirectional jute fibers are clearly seen. By coating SMC plate with jute-epoxy composite, its aesthetic appearance has improved as seen in the figures.

![Figure 2. SMC plate before coating.](image1)

![Figure 3. SMC plate after coating.](image2)

3.1.2. Gloss test
Gloss values obtained are shown in the table 3 given below. SMC plates with jute-epoxy composite coating gives more values of gloss and hence it can be said that SMC plate with coating of jute-epoxy composite is glossy than uncoated SMC plate.

| Sample ID        | Gloss value (OGU)       |
|------------------|-------------------------|
| Uncoated SMC plate | 20° - 38.1, 60° - 74.5, 85° - 92.2 |
| Coated SMC plate | 20° - 67.8, 60° - 85.3, 85° - 99.7 |

Table 4. Tensile test results (uncoated SMC plate).

|                  | Max Load | Peak Elongation | Break Load | Break Elongation |
|------------------|----------|-----------------|------------|------------------|
|                  | 2578.38 N| 5.6 %           | 101.92 N   | 6.1 %            |

3.2. Mechanical tests

3.2.1. Tensile test

*Uncoated SMC plate:* The tensile test results show that the maximum load applied was 2578.38 N and after which the specimen failed. The maximum displacement yielded by the material was 5.6 mm. Breaking load was 101.92 N and Break Elongation was 6.1 mm. Load vs displacement graph is shown in figure 4. Tensile test results are shown in table 4.

*Coated SMC plate:* The tensile test results show that the maximum load applied was 6026.02 N and after which the specimen failed. The maximum displacement yielded by the material was 8.6 mm. Breaking load was 49.98 N and breaking elongation was 8.7 mm. Load vs displacement graph is shown in figure 5 and table 5 shows tensile test results for jute coated SMC composite plate.

Both the samples were found to be brittle in nature as it underwent a sudden failure. It does not show a yield point and even strain hardening have not occurred. The typical characteristic of the brittle material is to fail while the deformation is elastic and does not show any plastic deformation. Here, table 6 depicts tensile test comparison between two SMC plates. Tensile strength of jute coated samples is almost 35.15 % higher than uncoated samples. The reason could be that, there is increase in the cross sectional area after coating with jute-epoxy composite. So, it could take higher loads than without coating composite before breaking.
Figure 4. Load vs displacement graph (uncoated SMC plate).

Figure 5. Load vs displacement graph (jute coated SMC plate).

| Table 5. Tensile test results (coated SMC plate). |
|-------------------------------|-----------------|-----------------|
| Max Load                      | 6026.02 N       | Peak Elongation | 8.6%            |
| Break Load                    | 49.98 N         | Break Elongation| 8.7%            |

| Table 6. Tensile test comparison. |
|-------------------------------|-----------------|-----------------|
| Sample ID                      | Uncoated SMC plate | Coated SMC plate |
| Tensile strength (MPa)         | 71.622          | 110.44          |

| Table 7. Compression test results uncoated SMC plate with coated SMC plate. |
|-------------------------------|-----------------|-----------------|
| Uncoated SMC Plate            | Coated SMC Plate |
| Peak Load                     | 5213.6 N        | 7536.2 N        |
| Peak                          | 2.3 %           | 3.4 %           |
| Compression                   |                 |                 |

3.2.2. Compression test

Uncoated SMC plate: The compression test result show that the maximum load applied was 5213.6 N after which specimen failed. Peak compression obtained was 2.3 mm. Load vs deformation graph is shown in figure 6 and table 7 shows compression test results.

Coated SMC plate: The compression test results show that the maximum load applied was 7536.2 N and after which the specimen failed. The maximum compression yielded by the material was 3.4 mm. Load vs deformation graph is shown in figure 7 and table 7 shows compression test results. Table 8 shows compression test comparison for coated and uncoated SMC plate specimens. Compression strengths for both the samples are nearly same. The reason could be that, there is increase in the cross sectional area after coating with jute-epoxy composite. So, it could take higher loads than without coating composite before breaking.

| Table 8. Compression test comparison. |
|-------------------------------|-----------------|-----------------|
| Sample ID                      | Without coating | With jute coating |
| Compressive strength (MPa)    | 140.151         | 142.407         |
3.2.3. Hardness test
Rockwell hardness is measured and results are shown in the following table 9 as follows. Hardness values are lower for developed jute-epoxy composite coated SMC plates. The hardness test is performed with a ball indenter with diameter ¼” and applied load of 100 kg. Rockwell hardness scale chosen was M scale. M-scale is mostly used to measure the hardness for plastics and soft materials. From the hardness values of both the samples, it was found to be almost similar. The results were found to be in close conjunction with each other. In the Rockwell test conducted the hardness value was found to be in the range 55-56 for uncoated and 50-51 for coated samples.

| Sample ID   | Hardness (Scale ‘M’, 100 Kg load, ¼” Dia. ball) |
|-------------|-----------------------------------------------|
| Without coating | 55-56                                      |
| With jute coating | 50-51                                     |

3.2.4. Surface Roughness test
Roughness average (Ra), 10 point height average (Rz) and Root mean square roughness (Rq) of coated and uncoated SMC plate samples were measured in micrometre (µm) and depicted in table 10. There is decrease in all these surface roughness values for jute-epoxy composite coated SMC plate. So, it can be said that coated SMC plate has good surface finish than uncoated SMC plate.

| Sample ID   | Without coating | With jute coating |
|-------------|-----------------|-------------------|
| Surface Roughness (µm) | Ra 0.30  | Ra 0.13 |
|              | Rz 3.0          | Rz 1.1            |
|              | Rq 0.47         | Rq 0.19           |

3.3. Thickness of coating
Table 11 depicts thickness values of SMC plates before and after coating. By using values in table 11, thickness of jute coating can be obtained. Average values of coating thickness for Plate A = 0.9325, Plate B = 1.0387 and Plate C = 1.0275. Hence, thickness achieved is between 1±0.20 mm.

Table 9. Hardness test comparison.

Table 10. Surface roughness test comparison.
4. Conclusions and future scope
Sheet moulding compound (SMC) composite plates can be coated with natural fiber jute as a reinforcement material and epoxy resin can be used as a matrix material to add aesthetic appeal to them by developed method. Jute mat gives aesthetically appealing look to the SMC plates. Jute mat coating is easy to coat on the SMC plates. Jute-epoxy composite coated SMC plate specimen’s gives better tensile strength values, almost same compression test values, reduced Rockwell hardness value as compared to uncoated SMC plate specimens. But jute-epoxy composite coated SMC plate specimen’s gives higher values of gloss and improved surface finish values when compared with uncoated SMC plate specimens. These coated SMC plates will have attractive and aesthetically appealing look for these applications.

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Table 11. Thickness values before and after jute-epoxy composite coating on the SMC plates (in mm).

| Pt. No. | Plate A Before | Plate A After | Plate B Before | Plate B After | Plate C Before | Plate C After |
|---------|---------------|--------------|---------------|--------------|---------------|--------------|
| 1       | 3.25          | 4.20         | 3.06          | 4.07         | 3.05          | 4.08         |
| 2       | 3.19          | 4.15         | 3.13          | 4.11         | 3.17          | 4.31         |
| 3       | 3.20          | 4.16         | 3.13          | 4.19         | 3.17          | 4.34         |
| 4       | 3.31          | 4.25         | 2.97          | 4.06         | 3.16          | 4.15         |
| 5       | 3.25          | 4.13         | 3.06          | 4.12         | 3.23          | 4.28         |
| 6       | 3.41          | 4.28         | 2.98          | 4.06         | 3.25          | 4.16         |
| 7       | 3.32          | 4.25         | 3.10          | 4.12         | 3.33          | 4.28         |
| 8       | 3.20          | 4.17         | 3.09          | 4.10         | 3.35          | 4.33         |

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