PREPARATION AND PROPERTIES IMPROVEMENT OF WOODFLOUR-POLYMER COMPOSITES MADE FROM POLYPROPYLENE AND WOOD INDUSTRIES WASTES

Part 1 : Effect of Sawdust-Recycle Polypropylene Ratio and Particle Size on the Physical and Mechanical Properties of Composites

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木材加工工場の木屑とポリプロピレンとによる木粉ポリマーボードの製造と材質改良

Part 1：木屑－ポリプロピレン配合割合と木片の大きさがボードの物理的・機械的性質に及ぼす影響

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要旨

研究の目的

この研究は、リサイクルポリプロピレンと木屑からつくる、リサイクル可能で、優れた物理的・機械的性質を有する新しいタイプのパーティクルボードを開発することを目的とする。

結論

1．パーティクルボードの物理的・機械的性質は、木屑とリサイクルポリプロピレンとの配合比に最も影響を受けた。

木屑の割合が低くなると、含水率、吸水、厚さの膨張、曲げ強度、曲げヤング係数、内部接着力、ねじ釘保持力が低くなった。優れた機械的性質のボードをつくるための木屑の限界割合は40%であった。

2．パーティクルボードの物理的・機械的性質は、密度及び厚さの膨張を除いて、木片の大きさの影響を受けた。細かい木屑のボードは、含水率、吸水性が高く、機械的性質（曲げ強度、曲げヤング係数、内部接着力、ねじ釘保持力）は低かった。

3．この研究におけるパーティクルボードの密度、含水率、吸水率、厚さの膨張、内部接着力、ねじ釘保持力等の物理的・機械的性質はJIS基準を満たした。

4．20メッシュの木屑40%、リサイクルポリプロピレン60%の配合比が、物理的・機械的性質最良のパーティクルボードであった。

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I. INTRODUCTION

I. 1. Background

Wood is not only a renewable and a biodegradable resource, but also predominant source of lignocellulosic materials most extensively used in the decoration and in the furnitire industries. The insatiable world demand for good quality timber has led to destructive logging of tropical hardwood forest in many developing countries and gave rise serious global concern. As rain forest supplies shrink, while development accelerates, it is expected to lead to a sharp rise in the cost of natural timber products in the near future.

Although timber substitutes in the form of particleboard and fiberboard are available, these products are generally of mediocre mechanical performance and can not meet the standard required for wide application in construction and industrial processes[1,4,5,6]. Thus, there is an increasingly urgent need for developing high industrial and business development, with due regard for the world environment.

On the other hand, a huge amount of wood–based waste and plastic are produced every year the forest, wood-related industry, agricultural applications, housing etc. These wastes are mostrly utilized as relatively valueless products or mostly burned without meaningful utilization and become a problem for the environment. Recycling and efficient use of these resources are proposed as a desirable way to minimize the negative impact to the environment.

The 1990s have witnessed a burgeoning interest in the development of industrial and consumer products that combine wood and other raw materials, such as plastics, gypsum, concrete, to form composite products with unique properties and cost benefits.

The primary impetus for developing these products has come from one or more of the following R & D goals[7]:

1. To reduce material costs by combining a lower cost material (acting as a filler or extender) with a high-cost material;
2. To develop products that can utilize recycled materials and have the products themselves be recyclable; or
3. To produce a composite product that exhibits specific properties that are superior compared to either of the component materials alone (e.g., increased strenth-to-weight ratio, improved abrasion resistance, etc.).

Among these, moldable wood-polymer composites from cellulosic and lignocellulosic materials with synthetic polymers have already been used as industrial products in some countries such as Japan and USA.

The kinds of synthetic polymers that can be used, however, are limited by the relatively low starting temperature for the thermal decomposition of wood (about 200°C. One example is the polyolefins, including high density polyethylene (HDPE), polypropylene (PP) and normal (PS) and impact-modified polystyrene (SB). These polyolefins are suitable because of their relatively low prices and moldable temperatures. These polyolefins also have good physical and chemical properties and are useful as fibers, films, and othe moldable materials[3].

It is apparent , however, that affinity and adhesion between polyolefins and wood are poor; the former is hydrophobic and the latter has hydrophylic cellulose and hemicellulose in quantities of 65-75%. Accordingly, blended composites of these tend to have disadvantages in thermal flow ability and moldability and in unsatified reinforcement caused by the wood filler. With this perspective, coupling or compatibilizing agents have been tested in order to improve dispersion, adhesion and compatibility for the system. These agents can modify the interface by interacting with both the fiber and the matrix, thus forming a link between the component. It has been reported in the literature [1,2,3,6] that maleic anhydride (MAH) can be introduced into polymers, such as polypropylene (PP), polyethylene (PE), trans-1,4-isoprene rubber, and acrylonitrile butadiene styrene (ABS) through radical coupling addition to form MAH-modified polymer in the presence and/or in the absence of peroxide. Then, the MAH-modified polymer can further react with the polymer having –OH or NH2 end-groups to form long chain graft copolymers that can be used as compatibilizers of the polymer blends. MAH introduced in this way into synthetic polymers has been proved to form ester linkages when reacting with hydroxy groups on the woodflour interface.

In order to achieve high quality composite of wood waste and recycled polypropylene (high dimenstional stabilization and high strength), the first part of this research about " Effect of sawdust-recycle polypropylene ratio and particle size on the physical and mechanical properties of composites" were investigated.

I. 2. Objectives

To develop a new type of recycleable composite products made from recycle polypropylene and sawdust with excellent physical and mechanical propeties.

II. MATERIAL AND METHODS

II.1. Materials

Wood waste of *Paraserianthes falcataria* in the form of saw dust (± 20 - 100 mesh size) was collected from sawmill industries located in Jasinga, Bogor and used as filler, while recycle polypropylene (PP) was purchased from Usaha Bersama Co. located in Semplak Bogor and used as matrix. Sawdust was dried to 7-9% moisture content.

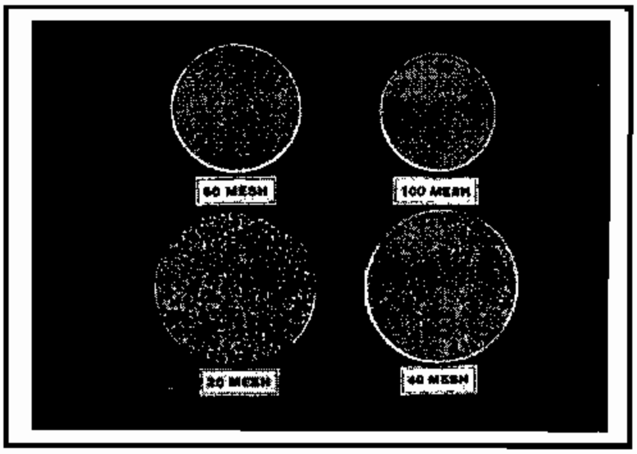
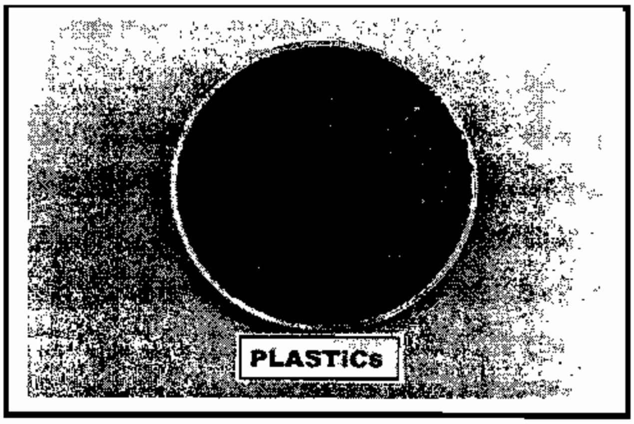


Figure 1. Raw materials (sawdust and recycle PP)



II.2. Methods

II.2.1. Mixing of wood waste and recycle PP

Recycle PP and wood waste in the ratio of 70 : 30 to 40 : 60 was hand-mixed. This mixture was then placed to the haul (35 cm x cm size). Three layer particleboard was made. The first and the third layer (face and back) containned only recycle PP with the amount of 15 %, and the rest about 70% of recycle PP was mixed with sawdust for the core (second layer).

II.2.2. Composite production

The mixture of wood waste and recycle PP were pressed by hot pressing. The temperature of the hot press was 170 °C , and subjected to 0-150 kgf/cm^2 pressure for 25 min. The composites were then conditioned at room temperature for 1 week.

II.2.3. Mechanical properties evaluation

The mechanical properties of composites i.e., modulus of elasticity, modulus of rupture, internal bond, and screw holder were measured from each composite with at least 4 repeated measurements.

II.2.4. Physical properties evaluation

The physical properties of composites i.e., density, water absorption and thicknes swelling were measured from each composite with at least 4 repeated measurements.

III. RESULTS AND DISCUSSIONS

III. 1. Physical Properties

III.1.1. Moisture content (MC)

The lowest and the highest moisture content (MC) of the composites was 2 and - 6% , respectively, with the average value was 4%. The lowest and the highest MC were achieved by the particleboard composed of sawdust and recycle PP ratio of 30/70% with particle size of 20 mesh, and sawdust and recycle PP ratio of 60/40% with particle size of 60 mesh, respectively. All the MC of the particleboards produced in this experiment were below the MC of *JIS A 5908* (5-13%). The average value of MC under various sawdust-recycle PP ratio and particle size were presented in Fig. 2.

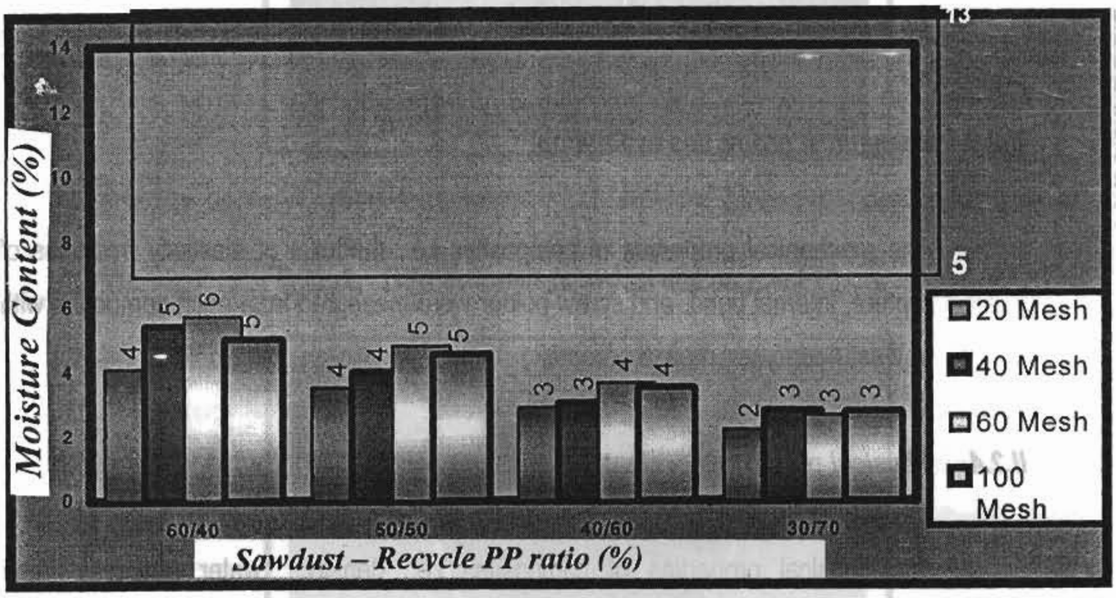


Figure 2. Moisture content of particleboard prepared under various sawdust - recycle PP ratio and particle size

III.1.2. Density

The value of particleboard density was in the range of 0.70 – 0.76 gr/cm³ with the average of 0.73 gr/cm³. According to *JIS A 5908* standard, these particleboards were classified to the medium density particleboard (0.40 gr/cm³ – 0.90 gr/cm³). The particleboard density prepared under various sawdust-recycle PP ratio and particle size were presented in Fig. 3.

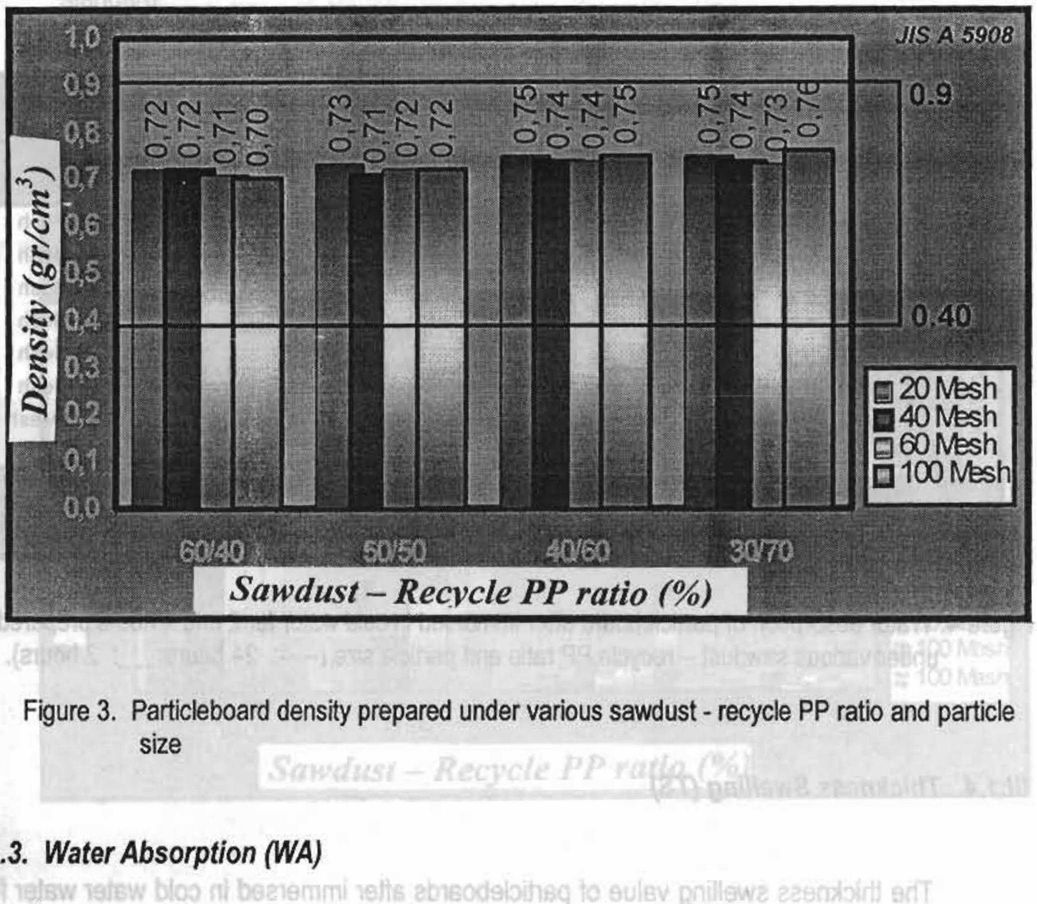


Figure 3. Particleboard density prepared under various sawdust - recycle PP ratio and particle size

III.1.3. Water Absorption (WA)

The water absorption of particleboards after immersed in cold water for 2 hours and 24 hours were in the range of 1.59 – 43.25%, with average of 16.07%, and in the range of 6.70 – 55.38% with the average of 9.55%, respectively (Figure 4). The value of water absorption both after 2 hours or 24 hours immersed in cold water showed similar phenomenon. It decreased with increased the proportion of recycle PP in the composites. Furthermore, the composites produced from smaller particle size tend to show the higher water absorption. The lowest water absorption was achieved by the particleboard composed of 30% sawdust and 70% recycle PP with particle size of 20 mesh, while the highest water absorption was achieved by the particleboard composed of 60% sawdust and 40% recycle PP with particle size of 100 mesh. PP is hydrophobic, while sawdust is hydrophillic. Thus, composites with higher amount of PP tend to absorb less water.

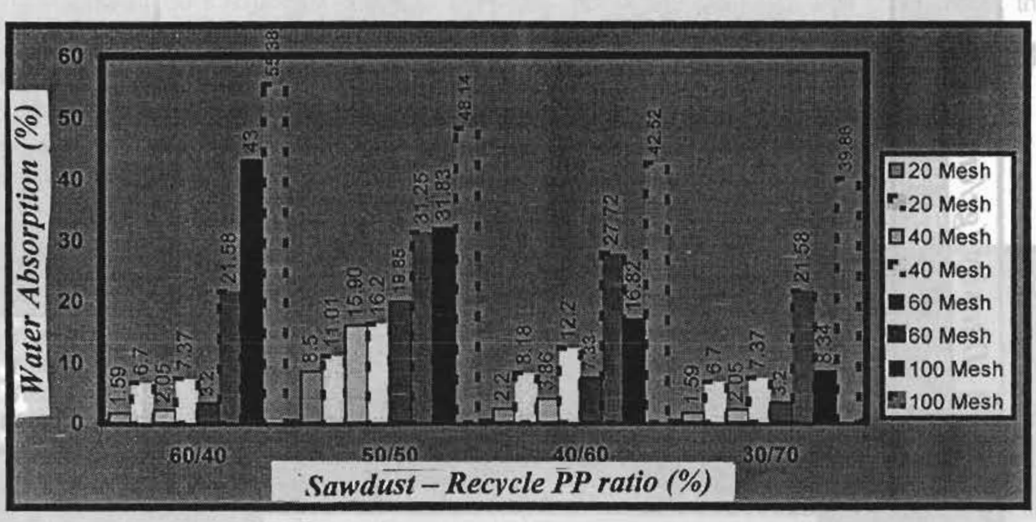


Figure 4. Water absorption of particleboard after immersed in cold water for 2 and 4 hours prepared under various sawdust – recycle PP ratio and particle size (-----: 24 hours;___: 2 hours).

III.1.4. Thickness Swelling (TS)

The thickness swelling value of particleboards after immersed in cold water water for 2 and 24 hours were in the range of 0.06 % - 8.20% with the average of 2.53%, and in the range of 0.38% - 9.60% with the average of 3.27%, respectively. As a whole the thickness swelling of particleboard after immersed in cold water for 2 and 24 hours prepared under various sawdust-recycle PP ratio and particle size are shown in Fig. 5.

The lowest thickness swelling value was achieved by the particleboard prepared from 30% sawdust and 70% recycle PP with particle size of 20 mesh, while the highest one was achieved by particleboard composed of 60% sawdust and 40% recycle PP with particle size of 100 mesh. According to *JIS A 5908* thickness swelling value maximum was 12 %. Based on the data mention above all the thickness swelling value of the particleboard produced in this experiment met the requirement of *JIS A 5908* standard.

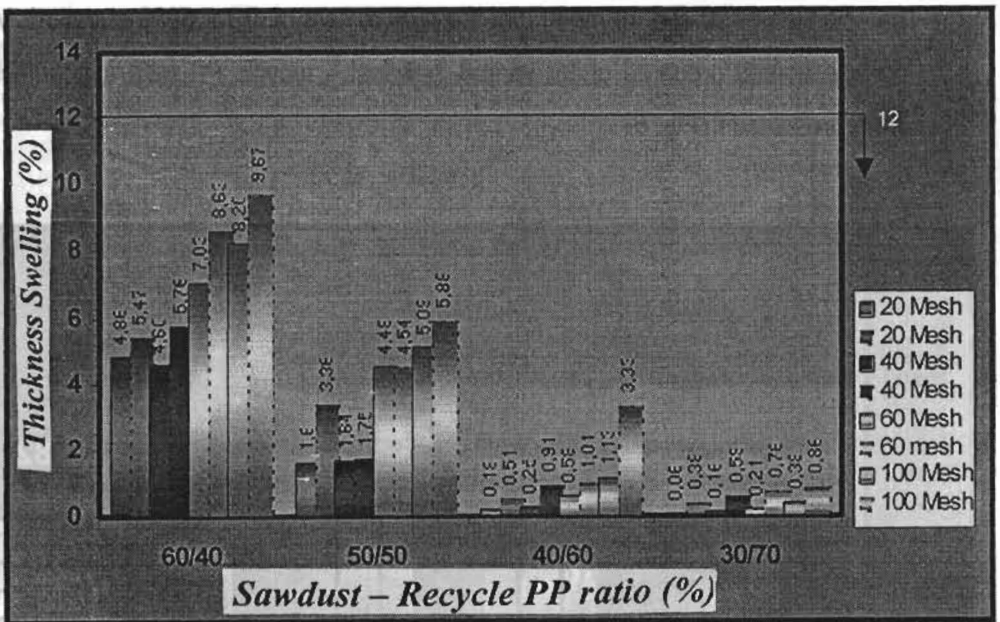


Figure 5. Thickness swelling of particleboard after immersed in cold water for 2 and 24 hours prepared under various sawdust – recycle PP ratio and particle size (----: 24 hours; ____: 2 hours)

III.2. Mechanical Properties

III.2.1. Modulus of Rupture (MOR)

The modulus of rupture (MOR) of the particleboards were in the range of 29.79 to 95.22 kg/cm^2 with the average of 65.20 kg/cm^2. The lowest MOR was achieved by the particleboard composed of 60% sawdust and 40% recycle PP with the particlesize of 100 mesh, while the the highest one was achieved by the particleboard prepared from 30% sawdust and 70% recycle PP with the particle size of 20 mesh. The minimum value of MOR based on *JIS A 5908* standard was 82 kg/cm^2. Most of MOR value of the particleboards produced in this experiment were below 82 kg/cm^2. The particleboard composed of 30% sawdust and 70% recycle PP with particle size of 20 mesh, and particleboards composed of 40% sawdust and 60% recycle PP both with particle size of 20 and 40 mesh met the requirement of JIS A 5906 standard. MOR of particle boards prepared under various sawdust – recycle PP ratio and particle size were presented in Fig. 6.

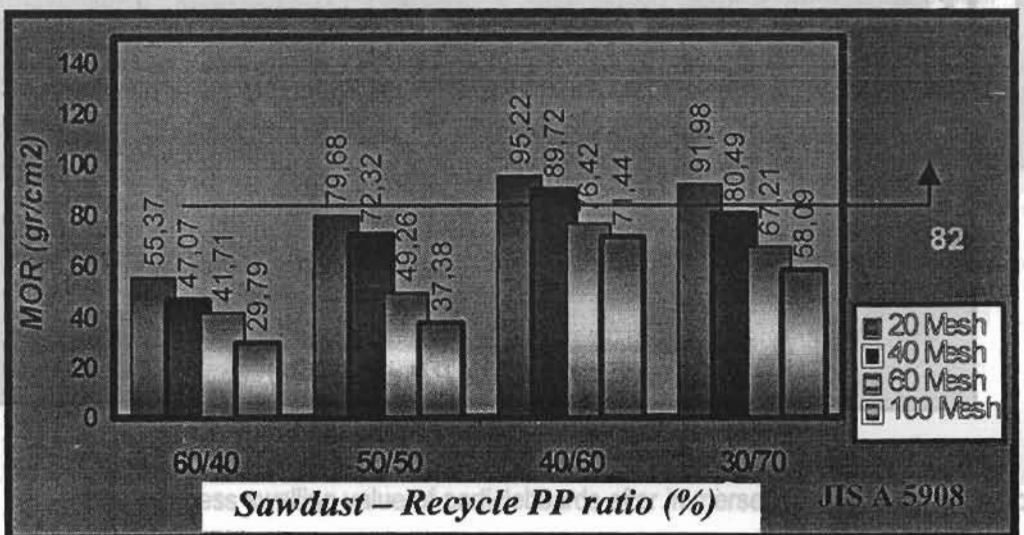


Figure 6. MOR of particleboard prepared under various sawdust – recycle PP ratio and particle size

III.2.2. Modulus of Elasticity (MOE)

The modulus of elasticity (MOE) of the particleboards were in the range of 5110 to 10360 kg/cm^2 with the average of 7944 kg/cm^2. The lowest MOE was achieved by the particleboard composed of 60% sawdust and 40% recycle PP with the particlesize of 100 mesh, while the the highest one was achieved by the particleboard prepared from 40% sawdust and 60% recycle PP with the particle size of 40 mesh. The minimum value of MOE based on JIS A 5908 standard was 20400 kg/cm^2. All the MOE valueof particleboards prepared in this experiment were lower than MOE value of the JIS A 5908 standard. MOE of particle boards prepared under various sawdust – recycle PP ratio and particle size were presented in Fig. 7.

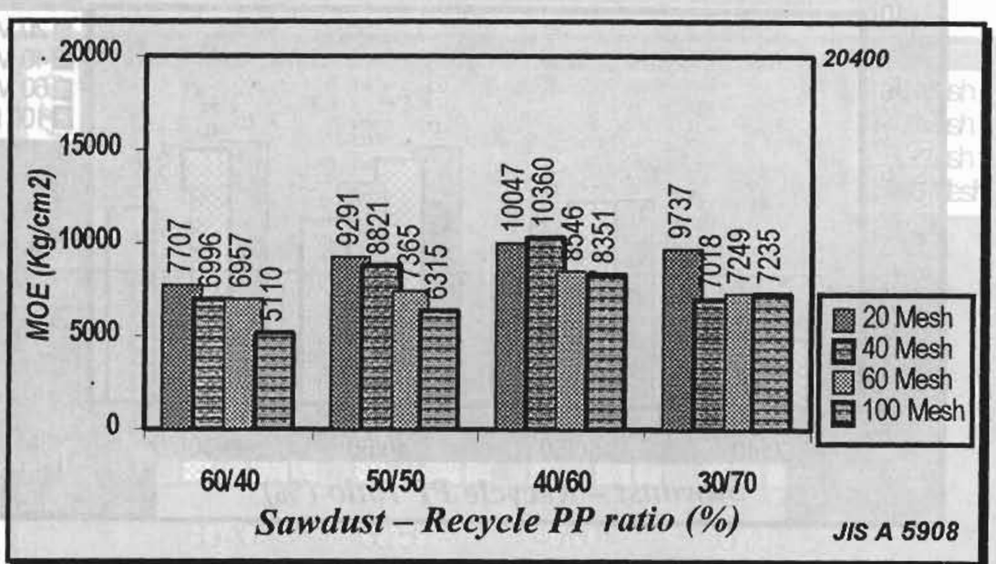


Figure 7. MOE of particleboard prepared under various sawdust – recycle PP ratio and particle size

III. 2.3. Internal Bond, (IB)

The internal bond (IB) of the particleboards were in the range of 0.26 to 6.63 kg/cm^2 with the average of 4.38 kg/cm^2. The lowest MOE was achieved by the particleboard composed of 60% sawdust and 40% recycle PP with the particlesize of 100 mesh, while the the highest one was achieved by the particleboard prepared from 30% sawdust and 70% recycle PP with the particle size of 20 mesh. The minimum value of IB based on JIS A 5908 standard was 3.01 kg/cm^2. Most of IB value of the particleboards produced in this experiment, particularly for particleboards composed of 30 to 50% sawdust met the requirement of the JIS A 5908 standard. IB of particle boards prepared under various sawdust – recycle PP ratio and particle size were presented in Fig. 8.

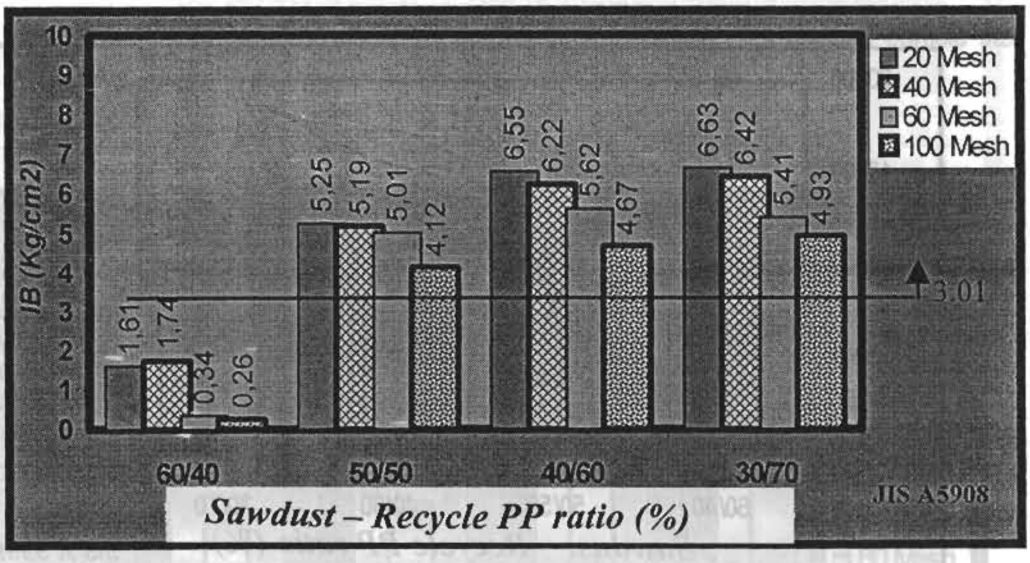


Figure 8. Internal bond of particleboard prepared under various sawdust – recycle PP ratio and particle size

III.2.4. Screw Holding Power (SHP)

The screw holding power (SHP) of the particleboards were in the range of 20 to 58 kg with the average of 42 kg. The lowest SHP was achieved by the particleboard composed of 60% sawdust and 40% recycle PP with the particlesize of 100 mesh, while the the highest one was achieved by the particleboard prepared from 30% sawdust and 70% recycle PP with the particle size of 20 mesh. The minimum value of IB based on JIS A 5908 standard was 31 kg. Most of IB value of the particleboards produced in this experiment, particularly for particleboards composed of 30 to 50% sawdust met the requirement of the JIS A 5908 standard. SHP of particle boards prepared under various sawdust – recycle PP ratio and particle size were presented in Fig. 9.

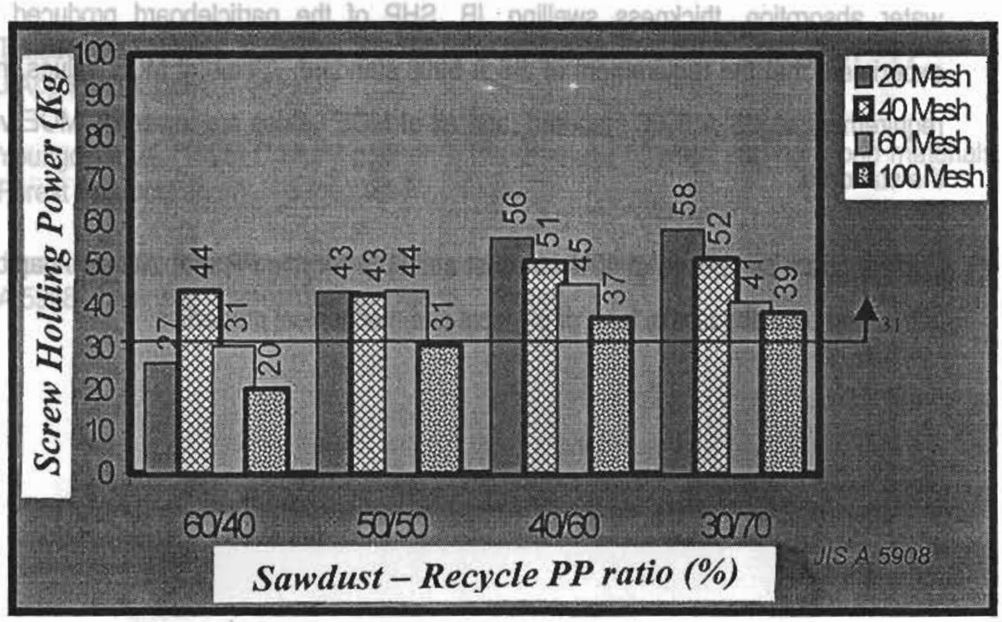


Figure 9. Screw holding power of particleboard prepared under various sawdust – recycle PP ratio and particle size

IV. CONCLUSION

1. The physical and mechanical properties of particleboard greatly affected by the ratio of sawdust and recycle PP. The lower the sawdust proportion in the composites resulted in the lower moisture content, water absorption, thickness swelling, MOR, MOE, IB, and SHP of the particleboard. To achieved great mechanical properties, the limit proportion of sawdust was 40%.

2. The phisical and mechanical properties except density and thickness swelling of particleboard also greatly affected by the particle size. The more fine the sawdust resulted in the greater moisture content and water absorption, and the lower the mechanical properties (MOR, MOE, IB, and SHP).

3. The physical and mechanical properties of particleboard i.e., density, moisture content, water absorption, thickness swelling, IB, SHP of the particleboard produced in this experiment met the requirement of JIS A 5908 standard. Some of MOR values met the requirement of JIS A 5908 standard, and all of MOE values are lower the MOE value of the standard.

4. Particle board composed of 40% sawdust and 60% recycle PP with 20 mesh particle size is the best particleboard in term of physical and mechanical properties.

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