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MANUFACTURING OF WOOD FROM RICE STRAW

Abd El-Fattah M. Khourshid, Abd El-wahed M.Assar, Ahamad M. El kassas, Maher Rashad Mohamed

Department of Production Engineering and Mechanical Design,
Faculty of Engineering, Tanta University, Egypt

ABSTRACT

Rice straw was used as an alternative raw material to obtain cellulosic's pulps. Pulping was done by using classics reagents as soda (with anthraquinone and parabenzoquinone as additives), potassium hydroxide and Kraft process. The holocellulose, α-cellulose and lignin contents of rice straw (60.7, 41.2 and 21.9 wt%, respectively) are similar to those of some woody raw materials such as pine and eucalyptus, and various non-wood materials including olive tree pruning, wheat straw and sunflower stalks. *In this paper*, rice straw composite boards were manufactured as using the method used in the wood-based panel industry. The raw material, rice straw, was chosen because of its availability. The manufacturing parameters were: a specific pressure of 15, 20, 30,40, and 50 bar, and a rice straw content (15/100, 20/100, 30/70,40/100, and 50/100 by weight of UF/ rice straw) A commercial urea–formaldehyde adhesive was used as the composite binder. The composite boards made from a random cutting of rice straw. The experimental investigation indicated that the optimum particleboard properties are obtained with a mixture ratio of 350 gm UF(Urea-Formaldehyde), pressure 40 bar, 12 mm thickness, the bending modulus of rupture (MOR) of the rice straw composite is 240 kg/cm^2 and a density of 1250 kg/m^3.When the intended use of these particleboards is as wood panels.

قش الأرز استخدم كبديل للحصول على المواد الخام السليلوزية. وكان ذلك باستخدام كواشف مثل الصودا وهيدروكسيد البوتاسيوم. حيث يحتوى قش الأرز على هيموسيليلوز و α سيلولوز واللجنين (60.7 ، 41.2 و 21.9 ٪ نسبه وزنيه ، على التوالي) مماثلة لتلك بعض المواد الخام الخشبية مثل شجرة ألكينا والصنوبر ، ومختلف المواد غير الخشبية بما في تشذيب شجرة الزيتون والقمح القش وسيقان عباد الشمس. في هذا البحث ، تصنيع قش الأرز يصنع مثل استخدام الطرق المستخدمة في تصنيع الخشب الصناعي.ويستخدم القش كماه خام نتيجة لسهوله الحصول عليه وأيضا التخلص من مشاكل حرق القش ومشاكل الساحبة السوداء.حيث تم دراسة تغير الضغط وكذلك تغير نسبه الإضافة للمادة الرابطة وبالتجارب العملية تم التوصل إلى أفضل ماده تم الحصول عليها وهى بها المواصفات الآتية ،نسبه الإضافة هي 350 جم/كجم و ذلك عند ضغط 40 بار وهذا يعطى معاير كسر 240 كجم/سم^2.

***Keywords*:** Rice straw, Pulping, composite boards, urea–formaldehyde.

1. INTRODUCTION

Forests, and the wood they produce, have played an important role in human activity since before recorded history. Indeed, one of the first major innovations of humankind was utilizing fire, fueled by wood, for cooking and heating. It is very likely that early hominids used wood fires for cooking as long as 1.5 million years ago [1].

Clear evidence of this use of wood exists from sites 400,000 years old [2]. Since this ancient beginning, the uses of wood, and the value of the forest, have expanded dramatically, as the population of humans and their economies grew. Wood was used in myriad products, including agricultural implements and tools, shelters and houses, bridges, road surfaces, ships and boats, arrows and bows, spears, shoes, wheelbarrows, wagons, ladders, and thousands of others. Other important products that forests provided were food, in the form of berries, nuts, fruits, and wild animals, and, of course, fuel. Wood was the most important material in early human economies, and though other materials have grown in importance, wood used for solid products, fiber, and chemicals is still the largest single type of raw material input by weight—with the one exception of crushed stone, sand, and gravel—into today's economy [3].Composites are comprised of combinations of two or more materials with different composition or form. The constituents retain their identities in a composite and do not dissolve or merge, but act together. A composite may have a ceramic, metallic or polymeric (Thermoset or thermoplastic) matrix. The fibers can also be ceramic, metallic or polymeric, however, a more common classification relates to whether they are synthetic (e.g. glass fiber, carbon fiber, Kevlar fiber) or natural (wood fiber, hemp fiber, flax fiber, jute fiber etc). Therefore, the number and variety of composites available are very large. Fiber-reinforced composite materials commonly consist of fibers of high strength and Young's modulus embedded in, or bonded to, a matrix with a distinct interface between them. In general, the fibers are the principal load carrying members, while the surrounding matrix holds them in the desired location and orientation, acting as a load transfer medium between them [4].The idea of using natural fibers as reinforcement in composite materials is not new. Natural fibers were used over 3000 years ago in composite systems in ancient Egypt, where straw and clay were mixed together to build walls. Many centuries later, in 1896, aero plane seats were made of natural fibers with a small content of polymeric binders. As early as 1908, the first composite materials were applied in the fabrication of large quantities of sheets, tubes and pipes. However, during the 70's and 80's, cellulose fibers were gradually substituted by newly developed synthetic fibers due to better performance. Over the past few years, there has been a renewed interest in using natural fibers as reinforcement materials in the plastics industry [5]. More recently, critical discussion about the preservation of natural resources and recycling has led to further interest concerning natural materials with the focus on renewable raw materials [6]. As mentioned earlier, there is a wide variety of different natural fibers which can be applied as reinforcement. Wood fiber is the most widely used lignocelluloses fiber for reinforcing plastics. It can be obtained from variety of processes, namely: herm mechanical, soda, sulphite, sulphate (Kraft) and semi-chemical pulping [7,8]. Wood fiber composites offer several advantages over synthetic fiber composites such as: low density, improved acoustic properties, favorable processing properties (e.g. low wear on tools), occupational health benefits compared to glass fibers, as well as positive effects on agriculture with comparable mechanical properties [9].

Wood is still the major source of cooking and heating fuel for most of the world. In 2002, world consumption of fuelwood and charcoal totaled 1,838,218,860 cubic meters. This represents nearly 54% of the world's consumption of wood. About 43% of this fuelwood consumption occurs in Asia, and Africa consumes 31%. The United States consumes only 4% of the world's total of fuelwood and charcoal.Total world consumption of round wood, which includes fuelwood, charcoal, and industrial wood, amounted to 3,390,684,310 m3 in 2002[10].

Besides producing fuelwood and wood for construction and other uses, forests have always been an important part of the American landscape, playing a key role in the social, economic, and spiritual life of the country. As the American population and economy grew, forests were removed to make way for farms, cities, and roadways. After the first European settlements in North America, forests were often viewed as an obstacle to farming and travel. Huge acreages were cleared in the 19th century to make way for fields, pastures, cities, and industry. In 1800, total cropland area in the United States extended across 20 million acres. By 1850, this had grown to 76 million acres, with pasture and hay land at perhaps twice that amount. Most of this farmland expansion was at the expense of forests [11]. The amount of cropland in the United States peaked in 1932, at about 361 million acres. [12] However, although much forestland has been converted to other uses, the net area of forestland has remained relatively stable since the 1920s [13]. As shown in Fig. 1, about 70% of the original amount of forested land still remains as forest, although much of it is likely modified from its structure and composition in 1600. Since 1932, however, as farmed land acreage decreased, forest area in the United States has been increasing. Forests have been the beneficiary of the conversion from animal power to mechanical power in farming. An estimated 20 million acres of grain fields and pastures were no longer needed when gasoline tractors replaced horses and mules [14].

As agricultural productivity per acre increased, as a result of plant breeding, fertilizers, and pesticides, forests have reclaimed many acres back from farm fields.

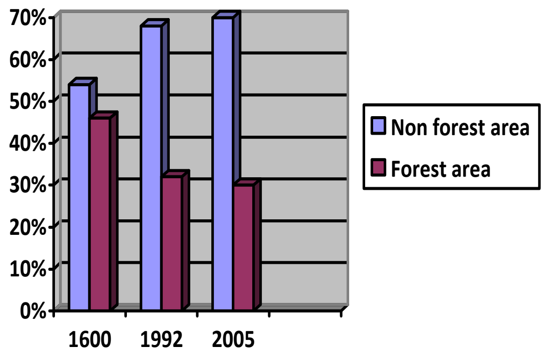

Fig. 1. United States forest area, Forests as a percentage of total U.S. land area

Wood has remained an important substance throughout history because of its unique and useful properties. Wood is recyclable, renewable, and biodegradable. Many species are shock resistant, bendable, and stable (although all wood changes dimensions as it loses or gains moisture). Density among species varies greatly; the balsa popular with model-airplane builders can weigh as little as 6 pounds per cubic foot, and some tropical hardwoods weigh more than 70 pounds per cubic foot. Wood and lignin can be converted to many useful industrial chemicals, such as ethanol and plastics. Wood can be treated to resist decay, and with proper construction techniques, and stains or paint, wood buildings can last hundreds of years. The oldest surviving wood structure is an Asian temple, built in the 7th century. Today, wood is used in tools, paper, buildings, bridges, guardrails, railroad ties, posts, poles, mulches, furniture, packaging, and thousands of other products [14].

Wood composites can be defined as materials made by gluing together small pieces of wood, residue materials from wood processing operations, or other elements into larger materials to produce products with specific definable mechanical and physical properties. Wood composite products continue to be among the most widely utilized building materials throughout the world. They are commonly manufactured as lumber, flooring, roofing, paneling, palettes, decking, fencing, cabinets, furniture, millwork, structural beams, etc.The increased number and importance of wood composite products are directly related to the decreased supply of high quality large timber, and as the quality and variety of wood composite products increases, and new applications for them are found, the trend toward increased use and importance of wood composites should continue. Wood composites offer numerous advantages over lumber. They can be produced from waste wood, agricultural residues, little used and low commercial value wood species, as well as smaller and fast growing trees, which can relieve stress on old growth forests that are increasingly unavailable for use.

Also, the increased homogeneity of the raw material obtained by combining small wood elements allows a wide variety of composite products to be produced that have consistent, high quality properties. The properties can often surpass those of lumber (e.g., have stronger and more uniform properties throughout the product, and be completely free of growth characteristics, weak spots, or defects such as knots), and often, the product can be produced with customized engineered properties, dimensions, and complex shapes (e.g., complex roof shapes, cathedral ceilings, cantilevered supports).The exact properties and the appropriate end use for a composite depend on the wood species and wood adhesive, and are very dependent on the size, shape, and arrangement of the wood in the composite. In fact, the names of the composite products are mostly based on the wood geometry (wood shape and size) and their arrangement in the product, without involving the name of the wood species or adhesive. These elements (species and adhesive) can be changed with far less effect on properties than changing wood geometry or arrangement.

The procedure for making a wood composite begins with the raw wood being processed by removal of leaves and bark, then being cut into pieces of the desired size and shape, followed by drying to the desired moisture content, and then going through a sorting process to ensure the wood pieces meet the selection criteria.

A large number of product types having quite different properties can be prepared using the same wood element. Processing conditions to convert the wood element into a composite product will depend on the type of adhesive selected and/or if the product being produced is pressed, impregnated, extruded, etc. Therefore, wood composites can be classified into two major types:

(*1*) Wood bonded with thermoset adhesives and

(*2*) Wood combined with other materials such as cement and thermoplastics

A collapse incident in natural forests in the world and also to the evolution of the standard of living in third world countries and which led them to dispense with the agricultural residues (such as cotton wood - rice straw - wood maize - the remnants of wood) as sources for cooking and heating fuel as well as in small-scale industries are The problem of the accumulation of agricultural residues require all Alaugep research and applied scientific theory.

So went scientists and researchers to try to turn this agricultural residues to the timber industry (wooden planks), where the nature of this waste is that it does not serve as food for animals or food source in addition to being relevant and strong environmental problems in both the overall environmental pollution or global warming. Therefore it was necessary for scientists to interact fully with the industry and development of wood-based panels and also search for the inclusion of this waste within the panels in any structure, whether direct or after treatment. Agricultural residues are still in the research area only has entered the industry in productivity and this is what led us to search for the production of timber application of agricultural residues. Therefore the objective of this research is to study the following:

1- Manufacture of pulping process.
2- Separating of salts, lignin and impurities from pulping.
3- Manufacture of wood from agriculture waste (rice straw).
4- Study of alternative die pressure on the manufacturing.
5- Study of alternative resin ratio on the manufacturing

Thus, the work in this area lies not in how to produce timber applications are valid, but difficult in the nature of the mechanical and chemical processing of raw material before the start of attempting to produce wood panels as a vehicle for agricultural residues.

2. PARTICLEBOARDS MANUFACTURING AND EXPERIMENTAL METHODOLOGY

In the present work the manufacture of wood from agriculture waste were carried out using tool shown in the following.

2.1 The die

The die consists of three main part are upper, lower plate and frame as shown in Fig. 2.

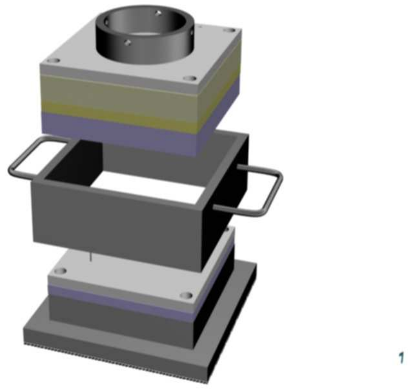

Fig. 2. The die used for Manufacture of wood from agriculture waste

2.1.1 Upper or lower plate

the lower or upper plate are used for heating the die and connecting with Digital temperature unit, Tool made from steel, the upper part of the tool design to mount into the piston of the hydraulic pressing machine and the lower part set into base of machine .

2.2 The hydraulic pressing machine

The work included in this machine is carried out by the author under the supervision of the supervisors and technical people. The hydraulic pressing machine used for Manufacture of wood from agriculture waste is shown in Fig. 3.

Fig. 3. Hydraulic pressing machine used for Manufacture of wood from agriculture waste (rice straw)

2.3 Raw Material

The agricultural lignocellulosic fibers used in this paper were rice straws. After removing the top 10 cm the rice straw stalks were cut into three sections top, center and bottom, the rice straw particle was prepared by cutting each of the sections of the rice straw into 2 or 4 cm lengths. The particle width depended on the native straw stem, which was wider at the bottom than at the top.

Commercial UF resin adhesive (65 wt. % of solid content) was used as the composite binder added with 10 wt. % NH_4Cl solution as a hardener [19].

2.4 Characterization of the raw material

The chemical properties of rice straw were determined as the following:

Table 1, The chemical properties of rice straw

composition	cellulose	Hemi-cellulose	Lignin	Ash	Silica
Unit %	32-47	19-27	5-24	13-20	9-14

Information on the chemical compositions of rice straw is important in order to understand the particleboards’ physical and mechanical properties. Actually, particleboards that have high lignin content will be rather stronger with a high water-resistance. Also, higher hemi-cellulose ratio will decrease boards’ water-resistance property, but increases the particleboards’ self-binding properties [5].

2.5 Pulping

Pulping is the process of converting wood or nonwood material to separated pulp fibers for paper making. Processes range from mechanical, in which the wood is ground into fibers by disk refiners or grindstones, namely: stone ground wood, pressurized ground wood, refiner mechanical pulp, thermo mechanical pulp to chemical, in which the fibers are separated by chemically degrading and dissolving, namely: soda pulp, sulphite pulp, sulphate (Kraft) pulp and semi-chemical pulps. This study will concentrate on thermo mechanical pulp for the production of MDF and Kraft pulp [5].

The raw material was cooked in a 15 L batch reactor that was heated by an outer jacket containing electrical wires. The reactor contents were stirred by rotating the reaction vessel via a motor connected through a rotary axle to a control unit including the required instruments for measurement and control of die pressure and temperature.

Rice straw was placed in the reactor together with the classic reagents (soda, soda–antraquinone, soda–parabenzoquinone, potassium hydroxide and Kraft process) and pulped by using a reagent concentration, temperature, cooking time and a liquid/solid ratio determined. Following pulping, the cooked material was washed to remove residual cooking liquor and fibreized in a disintegrator at 1200 rpm for 30 min, after which the pulp was beaten in a Sprout–Bauer refiner and the fibreized material passed through a screen of 0.16 mm mesh size in order to remove uncooked particles.

Finally, the pulp was drained in a centrifuge and allowed to dry to a moisture content of ca. 10% at room temperature [17].

2.6 Separating of salts, lignin and impurities from pulping

The pulp is washed with water to wash out the cooking chemicals and lignin from the fiber, so that they do not interfere with further processing steps. A sieve is used to remove knots and clumped-together uncooked fibers from the pulp. Bleaching commonly used to increase the brightness of pulp, largely removes lignin from wood fibers. This is done in two stages. Firstly, the pulp is treated with NaOH in the presence of O2. The NaOH removes hydrogen ions from the lignin and O2 breaks down the polymer. Then, the pulp is treated with ClO2, then a mixture of NaOH, O2 and peroxide and finally, again with ClO2 to remove the remaining lignin.

2.7 Board preparation

The 1^{rst} step is to calculate the quantity of fibers according to the desired mixture ratio for making board size of 350 × 350 × 10 mm^3. In this study, six mixing ratio are considered as follows (12:100,15:100,20:100,30:100,40:100,50:100) UF and rice straw by weight, respectively. Adhesive Urea–formaldehyde (UF) and paraLn wax emulsion 1% were sprayed on particles in a rotating drum blending machine with air–atomization nozzle.

Fig. 4. Separating of salts, lignin and impurities from pulping

Fig. 5. Cross sections of the board used.

Fig. 6. The upper and lower surface of the board used (rice straw).

The blended particles were formed by hand using a forming box. After forming, the mat was prepressed by hand and covered with TeMon sheets on both the top and bottom surfaces then transferred to a single-opening hydraulic hot press with platen temperature of 160◦C. Then a three step-down method of pressing die pressure was applied for manufacturing the boards. The total pressing time was 10 minute [16].

2.8 Wetting and penetration in general

For a bond to form the adhesive needs to wet and flow over a surface, and in some cases penetrate into the substrate. It is important to understand that the terms mean different things even though they sound familiar. Wetting is the ability of an adhesive drop to form a low contact angle with the surface. In contrast, flow involves the adhesive spreading over that surface under reasonable time. Flow is important because covering more of the surface allows for a stronger bond. Thus, a very viscous adhesive may wet a surface, but it might not flow to cover the surface in a reasonable time frame. Penetration is the ability of the adhesive to move into the voids on the substrate surface or into the substrate itself. The filling of the lumens has long been one measure of penetration, but penetration can also involve the movement of the adhesive into the cell wall. The difference between flow, penetration, and transfer are illustrated in Fig. 7.

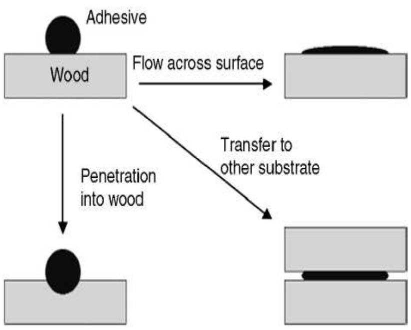

Fig. 7. Adhesive wetting of wood surfaces, showing the difference between flow, penetration, and transfer [15]

2.9 Wood composites manufacturing process

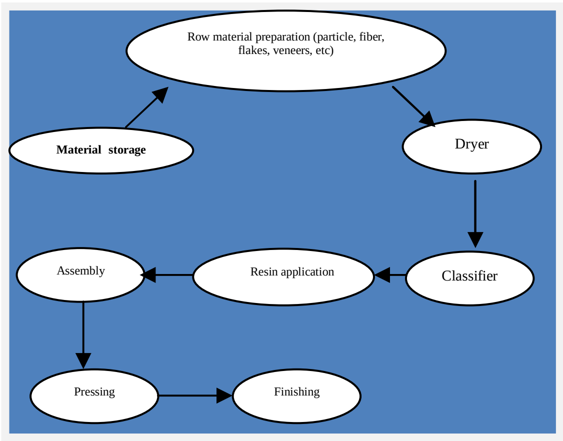

Fig. 8. A typical wood composites manufacturing process.

2.10 Physical properties

Moisture content and specific gravity were examined using the ASTM D 1037-99 (American Society for Testing and Materials, 1999) method. Each value represents the average of five samples.

2.11 Mechanical properties

3-point bending strength was determined using a Universal Testing Machine (at Engineering faculty - Tanta University) using the ASTM D 1037-99 (American Society for Testing and Materials, 1999) method. Each value represents the average of five samples.

3. RESULTS AND DISCUSSION

For each particleboard mixing ratio and density, five samples were manufactured.

3.1 Effect of die pressure and UF on thickness:

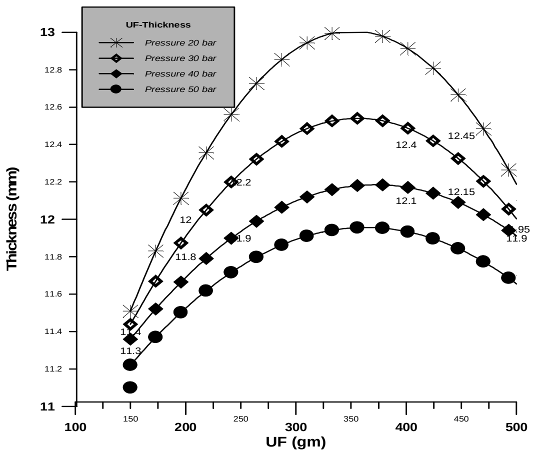

Fig. 9. Effect of die pressure on thickness of the rice straw composite

Figure 9, shows that the thickness is inversely proportional to the increase of the die pressure, but varies following the particleboards' UF. For the same board thickness, light particleboards (low density or low pressure) have low UF than heavy particleboards (high density or high pressure). This result in range up to 350 gm of UF binder and over 350 the result is exchanged. Consequently, high - pressure particleboards will have a low thickness value, while low - pressure particleboards will have a high thickness value, finally the maximum thickness at varies pressure at 350 gm UF.

3.2 Effect of die pressure and UF on the density

Figure 10, shows that the density is proportional to the increase of the die pressure, but varies following the particleboards' UF. For the same board UF, light particleboards (low pressure) have low density than heavy particleboards (high pressure). Consequently, high - pressure particleboards will have a high density value, while low - pressure particleboards will have a low density value, finally the maximum and minimum density at varies pressure at 500 gm and 150 gm UF respectively.

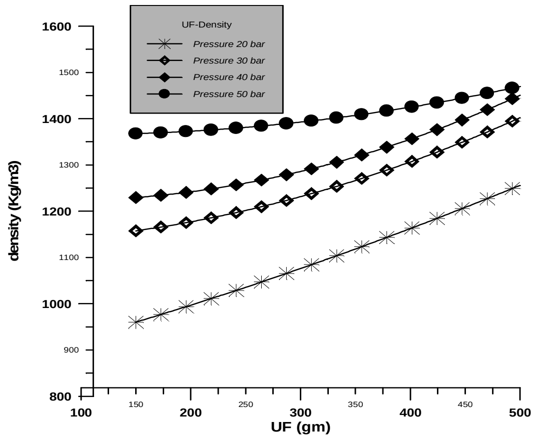

Fig. 10. Effect of die pressure on the density of the rice straw composite

3.3 Effect of die pressure and UF on the bending stress

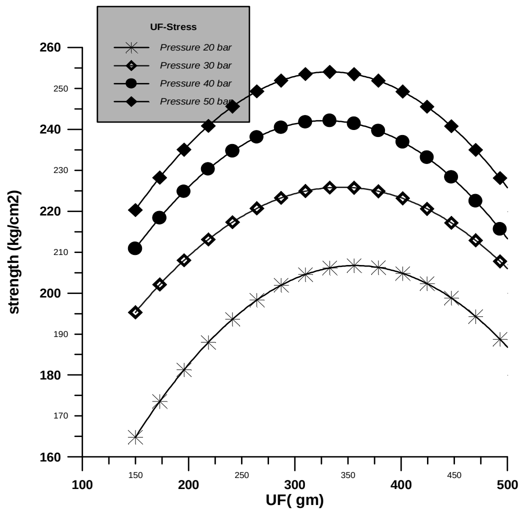

Fig. 11. Effect of die pressure on The bending modulus of rupture (MOR) of the rice straw composite

The bending modulus of rupture (MOR) of the rice straw composite boards shown in Fig.11. Bending MOR increased slightly with the UF increase. Composites with 350 gm UF showed better bending MOR, and this was in agreement with results previously obtained, a slightly better bending MOR was shown in the composite prepared with 350gm UF and although slightly low, MOR was not different in the composite prepared with 200 and 500 gm. Therefore, the maximum and minimum stress at varies pressure at 350 gm and (200 or 500) gm UF respectively. At 500 gm the stress is low due to the material is very brittle.

3.4 Effect of UF and pressure on thickness

Figure 12, shows that the thickness is inversely proportional to the increase of the die pressure, but varies following the particleboards' UF. For the same board thickness, light particleboards (low density or low pressure) have low UF than heavy particleboards (high density or high pressure). This result in range up to 50 bar of die pressure. Consequently, high - pressure particleboards will have a low thickness value, while low - pressure particleboards will have a high thickness value, finally the maximum and minimum thickness at varies pressure at 300 gm and 500 gm UF respectively.

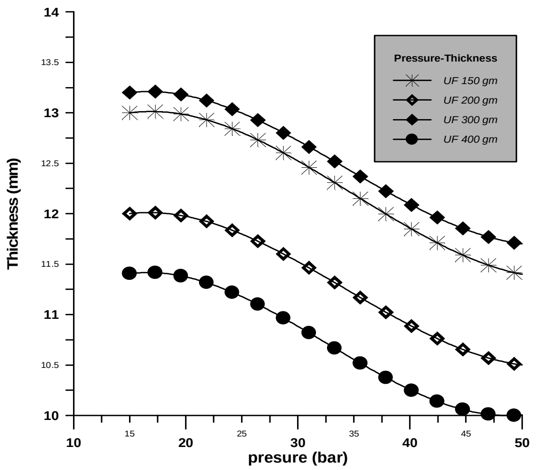

Fig. 12. Effect of UF on thickness of the rice straw composite

3.5 Effect of UF and pressure on density

Figure 13, shows that the density is proportional to the increase of the die pressure, but varies following the particleboards' UF. For the same board UF (any value), light particleboards (low pressure) have low density than heavy particleboards (high pressure). Consequently, high - pressure particleboards will have a high density value, while low - pressure particleboards will have a low density value, the density is convert from diverge to converge at 15 bar and 50 bar respectively. Finally the maximum and minimum density at varies pressure at 500 gm and 150 gm UF respectively.

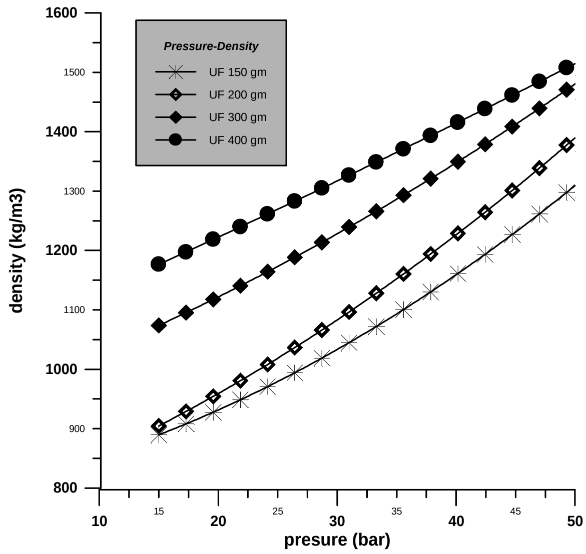

Fig. 13. Effect of UF on the density of the rice straw composite

3.6 Effect of UF and pressure on bending stress

The bending modulus of rupture (MOR) of the rice straw composite boards shown in Fig.14. Bending MOR increased slightly with the UF increase. Composites with 300 gm UF showed better bending MOR, and this was in agreement with results previously obtained, a slightly better bending MOR was shown in the composite prepared with 300gm UF and although slightly low, MOR was not different in the composite prepared with 200 and 500 gm.

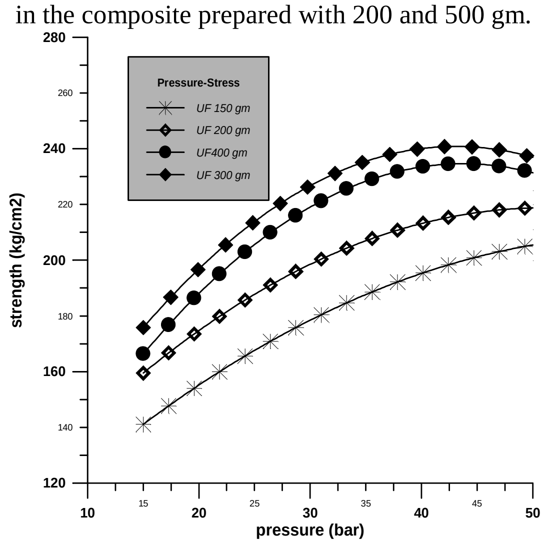

Fig. 14. Effect of UF on the bending modulus of rupture (MOR) of the rice straw composite

Therefore, the maximum and minimum stress at varies pressure at 300 gm and (200 or 500) gm UF respectively. At 500 gm the stress is low due to the material is very brittle.

4. CONCLUSION

The experimental investigation indicated that the optimum particleboard properties are obtained with a 350 gm UF, pressure 40 bar, 12 mm thickness, the bending modulus of rupture (MOR) of the rice straw composite is 240 kg/cm^{2}and a density of 1250 kg/m^3. When the intended use of these particleboards is as wood panels.

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