OPTIMISATION OF MECHANICAL PROPERTIES OF SHEESHAM WOOD NATURAL FIBER COMPOSITE

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ABSTRACT

Due to increased environmental awareness , natural fibers have gained importance because of its unique properties like ease of availability, light weight, eco-friendly , biodegradeable, renewable, strong, low density, and low cost. Materials such as sawdust can replace and reduce the utilization of plastic which relate with the environment issue and also offer other advantage. Saw dust is obtained from natural resources and in a large amount form wood industry as a waste. A large amount of sawdust are always found as a waste in wood industries like timber and furniture. Mixing sawdust with polymer in order to improve the mechanical properties of the composite can be very useful and valuable because of its high availability and low cost.

Generally, much higher strength and stiffness are obtainable with the higher performance plant fibers than the readily available animal fibers. An exemption to this is silk, which can have very high strength, but is relatively expensive, has lower stiffness and is less readily available. Because of these reasons, plant based fibers the most suitable for the use in composites with structural requirements. The plant fiber can be grown in many countries and can be harvested after short periods.

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CHAPTER 1

1. INTRODUCTION

The innovative improvement of the world relies on the headway in the field of materials. Likewise, the turn of events and progressions in the field of designing are profoundly subject to materials. That is the reason a few scientists are making progress toward the advancement of impeccable material that can hold up under the high help heaps of different mechanical segments, for example, turbine, airplane, or vehicle and so on. In such manner, the composite materials assume a significant job for steady undertaking of enhancement in materials[1].

In old occasions, the vast majority of the materials utilized for building applications were composites, for example, black-top blended in with sand, wheat straw blended in with sand, carbon dark in elastic and so forth. From most recent couple of decades, the interest for lightweight materials which are solid and extreme have expanded for their application, for example, aviation, developments and so on. That is the reason nowadays architects and planners are utilizing a similar idea of consolidating of various kinds of materials to create things that can satisfy the tough necessities of the business[2].

Presently, the researchers and scientists have been pulled in towards the utilization of common fiber in applications including composite materials. The important properties of the natural fibers, synthetic fibers and polypropylene are reported in the Table 1.1 and Table 1.2.

Table1.1 Properties of Natural Fibers

Fiber Materials	Density (g/cm^3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation (%)
Coir	1.3	130-227	5	14-39
Wood	0.4-1.31	-	10.2	2.8
Jute	1.2-1.6	182-535	3.1-55.2	1.2-1.3
Ramie	1.4	590-905	33.2	2.1-3.4
Hemp	1.4-1.5	581-1115	3.3-90.3	1.2-4.6
Pineapple	.8-1.6	401-628	1.45	14.4
Bamboo	.6-1.1	141-231	1.9-2.8	3.3
Flax	1.4	251-1005	12.6-100.5	1.2-40.1
Cotton	1.5-1.6	238-598	5.4-12.5	7.1-8.1
Sisal	1.4	508-857	24.4	2.9
Cotton	1.5-1.6	355	11.5	2.1-10.1
Banana	1.3	790	30.3	1.9-9.9
Kenaf	1.4	931	53.3	1.5
Coconut	-	545	14.1	-
Abaca	1.5	405	12.2	3.2-10.2
Bagasse	1.25	298	17.8	-

Table 1.2 Properties of Synthetic Fibers and Polypropylene

Fiber Materials	Density (g/cm^3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation (%)
E-glass	2.5	1625-3400	7.2	2.5
Steel	7.8	2800	-	-
Carbon	1.8-1.9	2090-5200	525	-
Alumina	2.8	1000	100	-
Polypropylene	0.90-0.91	29-34	1.1-1.3	175-350

1.1 COMPOSITE MATERIALS

Composite materials are set up by consolidating at least two distinct materials (blended and fortified) at a perceptible level. When all is said in done, composite materials are the blend of fortifying material (short filaments, particles or long strands) and the network material (polymer, earthenware production or metals)[3].

Fig. 1.1 Composite material

Composite materials have totally various properties when consolidated to its individual constituents and are more grounded, extreme and light weight. A portion of the composites, for example, wood, bone and teeth and so forth are accessible in nature.

Wood is a blend of cellulose and lignin. The emphatically stuffed cellulose molecule gives great mass and quality in the composites4. Presence of cellulose is responsible for adequate strength in plants and trees as shown in Figure 1.2.

Fig. 1.2 Tree (Natural Fiber composites)

Further, there are two significant materials through which a bone and teeth have been made, one is calcium phosphate (mineral) installed in other is collagen (protein) framework. Bone is an excellent examplse of the use of natural fiber in the natural composite as shown in Figure1.3.

Fig.1.3 Bone and Teeth (Natural Fiber composites)

A portion of the composite materials are manmade, for example, mud and cement for the motivation behind structure, houses, streets and so forth. The most crude man utilized blocks as composite material comprised of straw and mud for development. Mud has lower elasticity however comes up short after bowing. At the point when the straw is strengthened into mud and permitted to dry, it gives a decent protection from ductile and compressive power and turns into a magnificent structure material. Concrete is the blend of bits of stone and sand reinforced together. There are numerous instances of solid applications like scaffolds building, parking garages, building structures, establishments, motorways/streets, bridge, and footing for entryways, fences and shafts. Another classification of composite materials is engineered composites. These are set up by the man, utilizing characteristic fiber materials and engineered fiber materials. The compressed wood is an awesome case of the engineered composite. It is manufactured utilizing hard layers of wood and paste to shape level sheets of overlaid wood that is more grounded than normal wood and gives a progressive quality[5].

1.2 CLASSIFICATION OF COMPOSITES

Composites are classified by the geometry of the reinforcement as particulate, flake and fiber or by the type of matrix material as polymeric, metal, ceramic and carbon[6]. The classification of composite is presented in the Table 1.3.

Table 1.3 Particulate Filler Composites

Composites	Typical examples
Particulate	Aluminum particle incement, rubber, silicon carbidein aluminum, gravel, sand
Flake	Aluminum ,mica, glass, silver
Fiber	Short fiber-calcium aluminum silicate Long fiber-polymer, metal, ceramic, carbon

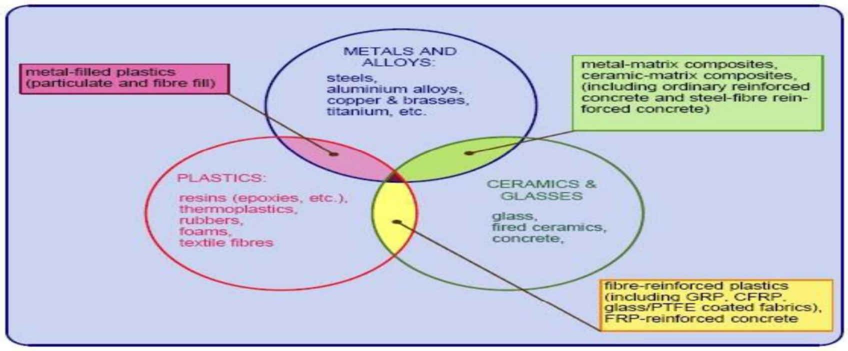

Fig.1.4 Evolution of Composites

Fig. 1.4 shows the development in the composite hypothesis. In the figure, the notable essential materials are metals, earthenware production and plastics and every material compounds are likewise introduced. The mix of metals and plastic structure metal filled composites and blend of metals and earthenware production structure metal artistic composite. Likewise, by the blend of plastic and pottery fiber fortified plastics (FRP) composites are framed however composites are comprehensively arranged based on support and lattice materia[7]l.

1.2.1 Based on Reinforcement Material

Based on the reinforcement composites are classified as shown in fig.1.5.

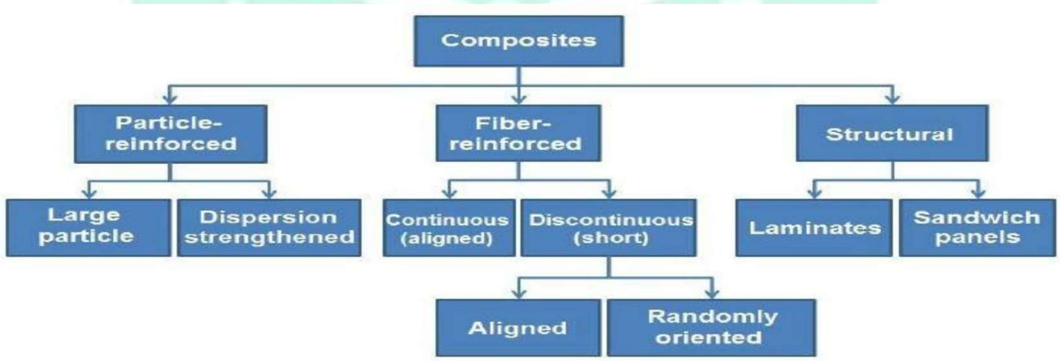

Fig.1.5 Classification of Composite Based on Reinforcement

1.2.1.1 Fiber Reinforced Composite

A composite wherein he scattered stage is as a fiber (for example a fiber that has a huge length to breadth proportion). Filaments are answerable for high quality and firmness proportion to weight of the composite. This class can be additionally partitioned into consistent and intermittent strands. Nonstop strands are those which have lengths typically more prominent than multiple times the basic length (l >15 l c) and irregular filaments have lengths shorter than this. The spasmodic filaments can be adjusted or arbitrarily arranged fig.1.6 shows the fiber directions of nonstop and intermittent fiber composites. Instances of certain strands are carbon filaments, boron filaments, E-glass filaments, SiC filaments, and so forth[4].

Fig.1.6 Fiber Reinforced Composite

1.2.2 Based on Matrix Material

Based on the reinforcement, Composites are classified as shown in fig. 1.7.

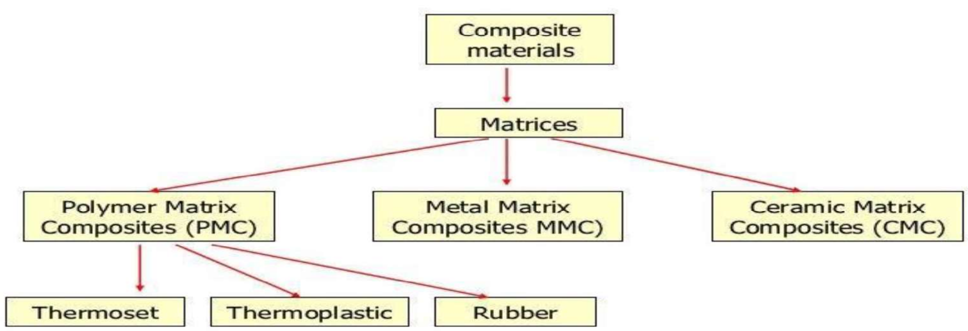

Fig.1.7 Classification of Composites Based On Matrix

1.2.2.1 Polymer Matrix Composites (PMC)

The framework utilized in the composite material is polymer which might be thermoplastic or thermosetting plastic. There is a wide scope of thermoplastic and thermosets materials now days are being utilized in cutting edge composites for the basic applications. Major thermoplastic and thermosets materials used in composites applications are shown in table 1.4[8]

Table 1.4 Thermoplastic and Thermosets Materials

Matrix	Materials	Density (g/cm3)	Cure Time (Min)	Tensile Strength (MPa)	Tensile Modulas (GPa)
	Polyethylene	0.90-0.98		25-35	0.4-1.1
	Polypropylene	0.90-0.94		28-40	0.5-1.3
	Polycarbonates	1.20-1.22		65	2-3
Thermoplastics	Polyamides	1.13-1.41	<20	78	2.6-3.0
	Polyethylene Sulfide	1.34		90-95	3.4-3.6
	Polyetherimide	1.27		40	5-5.5
	Polyetheretherketone	1.26-1.32		95-220	4-20
	Phenolic	1.1-1.40	60+	45-50	3.5-3.9
	Polyester	1.16-1.68	60+	72	
Thermosets	Epoxy	1.1-1.70	60-240	50-70	2.3-2.5
	Bismaleimides	1.15-1.36	120-300	70-80	25-28
	Cyanate Esters	1.18-1.30	60-180	50-90	2.6-3.1
	Polyimides	1.42-1.85	120+	90-120	

Polyester Pitch as appeared in fig.1.8 is the most generally utilized tars in the composites business. Polyester Pitches are more affordable, offer some erosion obstruction, and are more lenient than epoxies[9]. Polyester gums are anything but difficult to utilize, quick restoring and open minded of temperature and impetus limits[8].

Fig. 1.8 Polyester Resin

The eventual fate of car thermoset tar composites showcase looks great with circumstances in inside, outside and others segments. Thermoset tar in the worldwide car composites showcase is gauge to develop at a CAGR of 6.6% from 2016 to 2021. The significant development drivers for this market are expanding car creation and developing interest for lightweight and strong materials because of tough government guidelines to build eco-friendliness and diminish ozone harming substance discharges.

The eventual fate of worldwide unsaturated polyester tar in car composites advertise looks encouraging with circumstances in different applications, including conclusion boards, body boards, bumpers, GOR (grille opening fortification), heat shields, headlamp reflectors, pickup box and others. UPR in the worldwide car composites showcase is conjecture to develop at a CAGR of 5.3% from 2016 to 2021. The significant drivers for advertise development are the expanding interest for lightweight materials, and execution advantages of strengthened composites over adversary materials. UPR Composites with properties, for example, simple to process, high rigidity, lightweight, great erosion opposition and surface pressure are perfect for assembling lightweight and eco-friendly vehicles.

1.3 FIBERS

Fiber is a natural or synthetic material that is significantly longer than it is wide. Fibers are often used in the manufacture of other materials. Fibers can be classified in two groups as under:

- Manmade fibers or synthetic fibers

- Natural Fibers

1.3.1 Synthetic Fibers[10]

The synthetic fibers are fibers whose chemical composition, structure, and properties are significantly modified during manufacturing process. Synthetic fibers consist of regenerated fibers.

1.3.1.1 Glass Fibers

Glass is the most regularly utilized and most economical fiber. Silica makes up in any event 50 percent of glass fiber, with an assortment of metal oxides and different fixings added to modify the fiber qualities. E glass (or electrical glass) has aluminum, boron, calcium and different mixes in its cosmetics, making an amazing electrical encasing. S glass (or high quality glass) while more costly than E glass, is 40 to 70 percent more grounded and more erosion safe as a result of the expansion of more silica oxide just as magnesium and aluminum oxides. Much more prominent erosion obstruction is offered by ECR (or consumption safe) glass strands.

The broadest utilization of glass fiber is as crude material for composite materials. Glass fiber represents about 90% of the fortifications utilized in composite utilization all around. As indicated by showcase conjectures, India glass fibe advertise is required to arrive at 754 million pounds ($752.7 M) by 2018. The Indian government use glass fiber with all due respect portion and a few activities may have over half glass fiber materials utilized in them. Wind vitality is a developing business sector and in this market, the interest for glass fiber is expanding at a sound pace. Different utilizations of glass fiber are channel and tanks, transportation, wind vitality, aviation and resistance, development, marine. Glass fiber is the most favored material for wind cutting edges in light of its high solidarity to weight proportion and high strong quality. The interest for glass fiber is expanding in the Indian market because of high development exercises and furthermore in lights of the fact that fiber glass offers flexible shape and plan.

1.3.2 Natural Fibers[11]

Natural fiber develops or occurs in the fiber shape, and includes those produced by plants, animals, and geological process. They can be classified according to their origin as shown in figure 1.9.

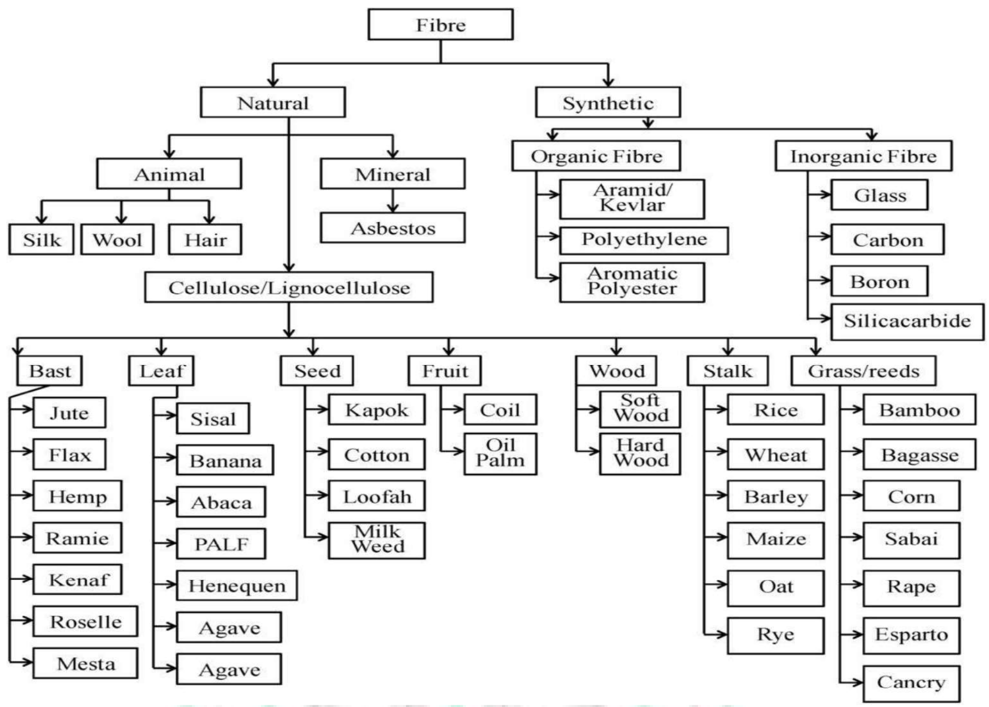

Fig. 1.9 Classification of Fiber

Regular strands which are agro-squander and effectively accessible in bounty, prudent, light weighted, condition amicable and solid. The weakness is that they are biodegradable, poor surface bond, non uniform in size and their utilization with engineered strands which prompts decrease of some mechanical properties. Then again the utilization of normal fillers prompts lesser measure of expensive sap and fiber utilized and consequently helps in cost decrease and may prompt increment of certain mechanical properties. The planners can utilize common fillers so as to lessen cost for creating FRP composites reasonable for specific circumstances[12].

1.3.2.1 Coconut coir

Coconut Coir fiber as appeared in fig. 1.10 goes under class of plant fiber. Properties of plant filaments rely for the most part upon the idea of the plant, region in which it is developed, age of the plant, and the extraction strategy utilized. Coir is a hard and intense multi-cell fiber with a focal part called "lacuna[13]".

Fig.1.10 Coconut Coir

1.3.2.2 Rice husk

Rice husk as appeared in fig. 1.11 is one of the most generally accessible horticultural squanders in many rice delivering nations around the globe. All inclusive, roughly 600 million tons of rice paddies are created every year. On normal 20% of the rice paddy is husk, giving a yearly all out creation of 120 million tones. For each 1000 kgs of paddy processed, around 220 kgs (22 %) of husk is delivered. The significant constituents of rice husk are 32% cellulose, 21% hemicelluloses, 22% lignin and 15% mineral debris. The enormous measure of creation of rice which is roughly 600 million tons for every year is the main wellspring of creation of such waste material. The writing affirms numerous utilizations of rice husk, for example, power age, molecule sheets, light weight solid, rice husk energized steam motors, building materials, as filler material in different polymers[13].

The importance of Rice Husk can be gauged from the following statistics:

- 1 ton of Rice paddy produces 220 kg Rice Husk
- 1 ton Rice Husk is equivalent to 410- 570 kWh
- Calorific value-3000 kcal/kg
- Moisture content = 5 – 12%

Fig. 1.11 Rice husk

1.3.2.3 Wheat Husk

Wheat husk or structure as appeared in fig. 1.12 in organic science is the external shell or covering of a seed and has the best capability of every single rural buildup due to its wide accessibility and minimal effort. It frequently alludes to the verdant external covering of an ear of maize (corn) as it develops on the plant. The normal yield of wheat husk is 1.3−1.4 kg/kg of wheat grain, with a world creation of wheat evaluated to be around 680 million tons in 2011. Wheat husk is light yellow shading strands. Wheat straw contains 35−45% cellulose, 20−30% hemicelluloses, and around 15% lignin, which makes it an appealing feedstock to be changed over to ethanol and other worth included items[14].

Fig. 1.12 Wheat Husk

1.3.2.4 Wood Powder

Wood is a composite which is available in abundance in nature. It is a composition of lignin and cellulose.

Fig.1.13Wood Powder

Wood powder is abundantly available in nature. Density of wood varies from 1.10 to 1.20g/cm³. Due to low cost wood is highly attractive. Lowest installation costs, good durability, lowest maintenance cost.

Wood squander is the sawdust which is absolutely a strong waste item (Figure 1.13). This squanders material is created by numerous wood working tasks, for example, sawing, processing, sanding penetrating, arranging and opening and so on. Sawdust is delivered as the particles and is particulate fiber. As the general public has gotten increasingly worried about the wellbeing of its residents, subsequently from the most recent couple of decades, the specialists are focusing on making the items produced using normal fiber composites. Numerous investigations have been done on the sawdust relating to society wellbeing cognizance and ecological mindfulness.

Wood flour or sawdust can be acquired from wood businesses and the sieving procedure is utilized to screen the needed and undesirable material. The wood flour pulls in light of a legitimate concern for specialists because of its remarkable properties for example light weight, dimensional dependability, and versatile modulus and so on.

Numerous analysts have been taking a shot at a few kinds of wood powders for researching the properties of wood like sisal, hemp, neem, sundi wood powder, and so on. In the current research work Sheesham wood powder is utilized. The logical name of the sheesham tree is Dalbergia sissoo. The sheesham wood is otherwise called Indian rosewood, which is found copiously in India[15].

1.4 FORMS OF FIBERS

Fibers used to reinforce composites are supplied directly by fiber manufacturers and indirectly by converters in a number of different forms, which vary depending on the application.

1.4.1Roving and Tow

Wandering is the easiest and most basic type of glass fiber. It very well may be hacked, woven or in any case handled to make auxiliary fiber structures for composite assembling, for example, mats, woven textures, meshes, weaved textures and half and half textures. Fig.1.14(a) shows meandering which are provided by weight, with a predetermined fiber distance across. The term yield is normally used to demonstrate the quantity of yards in each pound of glass fiber rovings. Also, tow is the essential type of carbon fiber which is appeared in fig.1.14 (b). Normal aviation grade tow size reaches from 1K to 24K (K = 1,000, so 12K demonstrates that the tow contains 12,000 carbon fibers)[16].

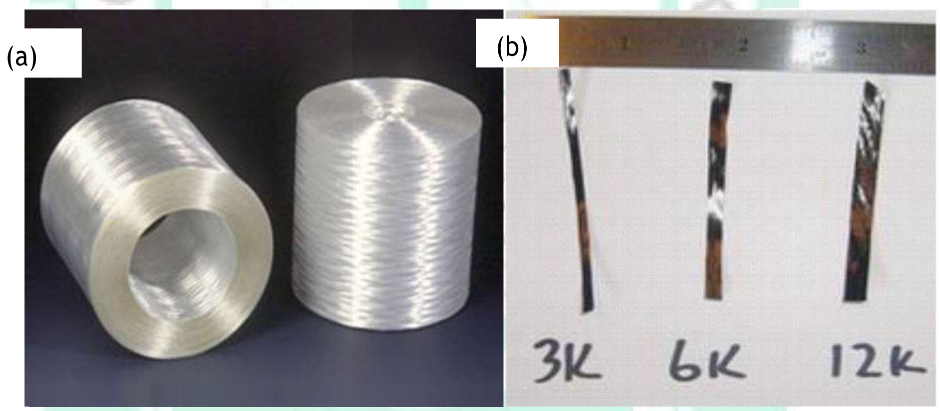

Fig.1.14 (a) Roving & (b) Tow

1.4.2 Mats

Tangles as appeared in fig.1.15 are non woven textures produced using filaments that are held together by a substance fastener. They come in two particular structures named cleaved and nonstop strand. Hacked mats contain haphazardly circulated filaments slice to lengths that normally go from 38 mm to 63.5 mm. Persistent strand tangle is shaped from twirls of consistent fiber strands. Since their strands are haphazardly arranged, mats are isotropic for example they have equivalent quality every which way. Cleaved strand mats give ease support principally close by layup, constant covering and some shut trim applications[17].

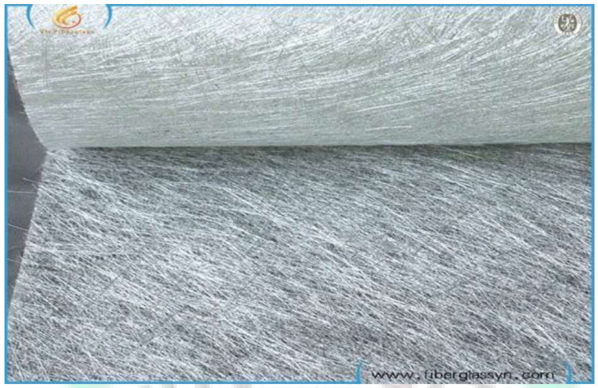

Fig. 1.15 Non-woven Mat

1.4.3. Woven Fabrics

Woven textures as appeared in fig. 1.16 are made on looms in an assortment of loads, weaves and widths. Woven textures are bidirectional, giving acceptable quality in the ways of yarn or wandering pivotal direction (0º/90º), and they encourage quick composite creation. Be that as it may, the rigidity of woven textures is undermined somewhat in light of the fact that filaments are pleated as they ignore and under each other during the weaving procedure. Under pliable stacking, these filaments will in general fix, causing worry inside the grid framework[18].

Fig. 1.16 Woven Fabric

1.5 HYBRID FIBER

Cross breed composites contain more than one sort of fiber in a solitary grid material. On a basic level, a few diverse fiber types might be consolidated into a half breed, however all things considered, a mix of just two sorts of filaments would be generally useful. They have been created as a sensible spin-off of traditional composites containing one fiber. Mixture composites have remarkable highlights that can be utilized to meet different structure prerequisites in a more prudent manner than regular composites. This is on the grounds that costly filaments like graphite and boron can be halfway supplanted by more affordable strands, for example, glass and Kevlar. A portion of the particular favorable circumstances of half breed composites over regular composites incorporate adjusted quality and firmness, adjusted bowing and film mechanical properties, decreased weight as well as cost, improved weariness obstruction, diminished indent affectability, improved break strength or potentially split capturing properties, and improved effect opposition[19].

1.6 ADVANTAGES/DISADVANTAGES OF NATURAL FIBER COMPOSITES

Composites are used to replace the metal parts because of its numerous advantages. Some advantages and disadvantages of the composites are discussed below[20]:

1.6.1 Advantages

There are many advantages of natural fibers which are given below

- High toughness
- Fire resistance
- Good environmental effect
- No moisture absorption
- No health hazards
- Good fatigue resistance

1.6.2 Disadvantages

Some of the disadvantages of PMC are

- Higher cost of some material system
- Relatively immature technology
- Complex fabrication methods for fiber reinforced system

1.7 MANUFACTURING PROCESS FOR POLYMER MATRIX COMPOSITES[21]

Manufacturing of composites can be broadly classified as Primary and Secondary manufacturing.

1.7.1 Primary Manufacturing

These processes result in a shape which is very near to net shape. There are several primary manufacturing processes out of which some of them are as mentioned below

- Manual layup/wet layup
- Manual layup, Prepare layup
- Injection molding
- Autoclave Processing
- Filament winding
- Resin Transfer moulding

Each process has its own advantages and limitations based on the accuracy, area, wastage and cost also. In this research hand layup method is used to manufacture composite laminates with matrix as polyester resin, reinforcement as glass fiber filled with natural fillers as Coir, Rice and Wheat husk.

1.7.2 Secondary Manufacturing

Albeit essential procedures bring about a close net shape item yet now and again the intricacy of the item powers the creation of the last item in parts. Auxiliary preparing manages machining, penetrating and joining of the parts created by essential handling/fabricating. The traditional optional assembling forms incorporate boring, edge cutting, molding and glue joining and mechanical attaching while nonconventional forms incorporate Electric Release Machining (EDM), Electro Substance Release Machining (ECDM), Water Fly Machining (WJM), Grating Plane Machining (AJT), Ultrasonic Machining (USM) and Microwave Joining (MWJ).

1.8 APPLICATIONS OF NATURAL FIBERS[22]

The uses of normal fiber based composites are broadly spread across different ventures. Numerous analysts have uncovered broad uses of the common strands in different ventures, for example, development, car, bundling, protection and electric enterprises. American market is brimming with wood thermoplastic composites. Numerous specialists have been accounted for some uses of the common fiber composites, for example, indoor and outside furnishings, dividers, deck and louvers.

- Weight decrease of 10 to 30%.
- Worthy mechanical properties.
- Good preparing properties, for example, low wear on instruments.
- Alternatives for new creation innovations and materials.
- Good mishap execution, high dependability, less fragmenting.
- Ideal proportionality for part creation.
- Good equality during vehicle activity because of weight reserve funds.
- Progressively word related medical advantages when contrasted with glass strands during creation.
- Lowest cost.

Further, there are many reasons to accept the natural fiber applications, in the automotive sector industry (Table 1.5). More specifically Karus et al., 2000 have reported the list of parts fabricated by using natural fiber composites in automotive industry.

Table1.5. Use of natural fibers in automobiles

Organization	Applications
Audi, BMW, Chrysler, Ford, Opel, Rover, Saab, Volkswagen	Seat back, Side and back, Door panel, Boot lining, Hat rack, Tire lining, Door panels, Headliner panel, Dashboard, Business table, Pillar cover, B-pillar, Insulation, Rear storage shelf/panel.

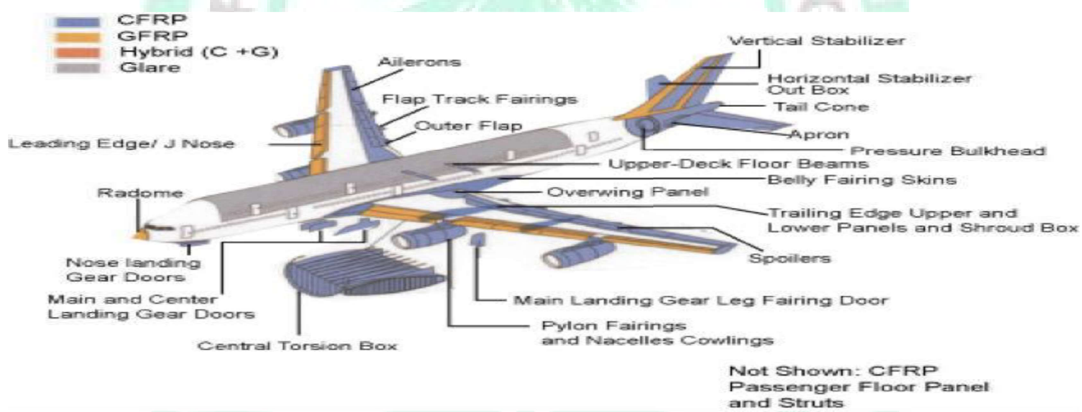

Fig1.17. Airplane parts made from natural fiber composites.

Fig 1.18 Application of natural fibers composite in cars

1.9 NEED TO DEVELOP NEW COMPOSITE USING NATURAL FIBERS

Common strands which are agro-squander and effectively accessible in plenitude, affordable, light weighted, condition inviting and solid. The disservice is that they are biodegradable, poor surface attachment, non-uniform in size and their utilization with engineered filaments which prompts decrease of some mechanical properties. Then again the utilization of regular fillers prompts lesser measure of expensive pitch and fiber utilized and subsequently helps in cost decrease and may prompt increment of certain mechanical properties[23]. The planners can utilize regular fillers so as to decrease cost for creating FRPP composites appropriate for specific circumstances.

So this energizes the utilization of biodegradable wood dust powder-squander as regular filler in the composite and same lattice it will get Composite. In view of this, sheesham wood normal biodegradable fillers have been chosen and polypropylene utilized as grid material for the composite.

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CHAPTER 2

LITERATURE REVIEW

The literature review is carried out as a part of thesis work to have an overview of the properties of natural fiber composite. Since last four decades, the synthetic fiber composites have been used in industry. In the past few years, it has been seen that natural fiber is used due to lower cost and easily availability. A number of research studies have been carried out; significant improvements in fiber properties have been reported and the feasibility of the fiber is well established. However many more issues need to be addressed before the natural fiber can formally accepted by the industry.

2.1 CURRENT RESEARCH STATUS OF COMPOSITE

The available literature on natural fiber composites has been summarized as below.

1. **Dr. Devendrappa et al[24]**: In this paper they had taken wood powder as natural fiber and PP as base material and preparing different composite by varying fiber weight percentage from 10% to 40%. On testing the result shows that the tensile strength of the composite was maximum at 10% fiber loading. On increasing fiber loading the tensile property of the composite start decreasing.

2. **Idrus et al[25]:** They had taken different fiber loading percentage (10%,15%,20%,25%,30% by weight) with base material as PP. After mechanical testing, it was found that the properties like Flexural strength, Modulus of composite, Hardness, Water absorption increases with the increase in fiber loading.

3. **Prachayawarakorn et al[26]:** Concludes that the Tensile property, Flexural property and Impact strength of the composite is higher when the aspect ratio (i.e L/D ratio) is higher. On varying fiber loading , the young’s modulus of the compsite increases with the increase in fiber loading whereas Impact property of the composite does not influenced by fiber loading.

4. **Khan et al[27]:** Found that the Tensile strength of the composite was maximum at 10% fiber loading. On increasing the fiber percentage the tensile strength decreases.

5. **Lette et al[28]:** Compares the property of the composite made from the combination of saw dust with phenolic resisns and Rice husk with Phenolic Resins. It was found that both the component are thermally unstable. The tensile strength of the composite containing sawdust was more than the composite containg rice husk whereas the rice husk composite shows better water repulsion property.

6. **Nair et al[29]:** Tested the mechanical property of the Epoxy based sawdust composite , it was found that the tensile strength of the composite drops with the increase in filler loading but the Hardness value is improved with the increase in filler percentage.

7. **Vignesh et al[30]:** Mixes the sawdust ash and PP in clay soil to stabilize the soil . On testing the soil it was found that the compressive strength of the soil increases at 15% of polypropylene and 15% of sawdust ash, Cohesion property is also enhanced at this fiber composition.

8. **Ranjan et al[31]:** Compounded the PP with the Wood flour at different fiber loading (10%,20%,30%,40%,50%) and concludes that the Tensile strength of the composite was maximum at 10% fiber loading. Flexural strength and density of the composite was maximum at 50% fiber loading.

9. **Nicole Stark[32]:** The wood four is mixed with the polypropylene at two different fiber loading i.e (20%, 40%). On testing the composite it was found that the composite is absorbing water and contains high moisture because of this property, the composite strength decreases. The tensile modulus also decreases.

10. **Fakhrul et al[33]:** Studied the property of sawdust (5% wt.) when combined with Polypropylene, it was observed that the water absorption by the composite and Flexural modulus of the composite is increased.

11. **Awal et al[34]:** Combines sawdust with Concrete , on testing it was found that the water absorption and compressive strength of the composite increases but the tensile strength of the composite decreases.

12. **Tilak et al[35]:** A composite material is prepared by replacing the sand with the sawdust in a concrete mixture at different volume percentage (10%,20%,50%,100% by volume) . When tested, the result shows that the compressive strength of the composite was highest at 10% replacement; density of the composite is also maximum at 10% replacement and the density of the concrete increases with time.

13. **Ajaj and Obaidi[36]:** This study includes preparing of RPET composite filled with different weight percentage of sawdust wood (10%,20%,30%,40%,50%and 60%).Result of the test shows that the composite which having melting point of 180^{o}C having lowest wear rate value .

14. **Malathi and Kumar[37]:** The feasibility of use of wood rust and rice husk fiber in polymers composite is studied. It was found that the yield strength, yield stress, tensile strength of the composite material made with wood chips is higher than the composite made up of rice husk.

15. **Mahajan and Aher[38]:** The aim of the research is to determine whether these natural fibers composite possess the mechanical properties that would allow them to be used in same automobile interior application. The J-PP composite found to be better than that of WS-PP composite against all physic-mechanical properties.

16. **Obilade and I.O[39]:** SDA was used to replace OPC by weight from 0 to 30% in steps of 5 %. The results revealed that the compacting factor decreased as the percentage replacement of OPC with SDA increased. The compressive strength of the hardened concrete also decreased with increasing OPC replacement with SDA.

17. **Miriyam and Anju[40]:** Sawdust debris can be utilized in light weight solid that has just gotten consideration over the previous years. To reinforce the SDA cement and making it progressively strong polypropylene fiber is being included. In this paper concrete has been incompletely supplanted with SDA by its weight, for example, 2.5%, 5%, 7.5%, 10% and 12.5% in M25 grade concrete alongside polypropylene strands. Results indicated that most extreme increment in the compressive quality watched was 7.5% from both damaging and non-dangerous tests alongside 1.2% of fiber content.

18. **Ambiga and Meenakshi[41]:** Creation of strong solid 3D shapes was made by fractional supplanting of sand with a differing extent (10%, 20%,30%) of sawdust. The quality of each square was resolved to find out similarity with the base satisfactory principles. Similarly, the loads were checked and contrasted and squares without sawdust. The tests were completed on the 7 and 28 days after creation. From information accumulated, it was seen that the compressive quality declines.

19. **Behazad Kord[42]:** In this study, the water uptake of composite based polypropylene and sawdust flour with different loading of compatibilizer agent was investigated. The result indicated that the water absorption and thickness swelling of composites decreased with increase of coupling agent concentration. Also, morphological study with scanning electron microscopy (SEM) revealed that the positive effect of compatibilizing agent on interfacial bonding between sawdust flour and polymer matrix.

20. **Gil et al**[43]: SEM was utilized to describe the morphology of the composite and to discover the attachment conduct of sawdust .The outcome show that compressive quality increments with sawdust content up to 0.5%. Utilizing sawdust content bigger than 1%, produces mortars with an extreme loss of compressive quality of particularly for 3% of WSW. As per SEM results, a decent grip was started was for 0.5 and 1% of WSW and for all WSW rate utilized a beneficial outcome on the post-breaking conduct was found.

2.2 INFERENCES DRAWN OUT OF LITERATURE REVIEW

1. Many application areas such as housing, fueling, packaging, insulation, furniture, toys, etc. are cited in the literature but the application in automobiles of shisham wood powder based polymeric composites are rarely found in literature.
2. In literature review the rice husk or wood powder (sawdust) based composite products, but the studies on the characterization of shisham wood powder based polymeric composites are rarely found in literature.
3. Many researchers' studies characterization of natural fiber polymeric composites with different application but characterization of shisham wood powder based polymeric composites is rarely found in literature.
4. ANOVA technique is used in the many engineering applications to optimize the experimentation work. The studies of natural fiber polymeric composites are largely experimental and the use of statistical techniques in the composite fabrication has been limited.

****

CHAPTER 3

PROBLEM FORMULATION

3.1 PROBLEM DESCRIPTION

In the serious and eco-accommodating condition, planners and designers are continually searching for light weight, exceptionally adaptable ease, biodegradable, recyclable, just as procedure capacity materials. The composites can satisfy their prerequisites with certain confinements. Possible utilizations of these materials are in building and development for overlays, boards, entryways, material, sheet, covering, brief havens, sections, shafts, post office boxes. Another significant application is in cars for entryway boards, vehicle hood run sheets, seat pads, back rests and high temperature applications may incorporate car insides, under hood parts, electrical connectors, and microwaves. Natural fibers have gained significant attention as potential replacement for synthetic fibers to produce green composites. The advantages of natural fibers as reinforcement for polymers include low density, wide availability and biodegradability.

A critical review of literature reported reveals that the investigation of mechanical properties such as tensile strength, compressive strength, tensile modulus and toughness of different types of organic powder polypropylene composites was carried out by several researchers but the studies pertaining to shisham wood powder polypropylene using weight ratio and length, composite are limited. Therefore, it has been decided to investigate the behavior of natural fiber composites made of polypropylene matrix reinforced with shisham wood powders, due to its ability to perform well under mechanical loadings. Fabrication and characterization of natural fiber (shisham wood powder) reinforced polymer composites will be carried out to explore the possible use of industrial waste shisham wood powder (WP) as filler materials in these composites. Polypropylene (PP) polymer will be used as a matrix which provides strength to the fibers.

3.2 RESEARCH TITLE

The title for this research work is "**OPTIMISATION OF MECHANICAL PROPERTIES OF SHEESHAM WOOD NATURAL FIBER COMPOSITE".**

3.3 OBJECTIVES OF THE PRESENT WORK

Following are the objectives of the proposed study:-

- To prepare Sheesham Wood Powder Polypropylene (SWPPP) composite with polypropylene as matrix material and sheesham wood powder as a fiber.
- To prepare specimen of SWPPP composite by injection moulding.
- To characterize mechanical properties of the composite viz. tensile strength, flexural strength, hardness and toughness.
- To investigate the effect of weight percentage of wood powder on mechanical properties of SWPPPC.
- To investigate the effect of sheesham wood powder particle size on mechanical properties of SWPPPC.
- To investigate the effect of moulding pressure on mechanical properties of SWPPPC.

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CHAPTER 4

EXPERIMENTAL METHODOLOGY

4.1 STEPS OF EXPERIMENTAL METHODOLOGY

The flow chart for experimental procedure is shown in fig. 4.1.

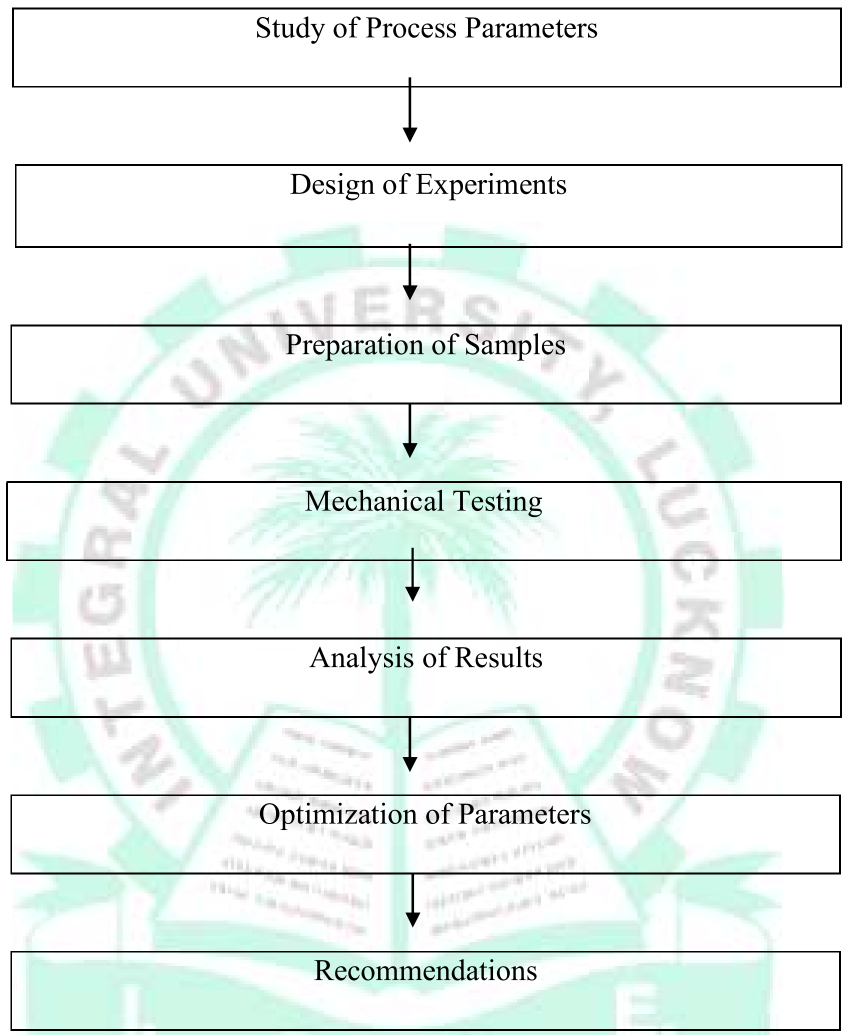

Fig. 4.1 Flow chart of experimental methodology

The present study is focused on the development and characterization of natural fiber composites with polypropylene as matrix material. The composite was produced using solid waste of wood powder (WP) by reinforcing in polypropylene matrix. The identification of these composite properties was attempted by optimizing various composite parameters, such as injection moulding pressure, fiber loading (weight percentage), and fiber size. To achieve this objective, WP fibers were treated chemically to improve the strength of fiber and to modify its surface. Composites were produced by compounding using twin extruder and the samples were fabricated by the use of the injection molding technique. This chapter describes the detail of the materials and methods used for this research work. The whole experimental work is composed of following steps.

- The initial step is the arrangement of wood powder filaments.
- The subsequent advance is endeavored to aggravating of materials.
- The third step is manufacture of composites utilizing infusion shaping strategy. The example for elasticity, flexural quality and hardness were likewise created this stage.
- The fourth step of the work is to assess the consequences of elasticity, flexural quality, sway quality and hardness for various manufactured of composites.

The one section of this examination has likewise announced the impact on mechanical properties of various chose boundaries, for example infusion shaping weight, fiber stacking, and fiber size of these PP composites utilizing the Taguchi factual technique to get the ideal arrangements of chose boundaries with the goal that nature of created composite can be upgraded. Further, microstructure of composites was additionally examined utilizing Scanning Electron Microscope (SEM).

4.2 MATERIALS USED IN PRESENT STUDY

In present study sheesham wood powder is used as fiber material and polypropylene as a matrix material.

4.2.1 Matrix Material

The matrix material is that material which provides strength to the fibers. To making the composite, different types of matrix materials are generally used, like metals, ceramics and polymer. Among these matrix materials, polymer materials are most normally used because of lowest cost efficiency, light in weight, ease of fabricating complex parts, low tooling cost and outstanding room temperature properties in comparison to ceramic and metal matrices. The main function of the matrix material is to protect the surface of fibers from unfavorable environmental effects and scratches especially throughout composite in use. Further, the matrix also provides the protection from the crack propagation and damage to the reinforcing fibers. The matrix also increases the load carrying capacity of reinforcing fillers through the proper orientation and position.

The decision models of the network materials rely upon the composite end client applications. For instance, if composite items are utilized at the compound applications with raised temperature opposition, at that point thermoset plastic grid is required. Then again if the composite material items are to be utilized in recyclable and high harm resilience then thermoplastic network are liked.

Polypropylene is a modest polymeric material that has remarkable properties like physical, mechanical, synthetic, electrical and warm properties. Other significant properties of PP are lightweight, effortlessly created, nontoxic, low dampness assimilation, liquefying temperature, superb dielectric properties, forming temperature, explicit warmth. The polypropylene is higher temperature battling material, because of this significant property, it is appropriate for some, things like plate, jugs and instrument shakes that must be usually utilized for therapeutic conditions.

Polypropylene of low density (0.9 g/cm^3) in pellet form was obtained from Bansal plastic private limited from Firozabad, Uttar Pradesh as shown in Figure 4.2.

Fig.4.2 .Polypropylene Pellets.

4.2.2. Fiber Materials

This research work employs sheesham wood powder (sawdust) as natural fibers in the polypropylene matrix to fabricate different set of composites.

Fig. 4.3 Sheesham Wood Powder.

4.3 PREPARATION OF WOOD FIBER

In the present work, sheesham wood powder, Figure 4.3 are used to fabricate the composite. Before composite fabrication, there are several treatments have been done on the fiber, separately. Among these treatments, physical treatment process methodology is shown in Figure 4.4

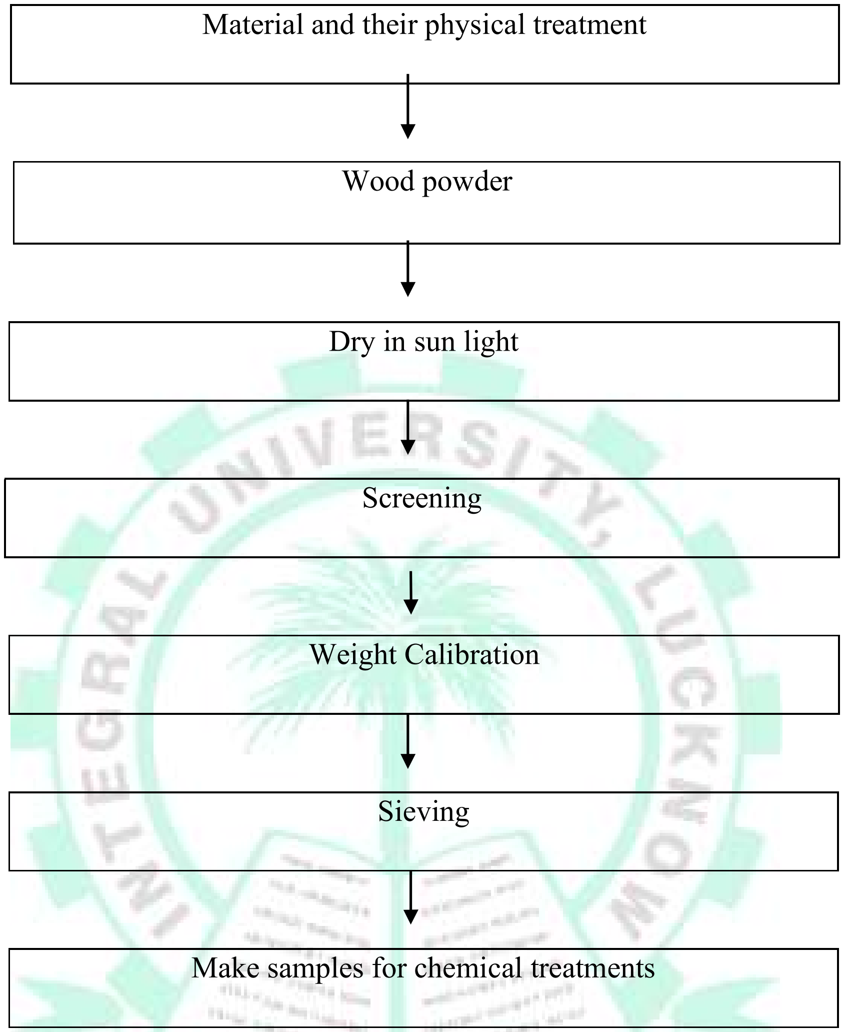

Fig. 4.4 Flow chart of Physical Treatment of Fibers.

Sheesham wood powder was collected from the local wood industry, Lucknow.

4.4 SHEESHAM WOOD POWDER (WP) OR SAWDUST

Wood powder is a sawdust of the saw plants and accessible bounteously. For this examination work sheesham tree wood powder is utilized. The logical name of the sheesham tree is Dalbergia sissoo. The sawdust is delivered from sawmill with fine molecule sizes. This kind of waste molecule size is in ranges from 20 to 5000 µm. The selected size of shisham wood powder (SWP) particle sizes are presented in Table 4.2.

Table 4.1. Natural Fiber Size Range

Size range in Micrometer (µm)	WP particle sizes range		
	1180	740	300

The above selected size of sheesham wood powder is shown in Figure 4.5, 4.6 and 4.7

Fig. 4.5. Wood Powder, Fiber 300 µm Size.

Fig. 4.6. Wood Powder Fiber 740 µm Size.

Fig. 4.7. Wood Powder Fiber 1180 µm Size.

The different sizes of SWP are obtained by Sieve Shaker as shown in Figure 4.8

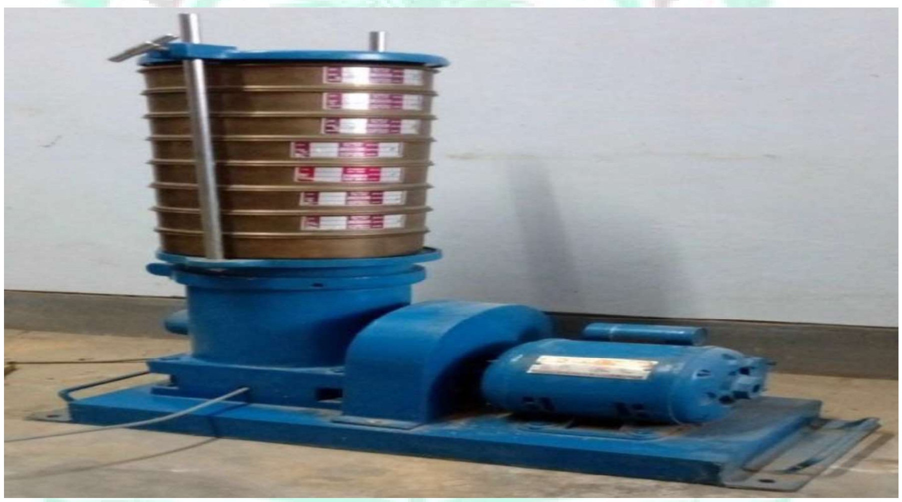

Fig 4.8. Sieve Shaker

4.5 CHEMICAL TREATMENT OF FIBERS

The invention amalgamation and surface holding of fiber are noteworthy boundary for making of trademark fiber based composites. A high estimation of surface holding among dispersoid and grid material is charming for better properties, for instance, tractable, flexural, hardness and impact properties. As such, various experts have done their investigation on the treatment of fiber to extend the holding with the system. The mechanical properties of the made composites can be overhauled by the proportion of the individual constituent and its properties and by the possibility of the interfacial locale between the lattice material and backing. Due to poor interfacial grasp ordinary fiber composites are not as a considerable amount of essentialness. Generally, the interfacial properties between the fiber and lattice are low, because of the hydrophilic thought of customary fiber. In this way, concoction alterations are important to improve the interface of strands. Treatment of wood powder was carried out by using NaOH (Sodium Hydroxide) solution. The NaOH in pellets form was obtained from the Gupta Scientific Store, Firozabad, Uttar Pradesh as shown in Figure 4.9.

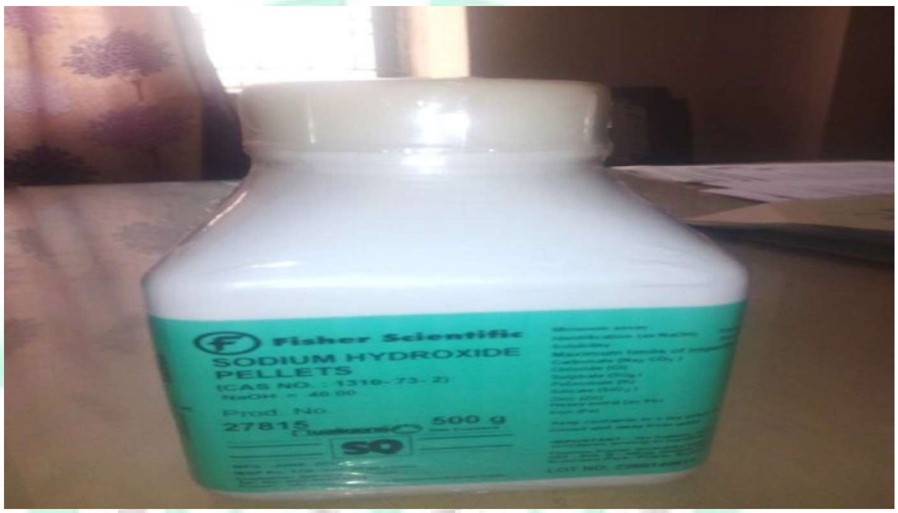

Fig. 4.9. NaOH Pellets

The NaOH pellets 900 grams were put in 15 liters water in the bucket. NaOH pellets are soluble in water and make a 6% NaOH solution as shown in Figure 4.10.

Fig. 4.10. Preparation of NaOH Pellets Solution.

To begin with, the wood powder is washed with the typical water for three-four times to evacuate dust and different materials, at that point dried in daylight at 43-45 0C four days at room temperature to expel the dampness. At that point wood powder (WP) was ground to fine powder and went through sifter shaker. .wood powder was submerged in NaOH answer for 24 hours, where the room temperature was kept up. Wood powder when drenched in this arrangement is indicated Figure 4.11. The rewarded wood powder at that point completely flushed in ordinary faucet water a few times to evacuate the overabundance NaOH, at long last washed with refined water twice. The immersed wood powder in NaOH solution is shown in Figures 4.11.

Fig. 4.11. Wood Powder Immersed in NaOH Pellets Solution.

After washing in water, the wood powder was kept in trays homogeneously for its drying in oven at 110^0C for 48 hours. The oven dried wood powder is shown in Figure 4.12.

Fig. 4.12. Oven Dried Wood Powder after Treatment.

4.6 FABRICATION OF COMPOSITES

The SWP composite are fabricated by injection moulding technique due to varying moulding pressure, weight percentage of fiber and fiber size than the optimum set fabrication of parameters are achieved by Box-Behnken.

4.6.1 Selection of optimized batch

A Box-Behnken design was adopted to optimize the formulation and an overlay plot was obtained using design expert software (Design-Expert software, version 8.0) which provides theoretical values of optimized batch. Design Parameters and Their Levels are shown in **Table 4.2**. The data responses in terms of flexural strength, tensile strength, hardness and impact strength are recorded in **Table 4.3**. The overlay plot display the values of impact strength, tensile strength, hardness, flexural strength.

4.6.2 Box-Behnken design Method

The Box-Behnken design procedure is exceptionally straightforward and monetary strategy that is utilized to take care of the trial issues. By utilizing Box-Behnken design procedure the scientists can decrease the expense and time required for leading the examinations to critical degree.

As we realize that for performing exploratory research work, examination strategies are exorbitant and tedious, along these lines, so as to get the destinations with minimal number of trials are clearly significant. In this respects the Box-Behnken design method gives a proficient and orderly methodology for test strategy to choose ideal settings of chose parameters for best execution, cost and to spare significant time. In this technique, on the premise exploratory conditions the built table has been picked referred to as symmetrical clusters as appeared. The huge number of test methodology is required when the quantities of chose parameters are expanded. Box-Behnken design method can take care of this issue effectively by the utilization of symmetrical exhibits.

The comprehensive audit uncovers that parameters, for example temperature, fiber stacking, fiber substance, molecule size, tumult speed, sway speed, mixing time, and so forth to a great extent impact the mechanical properties .Be that as it may, the investigation on the impact of trim weight, fiber stacking and fiber size on mechanical properties of polymeric composites are infrequently found in writing.

The manufacture was completed by the conditions set down in Table 4.3. The creation was led according to test configuration (number of parameters and their levels are given in Table 4.2). We have thought about the assortments of information by methods for 15 conditions. In which three conditions are same. So that we can say, there are only 13 conditions for observation. Each condition will decide by factors for example the main condition is distinguished by Injection moulding pressure (bar), fiber percentage (wt. %) and fiber size in micrometer (µm).

Table 4.2. Design Parameters and Their Levels.

Number of parameters	Selected parameters	Levels			Unit
		1	2	3	
1	Injection Moulding pressure	35	40	45	bar
2	Fiber percentage	9	18	27	Wt.%
3	Fiber size	300	740	1180	µm

Table 4.3. **Optimization of formulation variables** via Box-Behnken design**:** In this study, the four independent variables including Injection Moulding pressure, Fiber percentage, Fiber size were taken which significantly influenced the observed response for tensile strength, flexural strength, hardness and impact strength.

Table 4.3 Observed response for tensile strength, flexural strength, hardness and impact strength.

Std	Run	Factor 1 A:Injection M... Bar	Factor 2 B:Fiber perc... Wt%	Factor 3 C:Fiber size µm	Response 1 Tensile Stren... MPa	Response 2 Flexural Stre... MPa	Response 3 Hardness SHD	Response 4 Impact Stren... J/m
8	1	45.00	18.00	1180.00	27.62	50.11	82	11.56
2	2	45.00	9.00	740.00	24.33	48.87	81	8.85
6	3	45.00	18.00	300.00	24.65	50.34	82	8.34
11	4	40.00	9.00	1180.00	25.26	46.76	75	9.95
1	5	35.00	9.00	740.00	25.21	48.92	82	7.78
3	6	35.00	27.00	740.00	24.55	47.26	75	10.23
13	7	40.00	18.00	740.00	26.75	45.67	82	11.3
9	8	40.00	9.00	300.00	25.22	47.12	81	7.97
7	9	35.00	18.00	1180.00	24.86	48.98	76	10.45
10	10	40.00	27.00	300.00	24.26	44.32	82	8.83
4	11	45.00	27.00	740.00	24.28	50.58	77	9.3
12	12	40.00	27.00	1180.00	24.51	44.88	75	9.48
5	13	35.00	18.00	300.00	26.51	44.25	81	8.18
14	14	40.00	18.00	740.00	26.68	45.55	81	11.35
15	15	40.00	18.00	740.00	26.71	45.34	81	11.27

4.7 PREPARATION OF BATCHES FOR EXTRUSION PROCESS

Before material entering in the twin screw extruder for intensifying of materials, one–one kg material clumps are set up as per the Table 4.4. The loads of each clump material were aligned by weighting machine in the adjustment research facility at Central Institute for Plastic Engineering and Technology (CIPET), Lucknow, Uttar Pradesh. The readied material examples were pressed in the plastic packs in the wake of stamping with indelible marker.

After the weight adjustment of the considerable number of clumps, they are blended independently with the assistance of the stick in a plastic basin. The blended cluster is appeared in Figure 4.13. During blending of clumps, 1% by weight silane, coupling specialist S-69 is included the blend for good holding of fiber in polypropylene grid. Presently the bunch material is prepared to expel. The silane (Figure 4.13) was purchased from Mahaveer chemical private limited, New Delhi.

Fig. 4.13. Silane Coupling Agent (S-69).

4.8 EXTRUSION PROCESS

In this examination work, the twin extruder was utilized for exacerbating (blending) the strands and polypropylene. For aggravating the composites Siemens Ltd extruder, model Simatic HMI was utilized. Prior to aggravating of the composites, it is important to expel residue and cleaning of the extruder barrel. The twin extruder is appeared in Figure 4.14.

Fig. 4.14 Twin Extruder

Table 4.4 Twin Screw Extruder Operating Conditions

PARAMETERS	VALUES
Melting pressure(Bar)	30
Temperature (^{0}C)	30
Screw rotation speed (RPM)	50
Screw temperature (^{0}C)	170,180,190,200,210

Prior to beginning the intensifying of composite, it is important to clean the extruder barrel a short time later unadulterated polypropylene was poured in the extruder container at that point pouring the clusters of filaments in the container by little measuring glass for aggravating as appeared in Figure 4.15.

Fig. 4.15 Compounding of the Fiber and Polypropylene.

After the compounding of all the batches, these were cut separately in small pieces Figure 4.16 with the help of a cutter.

Fig. 4.16 Compounding Material pellets after Cutting by the Cutter.

In the wake of aggravating the material will goes through the water shower which is introduced on the extruder for cooling and to makes it straight. During the cooling procedure, the filaments ingested water, so all groups are dried at 110 0 C in the stove for 12 hours to evacuate dampness as appeared in Figure 4.17. Subsequent to drying of material in the stove, it is gathered in plastic sacks to forestall dampness.

Fig. 4.17 Compounding Material Drying in Oven.

4.9 SAMPLES PREPARATION

Infusion shaping machine (Electronica 70-90 ton machine model number 1656) Electronica Plastic Machine Ltd, Pune, India, was utilized for the example arrangement as appeared in Figure 4.18. The infusion shaping method gives a decent possibility of creating tests of filler and grid. This strategy can be effectively use for creating parts of both thermoset plastic and thermoplastic materials .The dried material clumps are independently taken care of into an infusion forming machine through a container for example readiness individually. Taking care of bunches happens with the assistance of power into an addition form hole where it chills off and solidified to the state of the shape. Examples of composites created by Injection forming machine, are appeared in Figures 4.19 - 4.21.

Fig. 4.18 Electronica Injection Moulding Machine.

Operating parameter of the injection molding machine shown in Table 4.5.

Table 4.5 Injection Moulding Conditions.

Screw rotation speed(RPM)	40
Cycle time(S)	30
Nozzle temperature range(^{0}C)	149,180,190,200,210
Mould temperature(^{0}C)	50

Trim temperature scopes of the infusion chamber are 149, 180, 190, 200 and 210, these range are discovered ideal in the back, center, front, and spout zones, individually.

The form temperature is 500C. Process duration for infusion is 30 second. At the overheating temperature, the polypropylene can be vanishing so it is important to keep up temperature beneath 2500C.

Fig. 4.19. Flexural Insert Mould.

Fig. 4.20. Hardness Insert Mould.

Fig. 4.21 Tensile Insert Mould.

4.10 MECHANICAL CHARACTERIZATION OF COMPOSITES

The diverse test was created for finding elasticity and ductile modulus, flexural quality and flexural modulus, sway quality and hardness according to ASTM gauges.

4.10.1 Matrix Tensile Test (ASTM D638)

The Tensile specimen tests with measurement 68.2 × 12.70 ×3.18 mm3 were created from the infusion shaping machine. The tractable tests were done according to the standard ASTM D 638. All analyses were performed at encompassing conditions and three examples are tried for every composite. In this examination work, the elastic test was done in the all inclusive testing machine Instron USA 3382 (as appeared in Figure 4.23) at the jaw crosshead speed of 50 mm/min and the outcomes are utilized to compute the rigidity and tractable modulus of lattice tests. Here, the example tests are rehashed multiple times on every grid and the mean worth is accounted for as the rigidity and elastic modulus of the network.

4.10.2 Tensile Strength of Developed Composites (ASTM D638)

The Tensile specimens with measurement 68.2 × 12.70 ×3.18 mm^3 are acquired from the infusion forming machine. The pliable trial of various created composites were completed in the agreement with the standard ASTM D638 utilizing a standard material testing framework with cross head speed 50 mm/min. In this examination work, this test is acted in the widespread testing machine Instron USA 3382. The outcomes are utilized to examine the rigidity and tractable modulus of the composite examples. Here, the example tests are rehashed multiple times on each created composite sort and mean qualities is accounted for as the rigidity and tractable modulus of that composite. The perspective on the composite example for pliable test and pliable stacking game plan is appeared in Figure 4.22, Fig 4.23 and Figure 4.24 separately.

Fig. 4.22 Universal Testing Machine Instron 3382 USA

Fig. 4.23. Tensile Test Specimen Before and After Testing.

Fig.4.24. Loading Arrangement for Tensile Tests.

4.10.3 Flexural Strength (ASTM D790)

The flexural example tests with measurement 50 × 12.40 × 3.30 mm3 were created by utilizing the infusion shaping machine. The flexural tests are acted in the understanding with the ASTM D790 utilizing a standard material testing framework with cross head speed 1.50 mm/min. The flexural properties of the created composites are determined in three point twisting tests. The composite example when testing for flexural testing and stacking course of action is appeared in the Figure 4.25.and 4.26. individually. Here the example tests are repeating multiple times for every composite definition and the midpoints esteems were accounted for as results.

Fig 4.25. Flexural Sample before Testing and After Testing

Fig. 4.26. Loading Arrangements for the Flexural Test.

4.10.4 Impact Strength (ASTM D256)

The effect tests examples were set up as per the standard ASTM D256. All the effect test examples were tried utilizing the Izod sway analyzer. Above all else, an indent (2.5 mm) at 450 point was cut by the manual step shaper as appeared in Figure 4.28. The testing device was pendulum sway testing machine Tinius Olsen, Model Impact 104 (as appeared in Figure 4.27). The effect test examples are appeared in Figure 4.29. The individual estimations of effect vitality of various examples are recorded straightforwardly from electronic board when the effect vitality hammer does pounding activity on the examples. Here the test is rehashed multiple times for grid and every composite kind and the normal worth is accounted for. Table 4.6 shows the Izod sway analyzer and Notch shaper model and name of manufacturer.

Table 4.6 Izod impact tester and Notch cutter model and manufacturer

Sr.No.	Name of machine	Model	Name Manufacturer
1	Izod Impact Tester	Model Impact 104	Tinius Olsen,USA
2.	Notch Cutter	TYPE 6530	CEAST,Tornino, Italy

Fig. 4.27 Izod Impact Tester.

Fig. 4.28. Notch cutter. **Fig. 4.29. Impact Sample after Testing.**

4.10.5 Hardness (ASTM D2240)

The hardness testing examples were formed from the infusion shaping machine. In the current work, the hardness properties are estimated utilizing a Durometer Shore D, DIN 53505 model hardness analyzer (Figure 4.30). The ASTM standard test technique for estimating the hardness properties of fiber sap composite ASTM D2240. The particular estimations of the hardness of various examples are noted straightforwardly from the dial pointer. The each assessment is rehashed multiple times on the lattice and every composite kind and the normal worth is accounted for as the hardness of that composite. The hardness testing examples are appeared in Figure 4.31.

Fig. 4.30. Shore D Hardness Tester.

Fig. 4.31. Hardness Test Specimens.

The results of mechanical properties for pure Polypropylene (PP) are presented in Table 4.7.

Table 4.7 Results of Mechanical Properties of Polypropylene (PP)

Material	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J/m)	Hardness ShoreD
PP	23.15	43.21	13.9	73

4.11 RESULTS AND DISCUSSION

Based on the data obtained from experimentation, testing and evaluation, we will be able to analyze the result.

****

CHAPTER 5

RESULTS AND DISCUSSION/ CONCLUSION

This chapter discusses the results obtained from the experiments that were carried out for developing the Sheesham Wood fiber reinforced composites using injection moulding method. After developing of composites, mechanical testing was done and results were analyzed. The experimental results obtained are analysed and discussed in the following sections.

5.1. MECHANICAL OPTIMISATION & CHARACTERIZATION OF COMPOSITES

Mechanical properties of Sheesham wood polypropylene composite were investigated and the results are shown as below.

Table 5.1 Investigated Mechanical properties of Sheesham wood polypropylene composite

Std	Run	Factor 1 A:Injection M... Bar	Factor 2 B:Fiber perc... Wt%	Factor 3 C:Fiber size µm	Response 1 Tensile Stren... MPa	Response 2 Flexural Stre... MPa	Response 3 Hardness SHD	Response 4 Impact Stren... J/m
8	1	45.00	18.00	1180.00	27.62	50.11	82	11.56
2	2	45.00	9.00	740.00	24.33	48.87	81	8.85
6	3	45.00	18.00	300.00	24.65	50.34	82	8.34
11	4	40.00	9.00	1180.00	25.26	46.76	75	9.95
1	5	35.00	9.00	740.00	25.21	48.92	82	7.78
3	6	35.00	27.00	740.00	24.55	47.26	75	10.23
13	7	40.00	18.00	740.00	26.75	45.67	82	11.3
9	8	40.00	9.00	300.00	25.22	47.12	81	7.97
7	9	35.00	18.00	1180.00	24.86	48.98	76	10.45
10	10	40.00	27.00	300.00	24.26	44.32	82	8.83
4	11	45.00	27.00	740.00	24.28	50.58	77	9.3
12	12	40.00	27.00	1180.00	24.51	44.88	75	9.48
5	13	35.00	18.00	300.00	26.51	44.25	81	8.18
14	14	40.00	18.00	740.00	26.68	45.55	81	11.35
15	15	40.00	18.00	740.00	26.71	45.34	81	11.27

5.1.1. Tensile Properties Of Composites

The results of Tensile strength of developed composites from Table 5.1 are given in Table 5.2.

Table5.2 .Tensile Properties Results

Exp. No.	A	B	C	Tensile Strength (MPa)
1	3	2	3	27.62
2	3	1	2	24.33
3	3	2	1	24.65
4	2	1	3	25.26
5	1	1	2	25.21
6	1	3	2	24.55
7	2	2	2	26.75
8	2	1	1	25.22
9	1	2	3	24.86
10	2	3	1	24.26
11	3	3	2	24.28
12	2	3	3	24.51
13	1	2	1	26.51

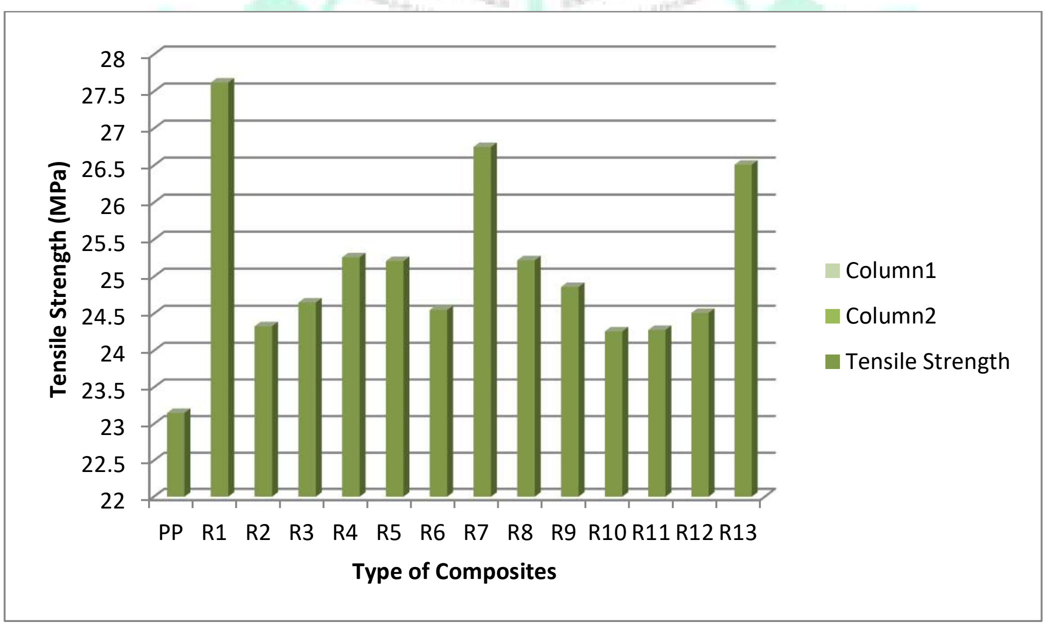

Fig 5.1 Tensile Strength of Developed Composites

It has been observed that the tensile strength of R1-R13 composites lie in the range 24.26 – 27.62 MPa All variations in the values are depends upon composites formulations according to design methodology.

The variation in tensile strength of developed composites, R1-R13 wood powder polypropylene composites with different moulding pressure is presented in Figure 5.1.

It has been observed that around maximum 19% improvement in the tensile strength of SWPPP composite takes place by the adding of 18% wt% of wood powder as compared to pure polypropylene. However, in respect of 27 wt% of the reinforcing materials, the tensile strengths of wood powder polypropylene composites are found to decrease as the filler increased. With the variation of filler loading in the increasing order, the tensile strength . It is maximum at 45 bar injection moulding pressure, 18% fiber and 1180 μm fiber size.

This decline in the tensile strength may be due to the occurrence of pores or holes at the bonding face between the fillers and the matrix.The bonding between fillers and matrix may be too poor to transmit the tensile strength.

5.1.2 Flexural Properties of Composites

The flexural quality is identified with twisting of materials. On the off chance that a composite material fizzles in twisting, the advancement of the new composite material is basic to improve the flexural properties. The variations of the flexural properties and hardness and impact strength of different composites are seen in Table5.1 & Table5.3.

Table 5.3. Flexural Properties, Hardness and Impact Strength of Composites

Ex. No.	A	B	C	Flexural Strength (MPa)	Hardness (SHD)	Impact Strength (J/m)
1	3	2	3	50.11	82	11.56
2	3	1	2	48.87	81	8.85
3	3	2	1	50.34	82	8.34
4	2	1	3	46.76	75	9.95
5	1	1	2	48.92	82	7.78
6	1	3	2	47.26	75	10.23
7	2	2	2	45.67	82	11.30
8	2	1	1	47.12	81	7.97
9	1	2	3	48.98	76	10.45
10	2	3	1	44.32	82	8.83
11	3	3	2	50.58	77	9.3
12	2	3	3	44.88	75	9.48
13	1	2	1	44.25	81	8.18

The trend of flexural strength of all developed SWPPP composites are shown in Figure 5.2.

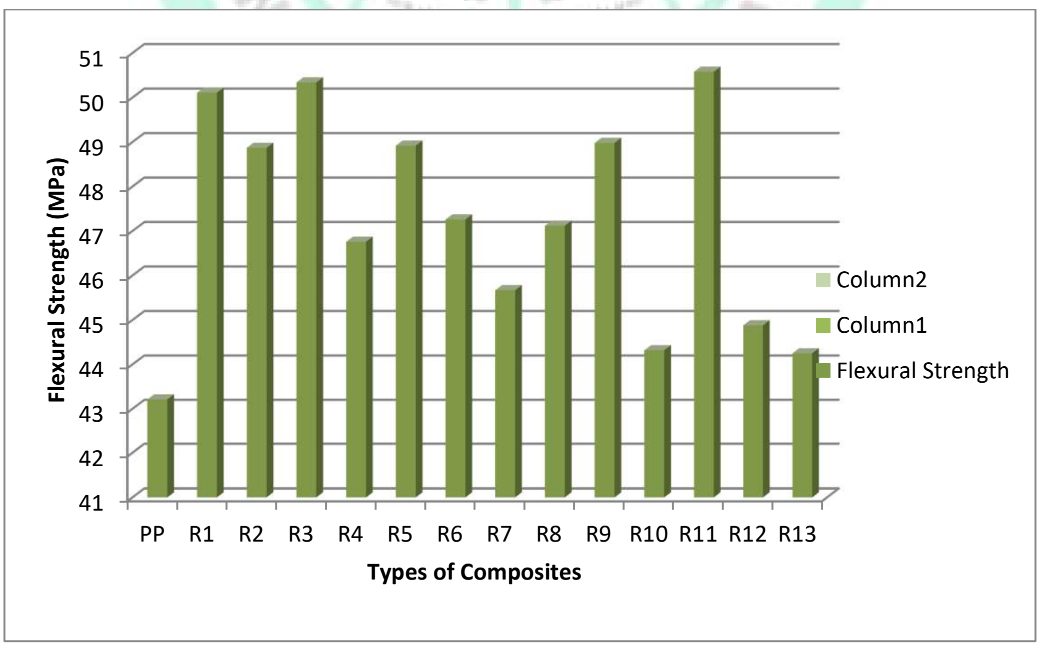

Fig. 5.2 .Flexural Strength of Composites

From the Table 5.3, it is seen that the scope of the flexural quality of R1-R13 composites lies between 44.25–50.58 MPa. The flexural quality of the R1-R13 wood powder polypropylene composites expanded up to the expansion of 18 wt% of fiber substance. Be that as it may, further expanded up to 27 wt% of fiber prompts decline in the flexural quality. It was discovered that the most elevated flexural quality is seen with 45 bar pressure, 27 weight level of fiber and 740 µm fiber size. The further increment in fiber stacking in the composite prompts decline in the flexural quality. The helpless holding among fillers and polypropylene grid might be the motivation to diminish the flexural quality.

In contrast with the flexural quality of created composites to polypropylene, some improvement in the flexural quality has been watched. In regard of fiber size, it is uncovered that the flexural quality is improved with expanded the fiber size.

5.1.3 Impact Strength of Composites

The impact strength is the capability of a material to soak up and dissipate energies under the shock or impact loading. The difference in the values of impact strength measured under this investigation of all developed composites and pure polypropylene are presented in Figure 5.3.

The experimental values of the impact strength of different developed composites are also presented in the Table 5.1 & 5.3. The Figure 5.3 shows the variation of measured values of the impact strength.

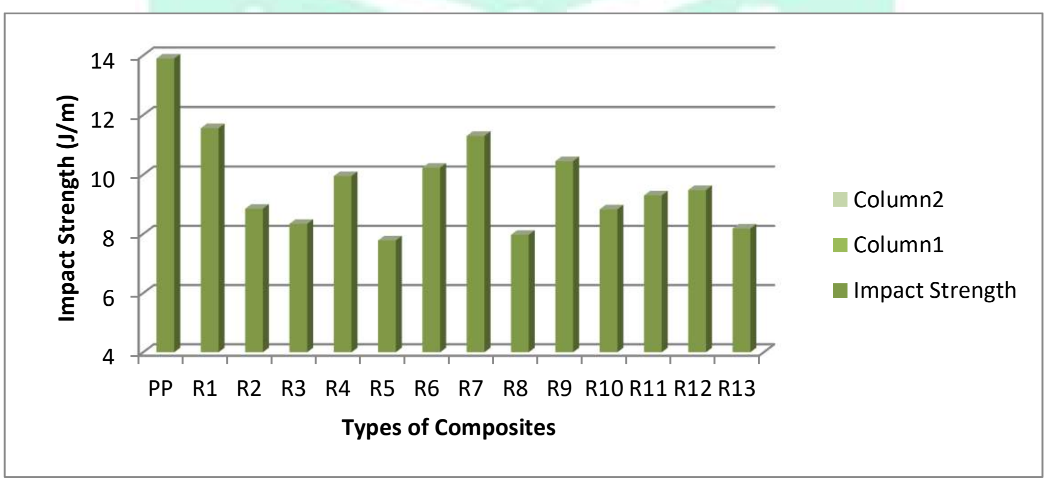

Fig. 5.3. Impact Strength of Developed Composite

It is observed that the impact strength of pure polypropylene (PP) matrix is very highest as compared to all developed composites. From the figure 5.3, it is observed that the impact strength of wood powder-polypropylene R1-R13 composites increased up to the 18 wt% of fiber loading and then decreased when fiber loading increased up to 27 wt%. The obtained value of polypropylene impact strength is 13.9 J/m. It can be observed from the Table 5.3 that the impact strength of WPPP composites lies in the range of 7.78 to 11.56 J/m. It is also observed that the impact strength of wood powder- polypropylene composites with 18 wt. % is very close to the value observed for polypropylene. It is clearly noticed that the R5 composite have lower impact strength than other developed composites. The most elevated impact strength is seen with 45 bar pressure, 18 weight level of fiber and 1180 µm fiber size.

5.1.4 Hardness of Composites

Hardness is the resistance offered by a material towards indentation cutting or scratching. Hardness is a very important property of the material to govern the wear resistance. Variation of hardness properties of the different composites with the variation of the fiber weight percentage is shown in Figure 5.4. It is observed that pure PP matrix has a very lowest hardness as compared to all developed composites in this present work. It is seen that the hardness of wood powder-polypropylene composite improved up 18 wt% of fiber content addition and thereafter decreased. However, It is also seen that the hardness of R10 composite improved with 27 wt% of fiber.

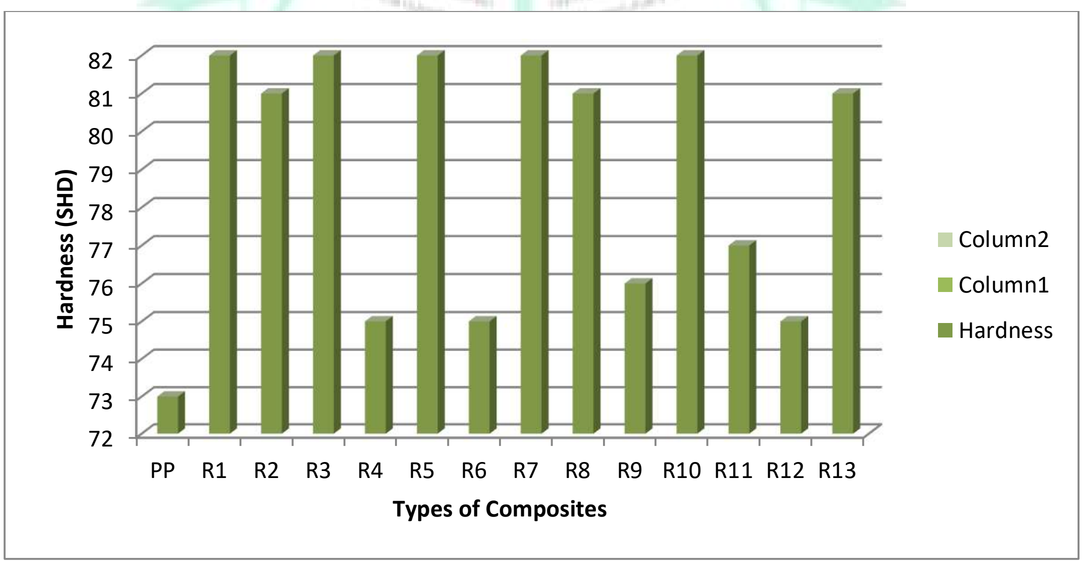

Fig. 5.4. Hardness of developed Composite

5.2 DESIGN OF EXPERIMENTS

A Box-Behnken design was adopted to optimize the formulation and an overlay plot was obtained using design expert software (Design-Expert software, version 8.0) which provides theoretical values of optimized batch, as shown in **Table5.10**. Design Parameters and Their Levels are shown in **Table 5.4**. The data responses in terms of flexural strength, tensile strength, hardness and impact strength are recorded in **Table 5.5**. The overlay plot displayed the values of impact strength, tensile strength, hardness, flexural strength those are 11.3067, 26.713, 79.533, 45.52**(Figure 5.8).** The results of optimized batch were in good alignment with the predicted values as depicted from overlay plot as shown in Table 5.10.

Table 5.4 Design Parameters and Their Levels.

Number of parameters	Selected parameters	Levels			Unit
		1	2	3	
1	Injection Moulding pressure	35	40	45	bar
2	Fiber percentage	9	18	27	Wt.%
3	Fiber size	300	740	1180	µm

5.2.1 Optimization of formulation variables via Box-Behnken design: In this study, the three independent variables including Injection Moulding pressure, Fiber percentage, Fiber size were taken which significantly influenced the observed response for tensile strength, flexural strength, hardness and impact strength **Table 5.1**.

5.3. TENSILE PROPERTIES ANALYSIS GRAPH

Final Equation in Terms of Actual Factors for Tensile Strength:

Tensile Strength =

+5.37814

+1.18158 * Injection Moulding pressure

+0.53621 * Fiber percentage

-0.018552 * Fiber size

+3.38889E-003 * Injection Moulding pressure * Fiber percentage

+5.25000E-004 * Injection Moulding pressure * Fiber size

+1.32576E-005 * Fiber percentage * Fiber size

-0.020467 * Injection Moulding pressure^2

-0.019866 * Fiber percentage^2

-1.50654E-006 * Fiber size^2

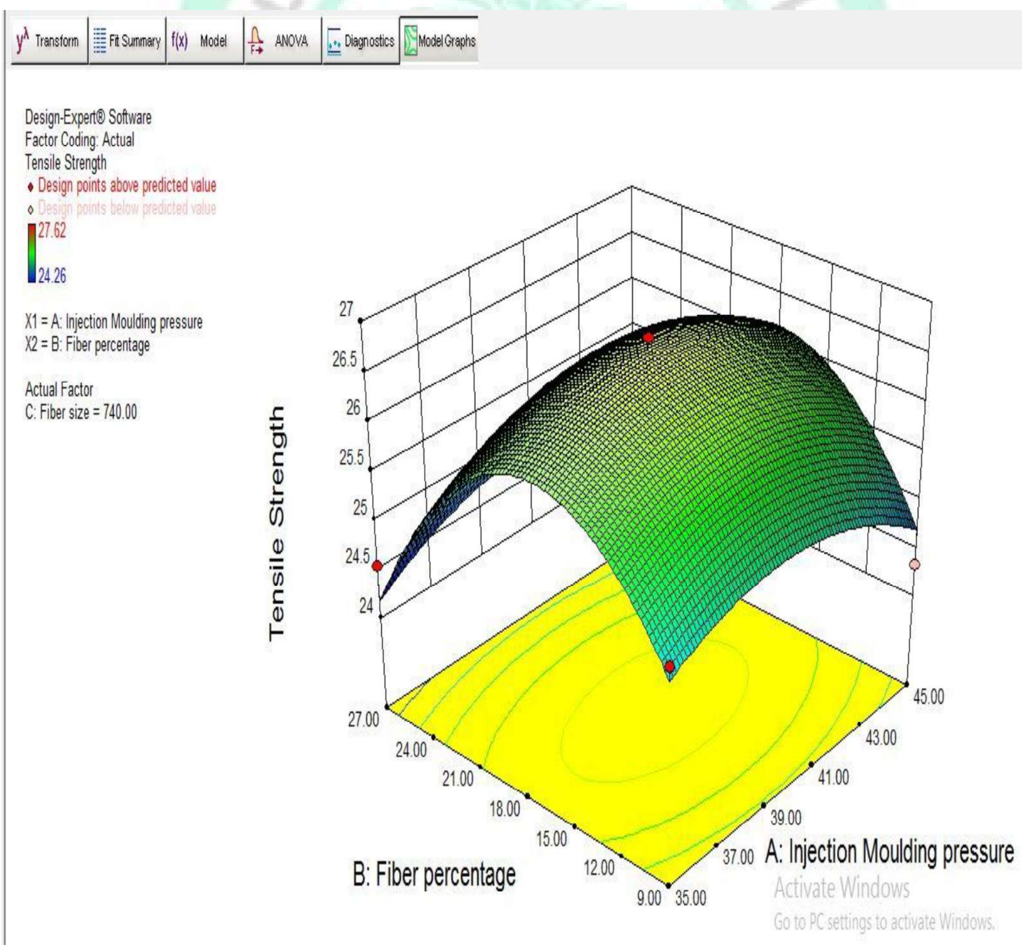

Fig 5.5 Response curve for tensile strength

5.3.1 ANOVA and Significance of Parameters on Tensile Strength

Non significant parameters and significant process parameter for tensile strength are given in ANOVA Tables 5.6. The last column of the table indicates the importance of the selected parameters on the performance of results. Less than 5 percent of p values show the highly significant p value.

Table 5.6 ANOVA table for Tensile strength.

yλ Transform | Fit Summary | f(x) Model | ANOVA | Diagnostics | Model Graphs

Use your mouse to right click on individual cells for definitions.

Response 1 Tensile Strength

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	16.70	9	1.86	11.81	0.0071	significant
A-Injection M	7.813E-003	1	7.813E-003	0.050	0.8323	
B-Fiber perc	0.73	1	0.73	4.66	0.0833	
C-Fiber size	0.32	1	0.32	2.06	0.2104	
AB	0.093	1	0.093	0.59	0.4763	
AC	5.34	1	5.34	33.97	0.0021	
BC	0.011	1	0.011	0.070	0.8016	
A^2	0.97	1	0.97	6.15	0.0558	
B^2	9.56	1	9.56	60.87	0.0006	
C^2	0.31	1	0.31	2.00	0.2165	
Residual	0.79	5	0.16			
Lack of Fit	0.78	3	0.26	211.60	0.0047	significant
Pure Error	2.467E-003	2	1.233E-003			
Cor Total	17.48	14				

.

5.4. FLEXURAL PROPERTIES ANALYSIS GRAPH

Final Equation in Terms of Actual Factors for flexural strength:

Flexural Strength =

+227.10855

-9.31766 *Injection Moulding pressure

-1.02006 * Fiber percentage

+0.023743 * Fiber size

+0.018722 * Injection Moulding pressure * Fiber percentage

-5.63636E-004* Injection Moulding pressure * Fiber size

+5.80808E-005* Fiber percentage * Fiber size

+0.12075 * Injection Moulding pressure^2

+4.55247E-003* Fiber percentage^2

-6.13378E-007* Fiber size^2

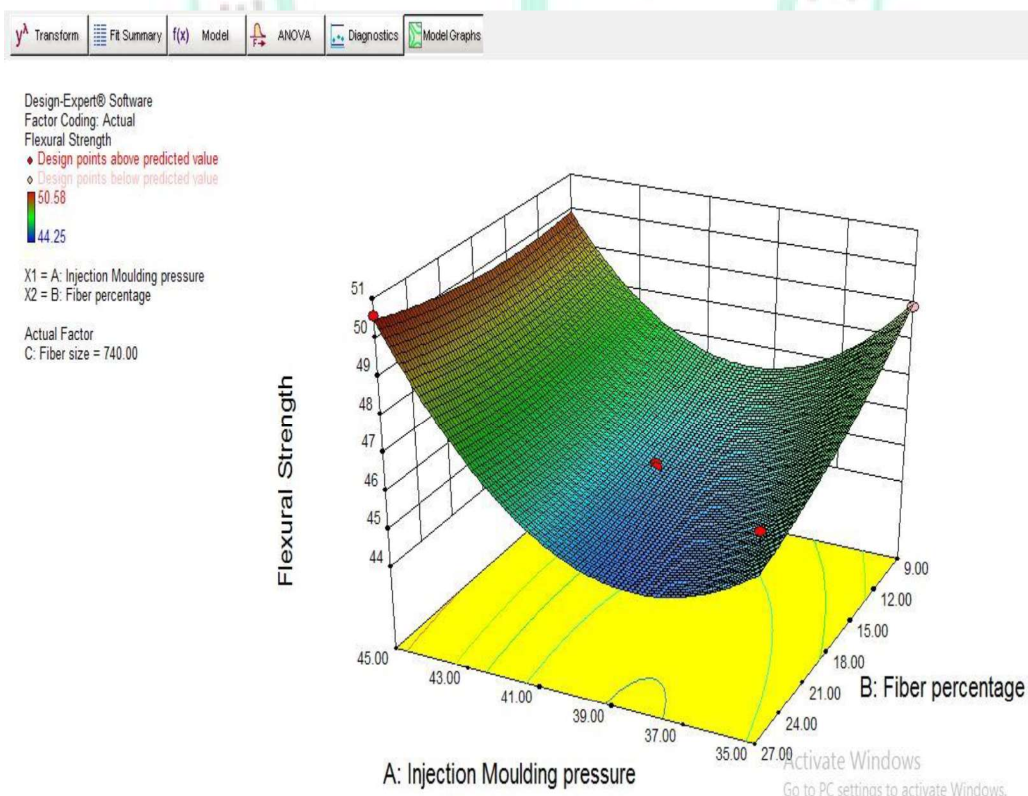

Fig 5.6 Response curve for flexural strength

5.4.1 ANOVA and Significance of Parameters on flexural Strength

. The last column of the table indicates the importance of the selected parameters on the performance of results. Less than 5 percent of p values show the highly significant p value.

Table 5.7. ANOVA for Flexural Strength

Transform | Fit Summary | f(x) Model | ANOVA | Diagnostics | Model Graphs

Use your mouse to right click on individual cells for definitions.

Response 2 Flexural Strength

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	62.60	9	6.96	4.89	0.0477	significant
A-Injection M	13.76	1	13.76	9.67	0.0266	
B-Fiber perc	2.68	1	2.68	1.88	0.2283	
C-Fiber size	2.76	1	2.76	1.94	0.2224	
AB	2.84	1	2.84	2.00	0.2169	
AC	6.15	1	6.15	4.32	0.0922	
BC	0.21	1	0.21	0.15	0.7156	
A^2	33.65	1	33.65	23.65	0.0046	
B^2	0.50	1	0.50	0.35	0.5783	
C^2	0.052	1	0.052	0.037	0.8558	
Residual	7.11	5	1.42			
Lack of Fit	7.06	3	2.35	84.33	0.0117	significant
Pure Error	0.056	2	0.028			
Cor Total	69.71	14				

5.5. HARDNESS PROPERTIES ANALYSIS GRAPH

Final Equation in Terms of Actual Factors for Hardness:

Hardness =	
+77.81742	
+0.20000	* Injection Moulding pressure
-0.13889	* Fiber percentage
-5.11364E-003	* Fiber size

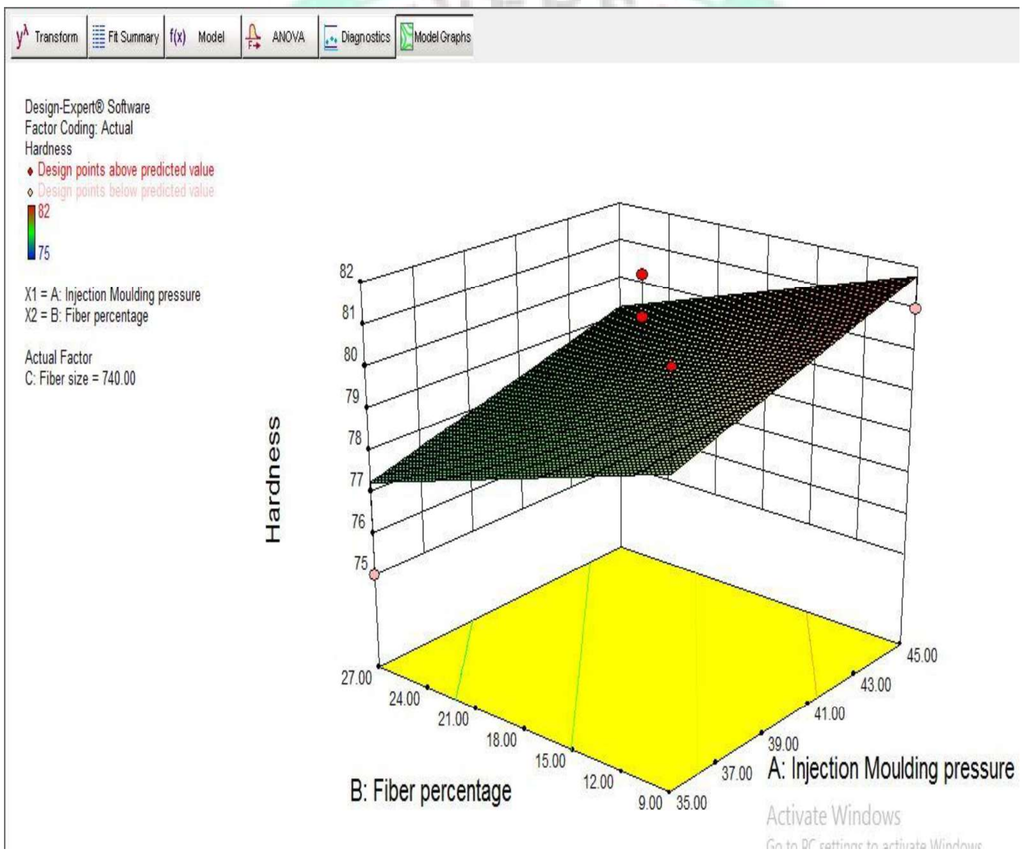

Fig 5.7 Response curve for hardness

5.5.1 ANOVA and Significance of Parameters on Hardness.

The last column of the table indicates the importance of the selected parameters on the performance of results. Less than 5 percent of p values show the highly significant p value.

Table 5.8 ANOVA For Hardness

Transform | Fit Summary | Model | ANOVA | Diagnostics | Model Graphs

Use your mouse to right click on individual cells for definitions.

Response 3 Hardness

ANOVA for Response Surface Linear Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	61.00	3	20.33	3.68	0.0468	significant
A-Injection M	*8.00*	*1*	*8.00*	*1.45*	*0.2540*	
B-Fiber perc	*12.50*	*1*	*12.50*	*2.26*	*0.1606*	
C-Fiber size	*40.50*	*1*	*40.50*	*7.34*	*0.0203*	
Residual	60.73	11	5.52			
Lack of Fit	*60.07*	*9*	*6.67*	*20.02*	*0.0485*	*significant*
Pure Error	*0.67*	*2*	*0.33*			
Cor Total	121.73	14				

5.6. IMPACT PROPERTIES ANALYSIS GRAPH

Final Equation in Terms of Actual Factors for impact strength:

Impact Strength =

-60.71545

+2.86203 * Injection Moulding pressure

+1.18375 * Fiber percentage

+5.83230E-003 * Fiber size

-0.011111 * Injection Moulding pressure * Fiber percentage

+1.07955E-004 * Injection Moulding pressure * Fiber size

-8.39646E-005 * Fiber percentage * Fiber size

-0.033833 * Injection Moulding pressure^2

-0.017541 * Fiber percentage^2

-4.27858E-006 * Fiber size^2

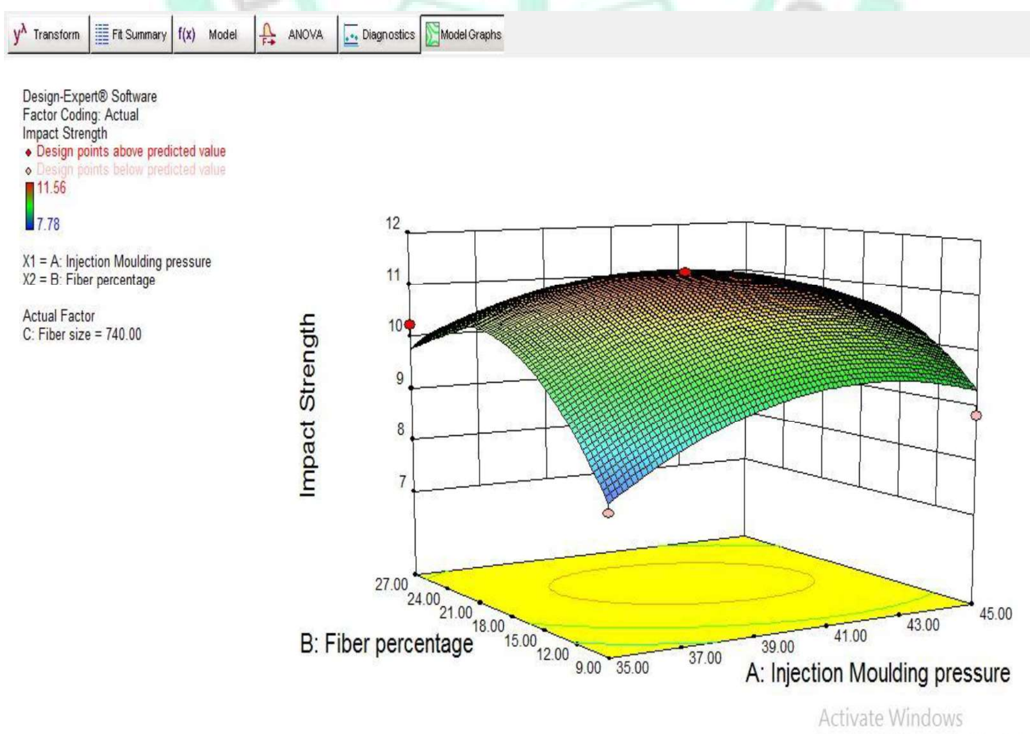

Fig 5.8 Response curve for impact strength

5.6.1 ANOVA and Significance of Parameters on impact strength.

The last column of the table indicates the importance of the selected parameters on the performance of results. Less than 5 percent of p values show the highly significant p value.

Table 5.9 ANOVA for Impact strength

Transform | Fit Summary | Model | ANOVA | Diagnostics | Model Graphs

Use your mouse to right click on individual cells for definitions.

Response 4 Impact Strength

ANOVA for Response Surface Quadratic Model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	22.64	9	2.52	6.37	0.0276	significant
A-Injection M	0.25	1	0.25	0.63	0.4634	
B-Fiber perc	1.35	1	1.35	3.43	0.1233	
C-Fiber size	8.24	1	8.24	20.89	0.0060	
AB	1.00	1	1.00	2.53	0.1723	
AC	0.23	1	0.23	0.57	0.4836	
BC	0.44	1	0.44	1.12	0.3382	
A^2	2.64	1	2.64	6.69	0.0490	
B^2	7.45	1	7.45	18.89	0.0074	
C^2	2.53	1	2.53	6.42	0.0523	
Residual	1.97	5	0.39			
Lack of Fit	1.97	3	0.66	401.95	0.0025	significant
Pure Error	3.267E-003	2	1.633E-003			
Cor Total	24.61	14				

5.7 OVERLAY PLOT- After analysis of each data the graphical method of optimization was adopted to find out the area of desired region (design space) and optimum formulation. Certain constants were applied on each dependent for purpose of optimization.

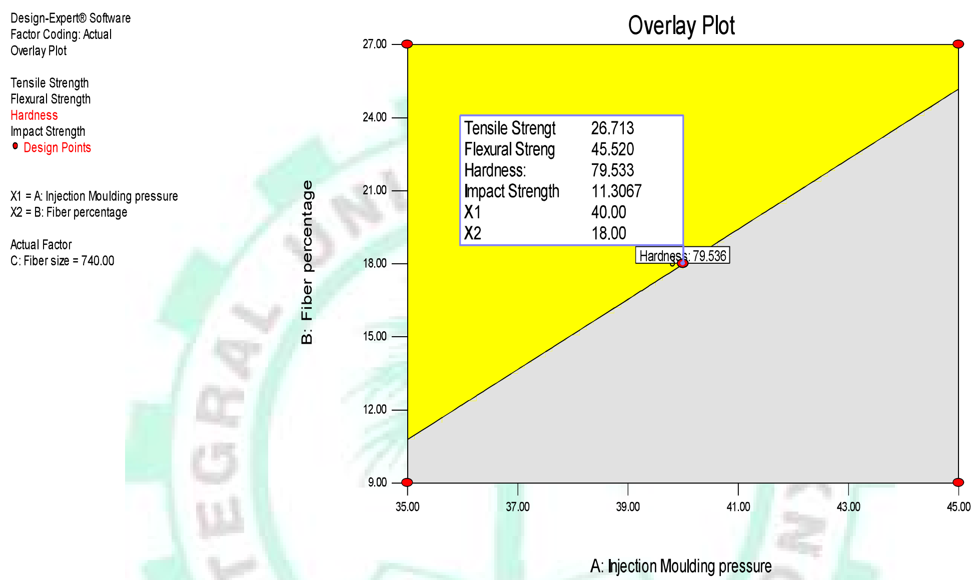

Fig 5.9 Overlay plot of design experiment

Table-5.10 Validation of parameters by DOE/ Overlay Plot

Parameter	**Predicted**	**Observed**
Impact strength	11.3067	11.12
Tensile strength	26.713	26.95
Hardness	79.533	80
Flexural strength	45.520	46.15

As seen in overlay plot, for optimized batch the set parameters are Injection moulding pressure 40 bar, Fiber percentage 18w% , Fiber size 740 μm. we can see the Predicted value given by overlay plot in table. We fabricate specimen with these parameters and found observed value very close to Predicted value given by overlay plot optimized batch.

5.8 CONCLUSION- This study was carried out for the purpose of development and characterization of shisham wood natural fiber based polymeric composites. The composites were fabricated by mixing wood powder in polypropylene matrix using Injection molding. These composites were tested in the laboratory for various mechanical properties and optimum parameters were identified.
On the basis of above, the following conclusions have been drawn.

Tensile strength of the wood powder polypropylene composite are observed maximum (27.62 MPa) at injection moulding pressure 45 bar, 18 wt% of fiber with 1180 µm fiber size particles and when compared to pure polypropylene it is 19% more.

The flexural strength of shisham wood powder polypropylene composite is the highest flexural strength (50.58 MPa) has been observed at the 45 bar injection pressure, 27 wt. % of fiber with 740 µm fiber size and the flexural strength of SWPPP composite has increased by (17.05%) in comparison to pure polypropylene.

The maximum value of impact strength has been found to be 11.56 J/m for SWPPP composite with 45 bar injection moulding pressure, 18 wt% fiber and 1180 µm fiber size, which is close to the value for polypropylene.

The impact strength of developed natural fiber composite has decreased as comparison to pure polypropylene. The lowest value of impact strength (7.78 J/m) has been observed for shisham wood powder composite with 35 bar moulding pressure, 9 wt% fiber and 740 µm fiber size.

The hardness of developed composite has increased up to 82 SHD with different combination of input parameters like 45 bar moulding pressure, 18 wt% fiber and 1180 µm in comparison to pure polypropylene which is 73 SHD.

5.9 LIMITATION- Followings are the limitations of the present work.
This present work was limited to shisham wood natural fibers as filler and propylene as a matrix material.

Homogeneous distribution of natural fillers was a challenging task.

This present work was limited to optimization of mechanical properties of natural fiber composite with variation of injection moulding pressure, fiber percentage and fiber size.

5.10 SCOPE FOR FUTURE STUDY- The present study may be extended in future on the following line;

Injection moulding technique has been used to fabricate the composite in the present work. However, numerous other manufacturing techniques such hand layup and compression moulding, may be explored that can provide more accuracy in fabrication.

The shape of the reinforcement is also an important parameter in composites. A study can also be carried out by considering this parameter.

Different additives like marble dust, mica, sludge of different primary industries etc. can be used in composite fabrication and their effect on its properties can also be analyzed.

A study on wear behavior of natural fiber composites can also be carried out.

Different natural fibers like rice husk, jute, other wood powders can be used in composite fabrication or hybrid composite fabrication and their effect on its properties can be analyzed.

REFERENCES

1) Saba, N.; Jawaid, M.; Alothman, O. Y.; Paridah, M., A review on dynamic mechanical properties of natural fibre reinforced polymer composites. *Construction and Building Materials* **2016,** *106*, 149-159.
2) Lau, K.-t.; Hung, P.-y.; Zhu, M.-H.; Hui, D., Properties of natural fibre composites for structural engineering applications. *Composites Part B: Engineering* **2018,** *136*, 222-233.
3) Clyne, T. W.; Hull, D., *An introduction to composite materials*. Cambridge university press: 2019.
4) Rajak, D. K.; Pagar, D. D.; Kumar, R.; Pruncu, C. I., Recent progress of reinforcement materials: A comprehensive overview of composite materials. *Journal of Materials Research and Technology* **2019,** *8* (6), 6354-6374.
5) Mochane, M.; Mokhena, T. C.; Mokhothu, T.; Mtibe, A.; Sadiku, E.; Ray, S. S.; Ibrahim, I.; Daramola, O., Recent progress on natural fiber hybrid composites for advanced applications: A review. **2019**.
6) Nikbakt, S.; Kamarian, S.; Shakeri, M., A review on optimization of composite structures Part I: Laminated composites. *Composite Structures* **2018,** *195*, 158-185.
7) Yuan, Z.; Wang, Y.; Yang, G.; Tang, A.; Yang, Z.; Li, S.; Li, Y.; Song, D., Evolution of curing residual stresses in composite using multi-scale method. *Composites Part B: Engineering* **2018,** *155*, 49-61.
8) Singh, L.; Goga, G.; Rathi, M. K., Latest developments in composite materials. *IOSR Journal of Engineering (IOSRJEN), ISSN* **2012**, 2250-3021.
9) CHEN, X.; ZHANG, B.; XING, L., Application and Development of Advanced Polymer Matrix Composites [J]. *Materials China* **2009,** *6*, 2-12.
10) Begum, S.; Fawzia, S.; Hashmi, M., Polymer matrix composite with natural and synthetic fibres. *Advances in Materials and Processing Technologies* **2020,** *6* (3), 547-564.
11) Pickering, K. L.; Efendy, M. A.; Le, T. M., A review of recent developments in natural fibre composites and their mechanical performance. *Composites Part A: Applied Science and Manufacturing* **2016,** *83*, 98-112.

12) Rajak, D. K.; Pagar, D. D.; Menezes, P. L.; Linul, E., Fiber-reinforced polymer composites: Manufacturing, properties, and applications. *Polymers* **2019,** *11* (10), 1667.

13) Sundarababu, J.; Anandan, S. S.; Griskevicius, P., Evaluation of mechanical properties of biodegradable coconut shell/rice husk powder polymer composites for light weight applications. *Materials Today: Proceedings* **2021,** *39*, 1241-1247.

14) Cui, J.; Sun, H.; Wang, X.; Sun, J.; Niu, M.; Wen, Z., Preparation of siliceous lignin microparticles from wheat husks with a facile method. *Industrial Crops and Products* **2015,** *74*, 689-696.

15) Yang, L.; Xinying, L.; Yan, T.; Yanhua, Z.; Mingwei, D., PLASMA SURFACE TREATMENT OF WOOD POWDER/POLYETHYLENE COMPOSITES——EFFECT OF TREATMENT TIME ON SURFACE CHARACTERISTICS OF THE COMPOSITES [J]. *Acta Polymerica Sinica* **2010,** *6*.

16) Srivastava, S.; Hoda, S., A brief theory on latest trend of filament winding machine. *International Journal of Advanced Engineering Research and Science* **2016,** *3* (4), 258859.

17) Monteiro, S. N.; Drelich, J. W.; Lopera, H. A. C.; Nascimento, L. F. C.; da Luz, F. S.; da Silva, L. C.; dos Santos, J. L.; da Costa Garcia Filho, F.; de Assis, F. S.; Lima, É. P., Natural fibers reinforced polymer composites applied in ballistic multilayered armor for personal protection—an overview. *Green materials engineering* **2019**, 33-47.

18) Ferreira, J. M.; Capela, C.; Manaia, J.; Costa, J. D., Mechanical properties of woven mat jute/epoxy composites. *Materials Research* **2016,** *19* (3), 702-710.

19) Ma, F.; Yang, M.; Wang, G.; Pu, Y.; Wang, X.; Dai, W., Response of carbon-basalt hybrid fiber reinforced polymer under low velocity impact load. *Materials Research Express* **2019,** *6* (9), 095311.

20) Taj, S.; Munawar, M. A.; Khan, S., Natural fiber-reinforced polymer composites. *Proceedings-Pakistan Academy of Sciences* **2007,** *44* (2), 129.

21) Advani, S. G.; Hsiao, K.-T., *Manufacturing techniques for polymer matrix composites (PMCs)*. Elsevier: 2012.

22) Dang, Z.-M.; Yuan, J.-K.; Zha, J.-W.; Zhou, T.; Li, S.-T.; Hu, G.-H., Fundamentals, processes and applications of high-permittivity polymer–matrix composites. *Progress in materials science* **2012,** *57* (4), 660-723.

23) Wang, X.; Jiang, M.; Zhou, Z.; Gou, J.; Hui, D., 3D printing of polymer matrix composites: A review and prospective. *Composites Part B: Engineering* **2017,** *110*, 442-458.

24) Devendrappa, K.; Guruchethan, A.; Suresh, K.; Mirashi, D. N., EXPERIMENTAL INVESTIGATION OF FLEXURAL PROPERTIES OF WOOD POLYMER COMPOSITES UNDER WET CONDITIONS. **2017**.

25) Frost, R.; Grandfils, C.; Cerda, B.; Kasemo, B.; Svedhem, S., Journal of Biomaterials and Nanobiotechnology. **2011**.

26) Prachayawarakorn, J.; Anggulalat, K., Influence of Meranti sawdust aspect ratios and amount of loadings on mechanical and morphological properties of composites from polypropylene and Meranti sawdust. *Songklanakarin Journal of Science and Technology* **2003,** *25*, 595-606.

27) Khan, G. A.; Terano, M.; Gafur, M.; Alam, M. S., Studies on the mechanical properties of woven jute fabric reinforced poly (l-lactic acid) composites. *Journal of King Saud University-Engineering Sciences* **2016,** *28* (1), 69-74.

28) Ly, E. B.; Lette, M. J.; Diallo, A. K.; Gassama, A.; Takasaki, A.; Ndiaye, D., Effect of reinforcing fillers and fibres treatment on morphological and mechanical properties of typha-phenolic resin composites. *Fibers and Polymers* **2019,** *20* (5), 1046-1053.

29) Nair, M. M.; Kamath, S. M.; Shetty, N., Study on distilled/sea water absorption behaviour influenced by non-uniform long piled up coir fiber composites. *International Journal of Innovative Research in Science, Engineering and Technology* **2016,** *5* (9), 15-21.

30) Vignesh, M.; Sasindran, V.; Krishna, S. A.; Madusudhanan, A.; Gokulachandran, J. In *Predictive model development and optimization of surface roughness parameter in milling operations by means of fuzzy logic and artificial neural network approach*, IOP Conference Series: Materials Science and Engineering, IOP Publishing: 2019; p 012011.

31) Ranjan, S. S.; Jain, P. P.; Agrawal, S., Compounding of Polypropylene with Wood Flour and Comparative Study of Mechanical Properties. **2018**.

32) Stark, N. M.; White, R. H.; Mueller, S. A.; Osswald, T. A., Evaluation of various fire retardants for use in wood flour–polyethylene composites. *Polymer Degradation and Stability* **2010,** *95* (9), 1903-1910.

33) Fakhrul, T.; Islam, M., Degradation behavior of natural fiber reinforced polymer matrix composites. *Procedia Engineering* **2013,** *56*, 795-800.

34) Awal, A. A.; Hussin, M. W., Effect of palm oil fuel ash in controlling heat of hydration of concrete. *Procedia Engineering* **2011,** *14*, 2650-2657.

35) Kumar, M. S.; Singh, M. M.; Niranjan, M., Use of Saw Dust as Fine Aggregate in Concrete Mixture. **2018**.

36) AL-Obaidi, M.; AL-Ajaj, I., Effect of sawdust wood on physical properties of recycled polyethylene terephthalate (RPET). *International Journal of Innovative Research in Science, Engineering and Technology* **2015,** *4* (1), 18443-18441.

37) Peyyala, P. K.; Baddepudi, M.; Rao, V. V. S. *An Analytical Study of Buckling Behavior of Nanocomposite Beams*; 0148-7191; SAE Technical Paper: 2018.

38) Mahajan, G.; Aher, V.; Katore, M. R., Fabrication of Jute-PP and Wood Stock-PP scomposites and Comparison of their Physico-Mechanical Properties.

39) Obilade, I., Use of rice husk ash as partial replacement for cement in concrete. *International Journal of Engineering* **2014,** *5* (04), 8269.

40) Mathew, G. M.; Sruthy, B.; Anju, V.; Raj, S. G., Experimental Evaluation of Strength Properties of Concrete using Saw Dust Ash and Polypropylene Fibres.

41) Ambiga, K.; Meenakshi, P.; INDIA, E., Studies on Strength of concrete by Partial Replacement of sand with Sawdust. *International Journal of Advanced Engineering Research and Studies* **2015,** *2*, 8-10.

42) Kord, B.; Hemmasi, A. H.; Ghasemi, I., Properties of PP/wood flour/organomodified montmorillonite nanocomposites. *Wood science and technology* **2011,** *45* (1), 111-119.

43) Gil, B. M.; Song, S. W.; Lee, J. H.; Jeon, J.; Lee, K. H.; Wie, J. J., Introduction of primary chemical bonding in lignin-based PP composites for

mechanical reinforcement via reactive extrusion. *Composites Part B: Engineering* **2019,** *165*, 510-515.

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Preparation and Optimisation of Sheesham Wood Natural Fiber Composite using Box-Behnken Technique

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Abstract: **In the present work natural fiber composites (NFCs) were prepared. Sheesham wood was used as a natural fiber and Poly propylene was used as a base material. Now-a-days natural fibers have been used by the researchers due to its various advantages such as renewability, biodegrability & low material price etc. In this study material such as Sheesham wood dust, NaoH pallets & Polypropylene were used and NFCs were prepared and optimized using Injection molding technique. Tensile strength, Impact strength, Hardness, Flexural Strength were analysed and the experimental results showed a higher tensile strength, Flexural strength, Hardness with less impact strength where optimized values for Tensile strength, Flexural strength, Hardness and impact strength were found to be 26.95,46.15, 80 & 11.12 respectively.**

Keywords: **Composite, Natural fibers, Polypropylene, Polymer, Sheesham wood.**

I. INTRODUCTION

Nowadays there are number of problems facing by the people of world due to various factors such as speedy growth in population which results in the shortage of resource and ultimately leading to environmental pollution that causes harm to the earth and society(Rahman & Bhoi, 2021). In our daily life we are using a large number of non-renewable and non-biodegradable materials such as metal, glass, plastic products, petroleum derivatives etc although these products are beneficial in our routine life when they are but consumed in large amount leads to deterioration of environment(Agarwal, 2020). So in order to protect our environment from pollution and side effects associated with it use of biodegradable (Subramanian et al., 2021)materials are suggested(Wang, Liu, Ding, Zhang, & Yu, 2021)**.** A huge variety of fibers of natural origin are obtainable that are paying attention to the scientists, technologists and researchers for example cotton, banana, coir, jute , wood powder and many more(da Silva Barbosa Ferreira, Luna, Araújo, Siqueira, & Wellen, 2021) . These natural fibers can be utilized because of various advantages such as beneficial for the production of consumer goods, low housing cost and for buliding other structures associated with civil(Khalid et al., 2021). These natural fibers can be formulated into composites(Karim, Tahir, Haq, Hussain, & Malik, 2021) which possess various properties like improved electrical resistance, high-quality thermal and acoustic insulating properties and advanced resistance to fracture(da Fonseca, Rocha, & Cheriaf, 2021). If we compare natural fibers with synthetic fibers(Begum, Fawzia, & Hashmi, 2020) than they show numerous advantages fibers such as low weight, low density, low cost, recyclable, biodegradable, renewable, comparatively high strength and stiffness and causes no irritations to skins(Venkateshwaran, Elayaperumal, & Sathiya, 2012). Therefore they can be used for fabricating wood plastic composites (WPCs). These are the composites that include plant, wood or non wood fibers, thermosets and thermoplastics(Post, Susa, Blaauw, Molenveld, & Knoop, 2020). Thermosets are the plastics whose melting is not possible by repeated melting process once cured for example resins (epoxies and phenolics)(Peters, 2002) whereas the plastics which can be melted repeatedly are known as thermoplastics due to these properties they can allows other materials like fibers obtained from wood, are to be mixed with plastic so as to form a product known to be composite product(Adeniyi et al., 2016; Wilczyński, Buziak, Lewandowski, Nastaj, & Wilczyński, 2021). Examples of thermoplastics are Polypropylene (PP), polyethylene (PE) and polyvinyl chloride (PVC) that are extensively used for WPCs and at present they are very widespread in building work, construction sites, furniture manufacturing and for making automotive products(Ashori, 2008). There are various factors that effects the properties of WPCs such as content of wood dust, type of wood species used, coupling agent properties, and matrix material(Vedrtnam, Kumar, & Chaturvedi, 2019). WPCs lessen the green house effects and known to be eco-friendly. A appropriate filler for WPCs is Wood flour (WF) it because of its ease in availability, density is also low , biodegradable in nature , renewable, stiffness is high , and moderately low cost(Kumar, Vedrtnam, & Pawar, 2019)

Extrusion and injection molding are the important methods used in the manufacturing of plastics and wood fiber filled with plastic parts(Alam, Kaur, Khaira, & Gupta, 2016). In extrusion process unbroken linear profiles are produce where melted thermoplastic is forced via a die whereas injection molding process prepares three-dimensional things with least post-manufacturing stages(Migneault et al., 2009).

Several researchers investigated different wood powder polypropylene composites but limited studies was conducted using shisham wood powder (Graebling, 2002)polypropylene by variation of injection moulding pressure, weight percentage of fiber and fiber size are limited.

II. MATERIALS AND METHOD

A. Materials

1) Matrix Material

The polypropylene is higher temperature battling material, because of this significant property, it is appropriate for some, things like plate, jugs and instrument shakes that must be usually utilized for therapeutic conditions.

Polypropylene of low density (0.9 g/cm^3) in pellet form was obtained from Bansal plastic private limited from Firozabad,

2) Fiber Materials

This research work employs sheesham wood powder (sawdust) as natural fibers in the polypropylene matrix to fabricate different set of composites. Saw dust was obtained from local wood industry Lucknow.

During blending of clumps, 1% by weight silane, coupling specialist S-69 is included the blend for good holding of fiber in polypropylene grid..

A. Preparation of composites

Before composite fabrication, there are several treatments have been done on the fiber, separately. This kind of waste molecule size is in ranges from 20 to 5000 µm. The selected size of shisham wood powder (SWP) particle sizes are 300,740,1180 µm. Treatment of wood powder was carried out by using NaOH (Sodium Hydroxide) solution. The NaOH pellets 900 grams were put in 15 liters water in the bucket. NaOH pellets are soluble in water and make a 6% NaOH solution. To begin with, the wood powder is washed with the typical water for three-four times to evacuate dust and different materials, at that point dried in daylight at 43-45 0C four days at room temperature to expel the dampness. At that point wood powder (WP) was ground to fine powder and went through sifter shaker. .wood powder was submerged in NaOH answer for 24 hours, where the room temperature was kept up. The rewarded wood powder at that point completely flushed in ordinary faucet water a few times to evacuate the overabundance NaOH, at long last washed with refined water twice. After washing in water, the wood powder was kept in trays homogeneously for its drying in oven at 110^{0}C for 48 hours.

B. Fabrication of Composites

The SWP composite are fabricated by injection moulding technique due to varying moulding pressure, weight percentage of fiber and fiber size than the optimum set fabrication of parameters are achieved by Box-Behnken Technique.

In Extrusion examination work, the twin extruder was utilized for exacerbating (blending) the strands and polypropylene. For aggravating the composites Siemens Ltd extruder, model Simatic HMI was utilized. Twin Screw Extruder Operating Conditions parameters are Melting pressure 30 bar, Temperature 30^{0}C, Screw rotation speed 50 RPM, Screw temperature 170,180,190,200,210^{0}C. After the compounding of all the batches, these were cut separately in small pieces. Infusion shaping machine (Electronica 70-90 ton machine model number 1656) Electronica Plastic Machine Ltd, Pune, India, was utilized for the sample preparation. Operating parameters of the injection molding machine are Screw rotation speed 40 RPM, Cycle time 30S, Nozzle temperature range (149,180,190,200,210)^{0}C and Mould temperature 50^{0}C. Trim temperature scopes of the infusion chamber are 149, 180, 190, 200 and 210, these range are discovered ideal in the back, center, front, and spout zones, individually.

The form temperature is 500^{0}C. Process duration for infusion is 30 second. At the overheating temperature, the polypropylene can be vanishing so it is important to keep up temperature beneath 2500^{0}C.

III. CHARACTERISATION, OPTIMISATION AND TESTING

A. *Tensile Strength of Developed Composites (ASTM D638)*

The Tensile specimens with measurement 68.2 × 12.70 ×3.18 mm^3 are acquired from the infusion forming machine. The pliable trial of various created composites were completed in the agreement with the standard ASTM D638 utilizing a standard material testing framework with cross head speed 50 mm/min. In this examination work, this test is acted in the widespread testing machine Instron USA 3382. The outcomes are utilized to examine the rigidity and tractable modulus of the composite examples. Here, the example tests are rehashed multiple times on each created composite sort and mean qualities is accounted for as the rigidity and tractable modulus of that composite.

B. *Flexural Strength (ASTM D790)*

The flexural example tests with measurement 50 × 12.40 × 3.30 mm3 were created by utilizing the infusion shaping machine. The flexural tests are acted in the understanding with the ASTM D790 utilizing a standard material testing framework with cross head speed 1.50 mm/min. The flexural properties of the created composites are determined in three point twisting tests.

C. *Impact Strength (ASTM D256)*

The effect tests examples were set up as per the standard ASTM D256. All the effect test examples were tried utilizing the Izod sway analyzer. Above all else, an indent (2.5 mm) at 450 point was cut by the manual step shaper. The testing device was pendulum sway testing machine Tinius Olsen, Model Impact 104.

D. *Hardness (ASTM D2240)*

The hardness testing examples were formed from the infusion shaping machine. In the current work, the hardness properties are estimated utilizing a Durometer Shore D, DIN 53505 model hardness analyzer. The ASTM standard test technique for estimating the hardness properties of fiber sap composite ASTM D2240. The particular estimations of the hardness of various examples are noted straightforwardly from the dial pointer. The each assessment is rehashed multiple times on the lattice and every composite kind and the normal worth is accounted for as the hardness of that composite.

IV. RESULT AND DISCUSSION

A Box-Behnken Technique design was adopted to optimize the formulation and an overlay plot was obtained using design expert software (Design-Expert software, version 8.0) which provides theoretical values of optimized batch. Design Parameters and Their Levels are shown in Table 1. The Results of Mechanical Properties of pure Polypropylene (PP) are shown in table 2. The data responses in terms of flexural strength, tensile strength, hardness and impact strength are recorded in Table 3. The overlay plot displays the values of impact strength, tensile strength, hardness, flexural strength.

Table I. Design Parameters and Their Levels.

Number of parameters	Selected parameters	Levels			Unit
		1	2	3	
1	Injection Moulding pressure	35	40	45	bar
2	Fiber percentage	9	18	27	Wt.%
3	Fiber size	300	740	1180	µm

Table II. Results of Mechanical Properties of Polypropylene (PP)

Material	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J/m)	Hardness ShoreD
PP	23.15	43.21	13.9	73

Table III. Investigated Mechanical properties of Sheesham wood polypropylene composite

Std	Run	Factor 1 A:Injection M... Bar	Factor 2 B:Fiber perc... Wt%	Factor 3 C:Fiber size μm	Response 1 Tensile Stren... MPa	Response 2 Flexural Stre... MPa	Response 3 Hardness SHD	Response 4 Impact Stren... J/m
8	1	45.00	18.00	1180.00	27.62	50.11	82	11.56
2	2	45.00	9.00	740.00	24.33	48.87	81	8.85
6	3	45.00	18.00	300.00	24.65	50.34	82	8.34
11	4	40.00	9.00	1180.00	25.26	46.76	75	9.95
1	5	35.00	9.00	740.00	25.21	48.92	82	7.78
3	6	35.00	27.00	740.00	24.55	47.26	75	10.23
13	7	40.00	18.00	740.00	26.75	45.67	82	11.3
9	8	40.00	9.00	300.00	25.22	47.12	81	7.97
7	9	35.00	18.00	1180.00	24.86	48.98	76	10.45
10	10	40.00	27.00	300.00	24.26	44.32	82	8.83
4	11	45.00	27.00	740.00	24.28	50.58	77	9.3
12	12	40.00	27.00	1180.00	24.51	44.88	75	9.48
5	13	35.00	18.00	300.00	26.51	44.25	81	8.18
14	14	40.00	18.00	740.00	26.68	45.55	81	11.35
15	15	40.00	18.00	740.00	26.71	45.34	81	11.27

A. Tensile Properties Of Composites

The results of Tensile strength of developed composites from Table 3 are given in Table 4.

Table.IV. Tensile Properties Results

Exp.No.	A	B	C	Tensile Strength (MPa)
1	3	2	3	27.62
2	3	1	2	24.33
3	3	2	1	24.65
4	2	1	3	25.26
5	1	1	2	25.21
6	1	3	2	24.55
7	2	2	2	26.75
8	2	1	1	25.22
9	1	2	3	24.86
10	2	3	1	24.26
11	3	3	2	24.28
12	2	3	3	24.51
13	1	2	1	26.51

In Table IV, A= Injection moulding pressure in Bar, B= Fiber Percentage (Wt %), C= Fiber Size (µm) and 1= Min value of factor , 2= Medium value of factor, 3= Max value of factor.

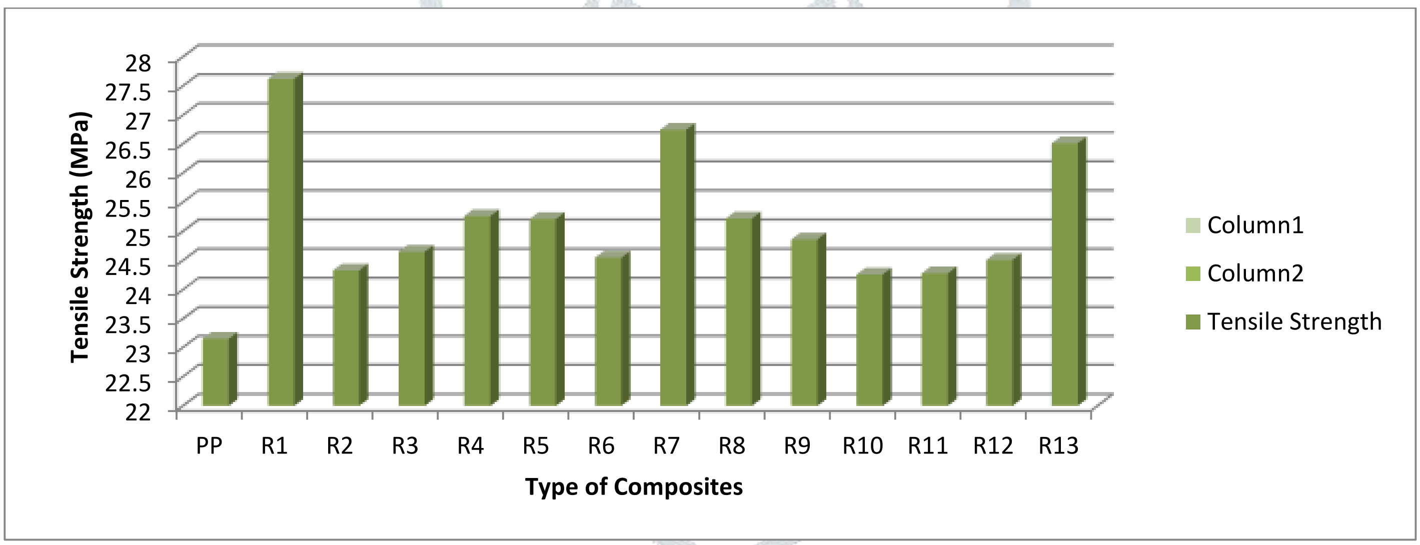

Fig 1 Tensile Strength of Developed Composites

It has been observed that the tensile strength of R1-R13 composites lie in the range 24.26 – 27.62 MPa All variations in the values are depends upon composites formulations according to design methodology. It has been observed that around maximum 19% improvement in the tensile strength of SWPPP composite takes place by the adding of 18% wt% of wood powder as compared to pure polypropylene. However, in respect of 27 wt% of the reinforcing materials, the tensile strengths of wood powder polypropylene composites are found to decrease as the filler increased. With the variation of filler loading in the increasing order, the tensile strength . It is maximum at 45 bar injection moulding pressure, 18% fiber and 1180 µm fiber size.

B. Flexural Properties of Composites

The flexural quality is identified with twisting of materials. On the off chance that a composite material fizzles in twisting, the advancement of the new composite material is basic to improve the flexural properties. The variations of the flexural properties and hardness and impact strength of different composites are seen in Table 3 & Table 5.

Table V. Flexural Properties, Hardness and Impact Strength of Composites

Exp. No.	A	B	C	Flexural Strength (MPa)	Hardness (SHD)	Impact Strength (J/m)
1	3	2	3	50.11	82	11.56
2	3	1	2	48.87	81	8.85
3	3	2	1	50.34	82	8.34
4	2	1	3	46.76	75	9.95
5	1	1	2	48.92	82	7.78
6	1	3	2	47.26	75	10.23
7	2	2	2	45.67	82	11.30
8	2	1	1	47.12	81	7.97
9	1	2	3	48.98	76	10.45
10	2	3	1	44.32	82	8.83
11	3	3	2	50.58	77	9.3
12	2	3	3	44.88	75	9.48
13	1	2	1	44.25	81	8.18

In Table V, A= Injection moulding pressure in Bar, B= Fiber Percentage (Wt %), C= Fiber Size (μm) and 1= Min value of factor , 2= Medium value of factor, 3= Max value of factor.

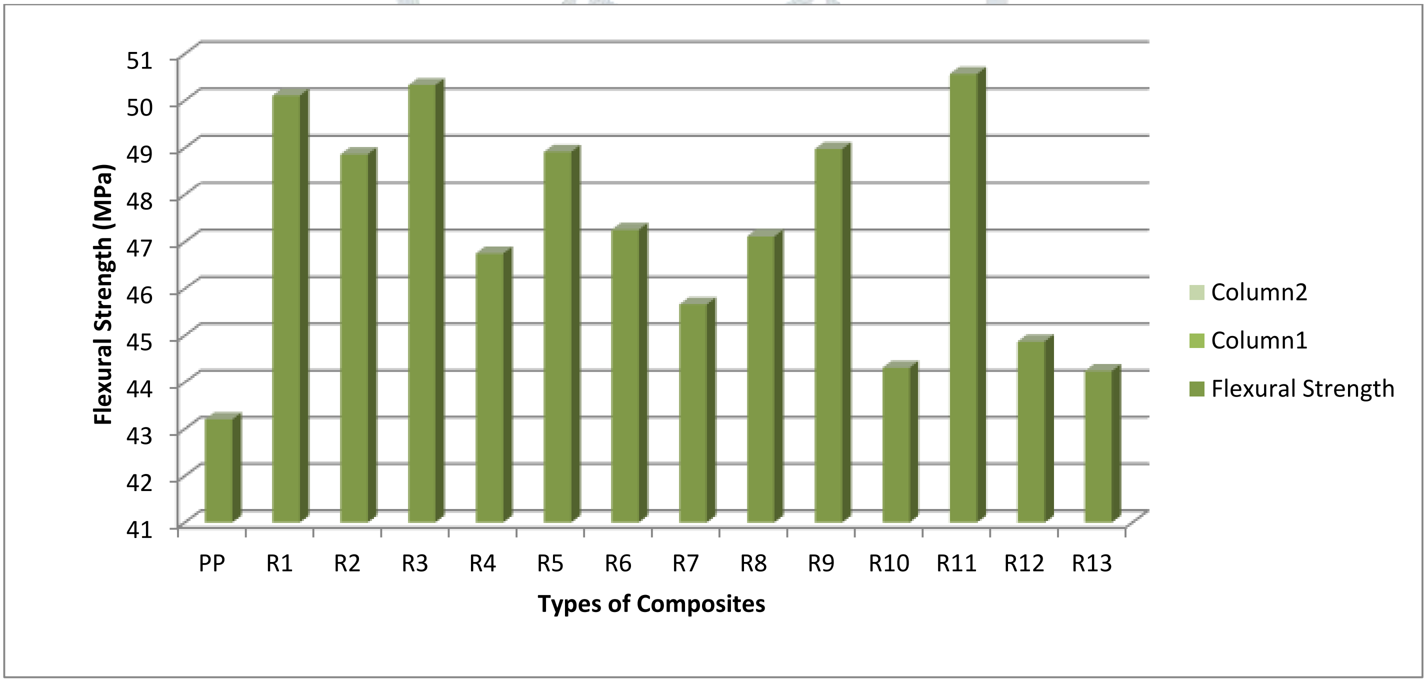

Fig. 2 .Flexural Strength of Composites

The trend of flexural strength of all developed SWPPP composites are shown in Figure 2.

From the Table 5, it is seen that the scope of the flexural quality of R1-R13 composites lies between 44.25–50.58 MPa. The flexural quality of the R1-R13 wood powder polypropylene composites expanded up to the expansion of 18 wt% of fiber substance. Be that as it may, further expanded up to 27 wt% of fiber prompts decline in the flexural quality. It was discovered that the most elevated flexural quality is seen with 45 bar pressure, 27 weight level of fiber and 740 μm fiber size. The further increment in fiber stacking in the composite prompts decline in the flexural quality.

C. Impact Strength of Composites

The impact strength is the capability of a material to soak up and dissipate energies under the shock or impact loading. The difference in the values of impact strength measured under this investigation of all developed composites and pure polypropylene are presented in Figure 5.

The experimental values of the impact strength of different developed composites are also presented in the Table 3 & 5. The Figure 3 shows the variation of measured values of the impactstrength.

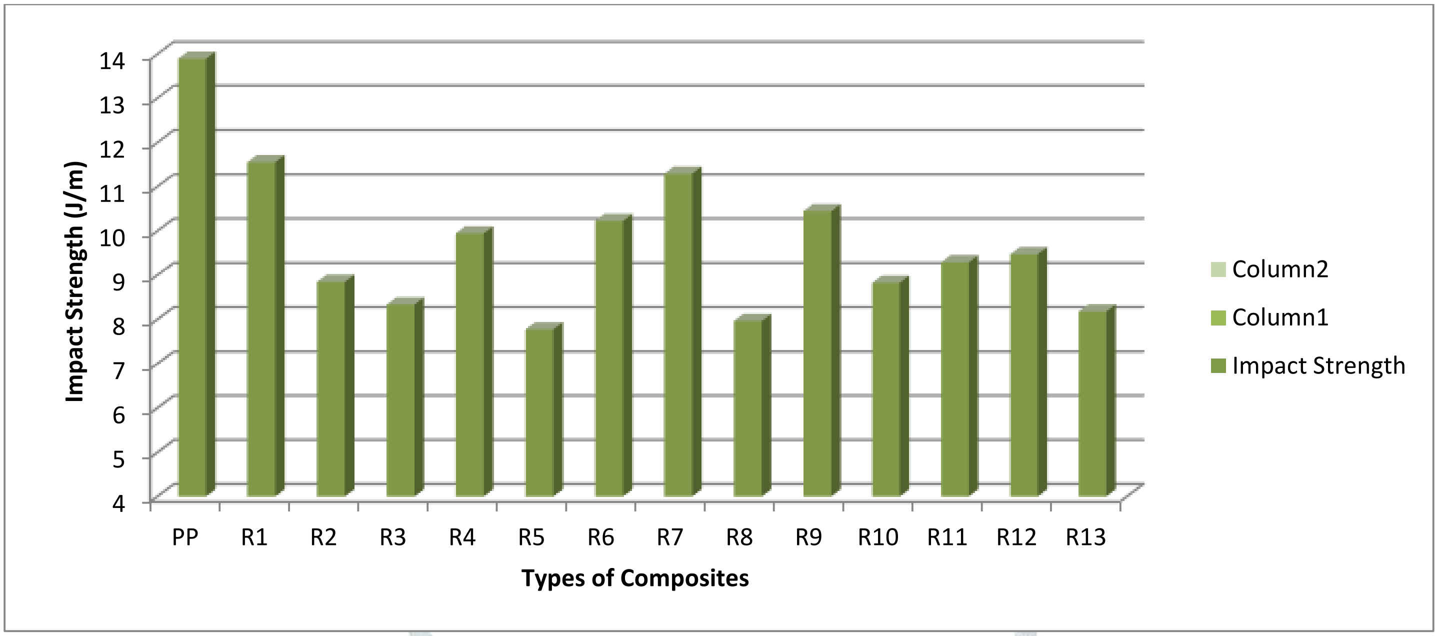

Fig. 3. Impact Strength of Developed Composite

It is observed that the impact strength of pure polypropylene (PP) matrix is very highest as compared to all developed composites. From the figure 3, it is observed that the impact strength of wood powder-polypropylene R1-R13 composites increased up to the 18 wt% of fiber loading and then decreased when fiber loading increased up to 27 wt%. The obtained value of polypropylene impact strength is 13.9 J/m. It can be observed from the Table 5 that the impact strength of WPPP composites lies in the range of 7.78 to 11.56 J/m. It is also observed that the impact strength of wood powder-polypropylene composites with 18 wt. % is very close to the value observed for polypropylene. It is clearly noticed that the R5 composite have lower impact strength than other developed composites. The most elevated impact strength is seen with 45 bar pressure, 18 weight level of fiber and 1180 µm fiber size.

D. Hardness of Composites

Variation of hardness properties of the different composites with the variation of the fiber weight percentage is shown in Figure 4. It is observed that pure PP matrix has a very lowest hardness as compared to all developed composites in this present work. It is seen that the hardness of wood powder-polypropylene composite improved up 18 wt% of fiber content addition and thereafter decreased. However, It is also seen that the hardness of R10 composite improved with 27 wt%offiber.

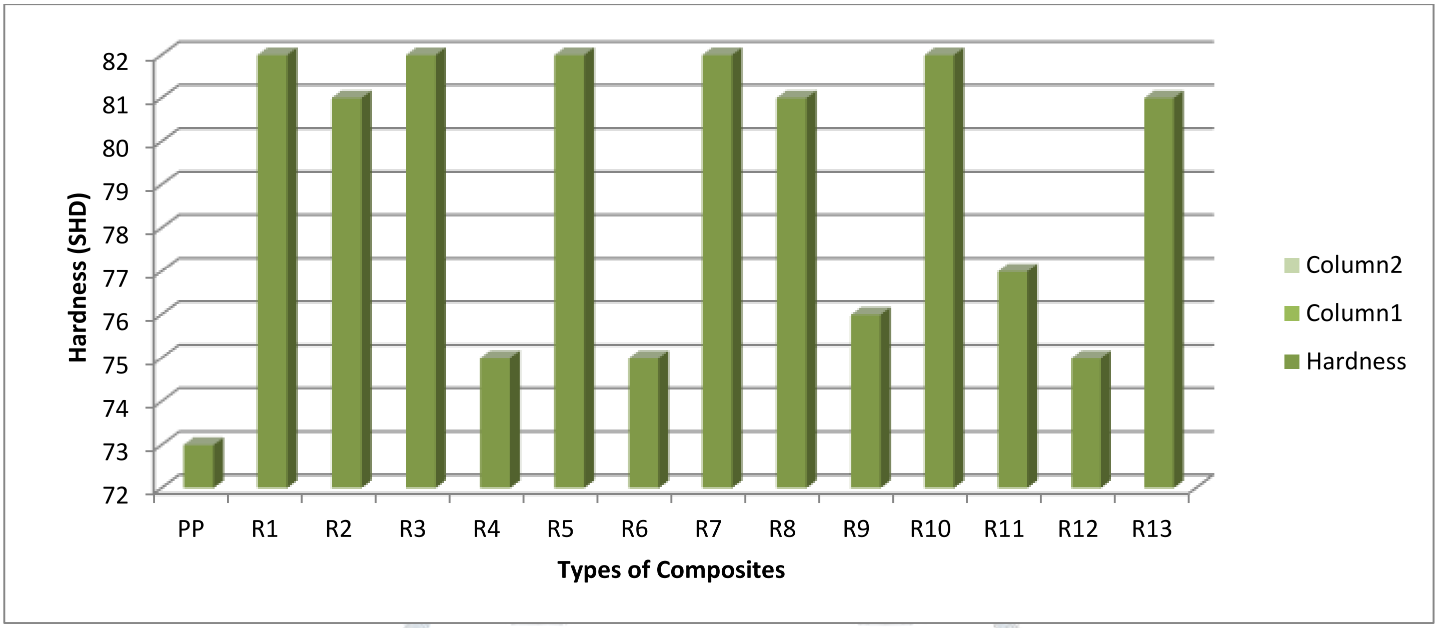

Fig. 4. Hardness of developed Composite

E. Ovarlay plot

An overlay plot was obtained using design expert software (Design-Expert software, version 8.0) which provides theoretical values of optimized batch. After analysis of each data the graphical method of optimization was adopted to find out the area of desired region (design space) and optimum formulation. Certain constants were applied on each dependent for purpose of optimization.

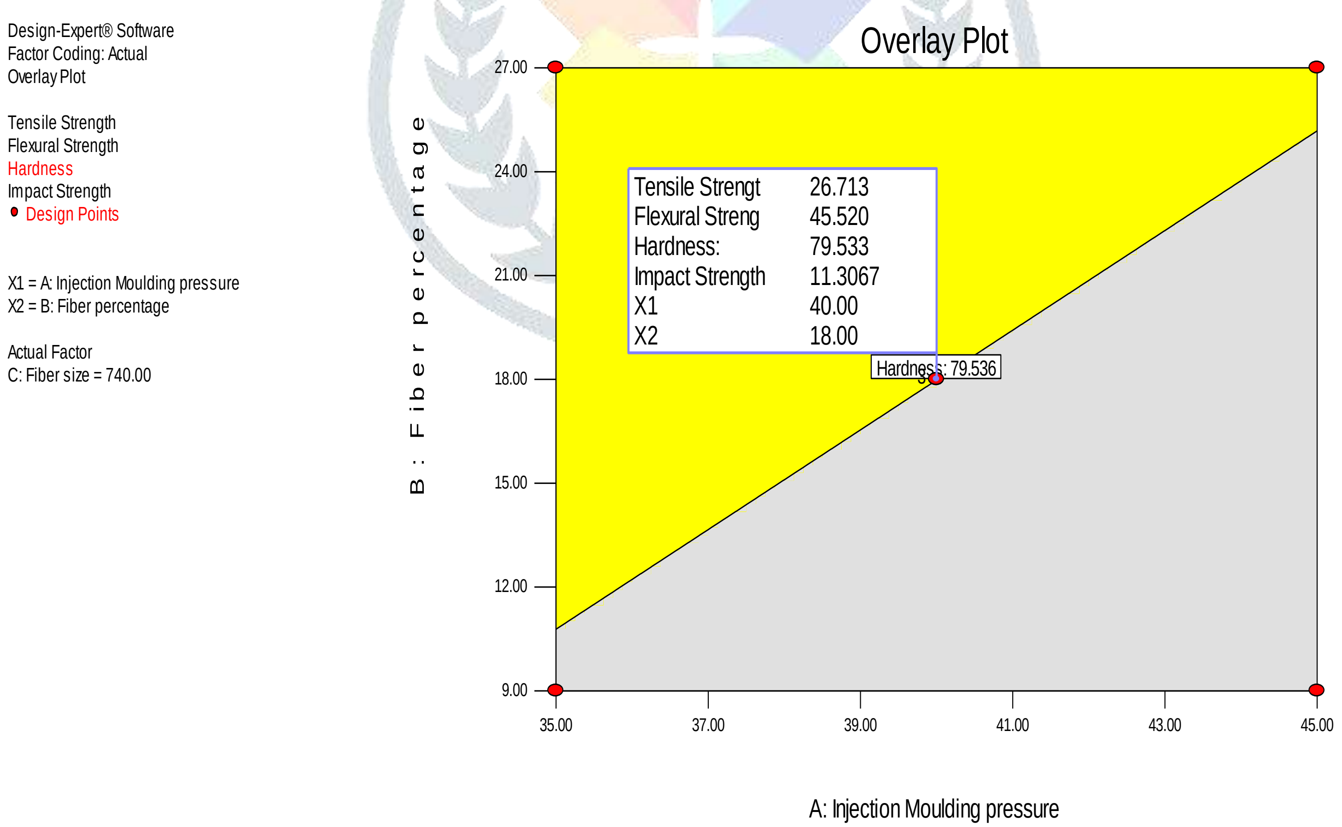

Fig 5. Overlay plot of design experiment

Table-VI. Validation of parameters by DOE/ Overlay Plot

Parameter	Predicted	Observed
Impact strength	11.3067	11.12
Tensile strength	26.713	26.95
Hardness	79.533	80
Flexural strength	45.520	46.15

As seen in overlay plot, for optimized batch the set parameters are Injection moulding pressure 40 bar, Fiber percentage 18w% , Fiber size 740 µm. we can see the Predicted value given by overlay plot in table. We fabricate specimen with these parameters and found observed value very close to Predicted value given by overlay plot optimized batch.

V. CONCLUSIONS

This study was carried out for the purpose of development and characterization of shisham wood natural fiber based polymeric composites. The composites were fabricated by mixing wood powder in polypropylene matrix using Injection molding. These composites were tested in the laboratory for various mechanical properties and optimum parameters were identified.

On the basis of above, the following conclusions have been drawn.

Tensile strength of the wood powder polypropylene composite are observed maximum (27.62 MPa) at injection moulding pressure 45 bar, 18 wt% of fiber with 1180 µm fiber size particles and when compared to pure polypropylene it is 19% more.

The flexural strength of shisham wood powder polypropylene composite is the highest flexural strength (50.58 MPa) has been observed at the 45 bar injection pressure, 27 wt. % of fiber with 740 µm fiber size and the flexural strength of SWPPP composite has increased by (17.05%) in comparison to pure polypropylene.

The maximum value of impact strength has been found to be 11.56 J/m for SWPPP composite with 45 bar injection moulding pressure, 18 wt% fiber and 1180 µm fiber size, which is close to the value for polypropylene.

The impact strength of developed natural fiber composite has decreased as comparison to pure polypropylene. The lowest value of impact strength (7.78 J/m) has been observed for shisham wood powder composite with 35 bar moulding pressure, 9 wt% fiber and 740 µm fiber size.

The hardness of developed composite has increased up to 82 SHD with different combination of input parameters like 45 bar moulding pressure, 18 wt% fiber and 1180 µm in comparison to pure polypropylene which is 73 SHD.

VI. REFERENCES

Adeniyi, A., Agboola, O., Sadiku, E. R., Durowoju, M., Olubambi, P., Reddy, A. B., . . . Kupolati, W. (2016). Thermoplastic-thermoset nanostructured polymer blends *Design and Applications of Nanostructured Polymer Blends and Nanocomposite Systems* (pp. 15-38): Elsevier.

Agarwal, S. (2020). Biodegradable Polymers: Present Opportunities and Challenges in Providing a Microplastic-Free Environment. *Macromolecular Chemistry and Physics, 221*(6), 2000017.

Alam, M., Kaur, J., Khaira, H., & Gupta, K. (2016). Extrusion and extruded products: changes in quality attributes as affected by extrusion process parameters: a review. *Critical reviews in food science and nutrition, 56*(3), 445-473.

Ashori, A. (2008). Wood–plastic composites as promising green-composites for automotive industries! *Bioresource technology, 99*(11), 4661-4667.

Begum, S., Fawzia, S., & Hashmi, M. (2020). Polymer matrix composite with natural and synthetic fibres. *Advances in Materials and Processing Technologies, 6*(3), 547-564.

da Fonseca, R. P., Rocha, J. C., & Cheriaf, M. (2021). Mechanical properties of mortars reinforced with amazon rainforest natural fibers. *Materials, 14*(1), 155.

da Silva Barbosa Ferreira, E., Luna, C. B. B., Araújo, E. M., Siqueira, D. D., & Wellen, R. M. R. (2021). Polypropylene/wood powder/ethylene propylene diene monomer rubber-maleic anhydride composites: Effect of PP melt flow index on the thermal, mechanical, thermomechanical, water absorption, and morphological parameters. *Polymer Composites, 42*(1), 484-497.

Graebling, D. (2002). Synthesis of branched polypropylene by a reactive extrusion process. *Macromolecules, 35*(12), 4602-4610.

Karim, M. R. A., Tahir, D., Haq, E. U., Hussain, A., & Malik, M. S. (2021). Natural fibres as promising environmental-friendly reinforcements for polymer composites. *Polymers and Polymer Composites, 29*(4), 277-300.

Khalid, M. Y., Imran, R., Arif, Z. U., Akram, N., Arshad, H., Rashid, A. A., & García Márquez, F. P. (2021). Developments in Chemical Treatments, Manufacturing Techniques and Potential Applications of Natural-Fibers-Based Biodegradable Composites. *Coatings, 11*(3), 293.

Kumar, S., Vedrtnam, A., & Pawar, S. (2019). Effect of wood dust type on mechanical properties, wear behavior, biodegradability, and resistance to natural weathering of wood-plastic composites. *Frontiers of Structural and Civil Engineering*, *13*(6), 1446-1462.

Migneault, S., Koubaa, A., Erchiqui, F., Chaala, A., Englund, K., & Wolcott, M. P. (2009). Effects of processing method and fiber size on the structure and properties of wood–plastic composites. *Composites Part A: Applied Science and Manufacturing*, *40*(1), 80-85.

Peters, E. N. (2002). *Plastics: thermoplastics, thermosets, and elastomers*: Wiley-Interscience, New York.

Post, W., Susa, A., Blaauw, R., Molenveld, K., & Knoop, R. J. (2020). A review on the potential and limitations of recyclable thermosets for structural applications. *Polymer Reviews*, *60*(2), 359-388.

Rahman, M. H., & Bhoi, P. R. (2021). An overview of non-biodegradable bioplastics. *Journal of Cleaner Production*, 126218.

Subramanian, K., Krishnasamy, S., Muthukumar, C., Siengchin, S., Gnaniar, K., & Kanagaraj, A. (2021). Tribology of Wood Polymer Composites. *Wood Polymer Composites: Recent Advancements and Applications*, 179.

Vedrtnam, A., Kumar, S., & Chaturvedi, S. (2019). Experimental study on mechanical behavior, biodegradability, and resistance to natural weathering and ultraviolet radiation of wood-plastic composites. *Composites Part B: Engineering*, *176*, 107282.

Venkateshwaran, N., Elayaperumal, A., & Sathiya, G. (2012). Prediction of tensile properties of hybrid-natural fiber composites. *Composites Part B: Engineering*, *43*(2), 793-796.

Wang, W., Liu, L., Ding, N., Zhang, R., & Yu, J. (2021). Mechanical and thermal behavior analysis of wood–polypropylene composites. *Textile Research Journal*, *91*(3-4), 347-357.

Wilczyński, K., Buziak, K., Lewandowski, A., Nastaj, A., & Wilczyński, K. J. (2021). Rheological Basics for Modeling of Extrusion Process of Wood Polymer Composites. *Polymers*, *13*(4), 622.