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RESEARCH ARTICLE - MECHANICAL ENGINEERING

Analysis of the Physical Properties and Hardness of Teak Wood-Reinforced High-density Polyethylene and Polycarbonate Composites Produced Through Injection Moulding Technology

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Environmentally friendly materials have become an important topic in practical research due to their importance to people's lives and the preservation of the environment. The use of wood plastics is of utmost importance in this field, as it is possible to obtain materials with properties that combine the strength of polymers with the properties of wood. The goal of the current study is to enhance wood-plastic composites by incorporating high-density polyethylene (HDPE), Polycarbonate (PC), and teak wood to improve their hardness and physical properties. An injection molding machine is used to prepare the samples. The Taguchi method is adopted to test the experimental design and three independent variables including teak wood particle size, weight %, and PC content. Samples are tested for water absorption, swelling thickness, density, and Shore D hardness. The findings show that an enlarged teak wood composition can result in greater water absorption and increased swelling thickness. However, the incorporation of PC added in the ratio of 7.5–15% of PC can result in better dimensional stability and decreased water absorption. Wood and PC are also added, which enhance the hardness with respect to pure polyethylene. Through Taguchi method analysis indicate that teak wood content is the most contributing factor towards these properties, followed by PC content and particle size, being least. The results also show that the model L7 type can provide the most balanced performance against mechanical and physical properties. It can be observed from the present work that the wood-plastic composites used have good mechanical properties and good moisture resistance, and are highly suitable for sustainable engineering applications.

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Keywords: Wood Plastic Composite; Water Absorption; Swelling Thickness; Density; Hardness; Injection Molding Technology.

1. Introduction

In recent decades, industrial products have seen significant improvements in functional performance due to the increased use of composite materials, particularly polymers. Polymers reinforced with natural materials, such as wood fibers, have emerged as popular and cost-effective solutions due to their lightweight nature, low cost, and recyclability. In this context, natural materials, including wood fibers and plant powders, have garnered increasing attention for their integration into thermoplastic polymer reinforcement to develop environmentally friendly materials that meet the demands of industrial sustainability.

With the growing interest in green production, wood-plastic composites (WPCs) have become a focus of numerous studies, combining the aesthetic appeal of wood with the durability and functional requirements of plastics. However, these composites still face challenges related to component compatibility and balancing mechanical and thermal properties. Recent studies have shown that the performance of these composites is influenced by several factors, including the type of natural material used, loading ratio, particle size, binder type, and manufacturing conditions. This highlighted the need for systematic studies to understand the impact of these factors and improve the properties of the resulting composites.

Guo et al. (2019) [1] analyzed the effect of wood fiber ratios and mix composition on the thermal stability of composites. The results showed that increasing the fiber content up to 60% can enhance dimensional stability and reduce the coefficient of thermal expansion. However, an excessively high fiber content can cause processing difficulties, highlighting the importance of balancing the wood-polymer ratio to improve WPC quality.

Al-Arkawazi et al. (2025) [2] investigated the mechanical properties, including the tensile strength, elongation at break, flexural strength, and impact resistance of the composite materials. The results and Taguchi analysis showed that teak wood can significantly improve flexural strength

Nomenclature & Symbols

PC	Polycarbonate	S/N	Signal-to-Noise Ratio
HDPE	High-Density Polyethylene	MA-PE	Maleic Anhydride Grafted Polyethylene
WA	Water Absorption	TS	Thickness Swelling

by more than 94.6% if compared to the pure HDPE composites. The effect of PC on the remaining properties was negligible. In terms of particle size, the best composite had 0% PC and 20% teak wood (1 to 1.5 mm particle size). These results demonstrated the best overall mechanical performance. More importantly, the teak wood has a high level of benefit in improving the flexural performance of HDPE panels, while PC content would not produce an economical performance value under the experimental conditions.

Zhang et al. (2020) [3] found that the thermal stability of lignocellulose fibers in PC composites is a critical source of limitations for the use of PC composites. To improve wood flour stability, boric acid treatment was applied. Esterification of wood flour/PC composites developed during extrusion (melt extrusion and injection molding). The researchers reported a 147.2% improvement in flexural modulus, creep resistance, and thermal properties with no change in flexural strength. The investigators found that boric acid modification protects lignocellulose from thermal degradation, thus leading to a high-performance PC bio-composites.

Zhang et al. (2021) [4] concluded that the mixing of PC, wood flour, and HDPE produces bio-composites with higher fire resistance and better mechanical properties. Extrusion technology was used to mix the materials, and injection molding was used to obtain test samples. The injection molding machine's cylinder temperature ranged between 200 to 220 °C, while the extruder and mold temperatures were set to 200 and 220 °C, respectively. Additionally, the concentration of MAPE (weight percentage) was kept constant at 4 wt.%. The researchers treated the wood flour with boric acid to improve thermal stability. Micro- or Nano-dispersed PC within HDPE matrix improved thermal stability and char residue by 6.7% (at 28% PC) while suppressing heat release during combustion. In addition, hybridization improved tensile strength by 27.7%, elastic modulus by 91.1%, flexural strength by 22.7%, and elasticity by 53.8%, producing durable, thermally stable, low-flammability bio-composites.

Zhang et al. (2022) [5] stated that thermoforming wood flour/HDPE/PC multilayer composites can enhance flame retard. Boric acid treatment lowered heat release and total heat output while increasing residue mass, though it reduced flexural strength. The tests showed that PC layers formed carbonaceous coatings, further reducing heat release and improving flexural strength. Excellent thermal and mechanical properties were achieved by the finite element analysis during a three-point bending test.

In 2024, Mitaľová et al. [6] investigated WPCs, which are polymer matrix reinforced cellulose-based composites with many additives. They indicated wood as the primary source of lignocellulosic fibers, mentioning the criteria for wood flour choice and storage, and morphological characteristics. Wood adds a cost benefit and an increase in stiffness, and the matrix choice is controlled to below 200 °C processing temperatures to avoid thermal decomposition. The researchers also discussed additives like binding agents and stabilizers, and mentioned that WPCs can be considerably used in automotive, construction, and aerospace sectors.

Vasiljevs et al. (2024) [7] reported the formation of discoloration, micro-cracks, and micro-plastic after two years of natural weathering on 50% WPCs made of 50% wood and 50% polypropylene (heat-treated and untreated), respectively. ATR-FTIR measurements suggested that various surface chemical alterations affected the roughness and hydrophobicity of the material. This indicated that with inadequate additives, WPC boards undergo rapid degradation of their aesthetics and physical properties, posing a negative impact on their environmental friendliness.

Yao et al. (2023) [8] studied WPC thermoforming by developing a "compolytics" approach that integrates materials analysis and manufacturing processes. This study contributed to establishing design principles for producing three-dimensional WPC products instead of their traditional linear forms, opening up broader engineering applications that require complex shapes and high-precision production.

An investigation of the mechanical, thermal, and flame-retardant properties of WPCs was conducted by Boztoprak et al. (2024) [9] via incorporating beech wood shavings with flame-retardant additives such as TBBPA and ATO. The study demonstrated that adding these materials can improve the composite's fire resistance without significantly affecting its mechanical properties, making this type of WPC suitable for applications requiring high safety standards, such as interior construction and aesthetic cladding.

Hassona et al. (2025) [10] developed an innovative approach to blending and manufacturing WPCs using low-density polyethylene with residual MDF powder as wood fibers. The new technique relied on separating the fibers from the plastic during the polymer melting stage to minimize heat-induced fiber degradation, followed by efficient blending. The researchers conducted water absorption and thickness-swelling tests, demonstrating that different fiber-polymer ratios (from 50:50 to 70:30) can be used depending on the desired product, while improving the composite's physical stability.

Chen et al. (2025) [11] presented advanced research on enhancing WPCs for high-performance structural applications. The researchers developed a co-extrusion technique with internal reinforcement using screws and GFRP components, resulting in a novel composite known as S-WPC. This composite exhibited high load-bearing capacity, excellent creep resistance, and significantly improved structural durability. These findings paved the way towards using WPCs in structural applications that were previously impossible.

Ayrilmis et al. (2025) [12] found that reinforcing HDPE polymer with a combination of barley straw flour and recycled glass powder can significantly improve its water absorption resistance and mechanical properties. Specifically, the 24-hour water absorption decreased from 8.38% to 2.2% with the addition of 15 wt.% of glass powder. These additions also enhanced thermal stability and increased the crystallinity index of the composite.

Paramasivam et al. (2025) [13] conducted a study on the mechanical and thermal properties of hybrid composites made from epoxy resin reinforced with natural fibers, specifically chicken feathers and Sesbania grandiflora fibers. The researchers revealed significant performance improvements, particularly in reduced water absorption. The optimal fiber ratio was 30%, with a 2:1 ratio of chicken feather fibers to Sesbania grandiflora. These findings highlighted the significant potential for developing environmentally friendly, sustainable materials.

Pandiarajan et al. (2025) [14] demonstrated that fibers from Aristida hystrix treated with nanoparticles can enhance the mechanical properties of polyester composites when used at a concentration of 5 wt.%. However, higher loadings can lead to particle agglomeration and reduced performance. The study also revealed that increasing the nanofiber content can influence water absorption and the overall lifespan of the composite. This highlighted the potential of these fibers for developing sustainable, high-performance materials suitable for lightweight structural applications in the automotive, aerospace, and marine industries.

The effects of alkaline treatment on the properties of sugar palm fiber-reinforced thermoplastic composites (SPFs) were explored by Bachtiar et al. (2025) [15]. Their study demonstrated that treating the fibers with a sodium hydroxide (NaOH) solution can improve the compatibility between the fiber and matrix, as well as increase the fibers' crystallinity and thermal stability. The optimal flexural strength was achieved with a 2% NaOH solution, while the maximum impact strength and thermal stability were attained with a 6% NaOH treatment. This research underscored the significance of chemical treatment in enhancing the performance of natural composites.

Similar composites and manufacturing methods were used in Al-Arkawazi et al. (2025) [16]. The mechanical properties, namely tensile strength, flexural strength, and impact resistance, were investigated, specifically focusing on replacing sawdust with walnut shells as a filler. This was accomplished to evaluate the possibility of using walnut shells in forming WPCs. The same proportion of PC combined with HDPE was maintained and a Taguchi Design of Experiments (DOE) approach was used. Multi-Criteria Decision Making (MCDM) analysis was used to determine the optimal composite formulation. The results showed that the composite with 0% PC and 20% walnut shells of a particle size of 1–1.5 mm can perform the best. The results also showed a good tensile strength and flexural strength as well as impact resistance, which supported the effective use of agricultural waste as a reinforcement in WPCs.

Based on the aforementioned studies, it is clear that most researchers focused primarily on the mechanical properties of WPCs, such as tensile strength, flexural strength, and impact resistance to evaluate the performance of these materials under variable mechanical stresses. However, there remains a lack of studies that comprehensively address the physical properties and hardness, despite their crucial importance in determining the material's behavior in practical applications, particularly in industrial applications that require stability and surface durability. Accordingly, this study aims to analyze the physical properties and hardness of teak composites reinforced with HDPE and PC and produced via injection molding. The study also seeks to understand the relationship between the composite's structure and the proportions of its components, and the impact of these factors on its physical performance. Indeed, this would improve the potential of these materials for various industrial applications and enhance their use as sustainable composites with improved properties.

2. Materials and Methods

2.1. Materials

The same materials used in the previous research work [2] were employed in the current study. The selected base material was HDPE (CRP100N), imported from an Iranian petrochemical company, with a density of 0.948 g/cm³ [17]. Teak wood was chosen as the filler material due to its availability in the local market, given its purity and high quality compared to other natural materials used in domestic production. The study aimed to evaluate the effect of teak particle size and weight percentage on the composite's properties. Additionally, PC (Lotte PC-1100, Korea) with a density of 1.2 g/cm³ [18] was used at various weight percentages, and maleic anhydride polyethylene (MA-PE) was added at 4 wt.% to improve the inter-compatibility of the components [19]. MA-PE served as a fixed compatibilizer based on existing literature [4, 20].

2.2. Design of experiments

The Taguchi method is a well-established statistical method that minimizes the number of experiments required to reach optimal performance at minimal cost and effort. The approach methodically organizes the variables of the experiment so that one can extract maximal data from a smaller set of tests. Therefore, it makes the design of experiments easier, makes efficient use of resources, and validates data to detect which attributes contribute most towards the outcome. Minitab software was also applied for the experiments and data analysis in the present study using the Taguchi approach [21-24]. Particle size, the weight percentage of Teak Wood, and the weight percentage of PC were the three main variables investigated in this study. All variables were assigned three levels. The criteria and levels used in the experimental design are shown in Table 1, while the Taguchi orthogonal matrix (L9) for conducting the experiments and studying the results is shown in Table 2. Means and signal-to-noise ratios (S/N) were determined for each set of factor levels depending on the type of response. For properties that were characterized as "larger is better," Eq. 1 was used. On the other hand, for the "smaller is better" characteristics, the signal-to-noise ratio was determined according to Eq. 2:

$$SN = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^{\frac{1}{2}}\right) \tag{1}$$

$$SN = -10\log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^{2}\right) \tag{2}$$

n: Number of observations or experiments for each set of factors.

y: measured value of the response in experiment (i).

These two equations illustrate the relationship between average performance and the dispersion of results. Higher S/N values indicate more stable performance and better quality under the specified operating conditions.

The S/N values and averages were then analyzed to determine the optimal levels for achieving the best performance. In the "larger is better" scenario, the level with the highest S/N value was selected, while in the "smaller is better" scenario, the lowest average value was identified as the optimal level. Main Effects Plots for both S/N values and means were created using Minitab software to illustrate the general trends of how each factor affects the response characteristic.

Table 1. Parameters and their respective levels

No.	1	2	3
PC wt.%	0	7.5	15
Teak Wood wt.%	20	30	40
Particle size mm	1.5 – 1	1 – 0.8	0.8 – 0.6

Table 2. Taguchi experiments levels for nine compounds

Models	PC wt.%	Teak Wood wt.%	Particle size mm
L1	0	20	1.5 – 1
L2	0	30	1 – 0.8
L3	0	40	0.8 – 0.6
L4	7.5	20	1 – 0.8
L5	7.5	30	0.8 – 0.6
L6	7.5	40	1.5 – 1
L7	15	20	0.8 – 0.6
L8	15	30	1.5 – 1
L9	15	40	1 – 0.8

2.3. Manufacturing of experimental specimens

The sample preparation procedures followed in this study were identical to those used in previous research [2]. Initially, Teak Wood was ground into fine particles using a Masala-Herb Grinder Machine (VI-1000(B), Spice Grinder) and then sieved through a mechanical sieve (Model: SY-200/SY-300) to achieve the desired particle size.

The ingredients were weighed using an extremely sensitive electronic balance to obtain nine samples of different compositions. In each instance, a twin-screw extruder was used for homogeneous mixing of the ingredients. The operating temperature was set between 170 °C and 185 °C, and the rotation speed was 110 rpm to ensure uniformity while not burning the wood particles. After extrusion, the resulting mixture underwent a granulation process using a plastic granulator (WIESER-MASCHINENBAU-GES.MB.H, A-8992-ALTAUSSEE), yielding homogenous granules. Finally, an injection molding machine (NBM HXF128) was used at a temperature of 185 °C and an injection pressure of 120 MPa to form the final laboratory specimens, which were used for mechanical and physical testing. Fig. 1 illustrates the experimental procedure diagram.

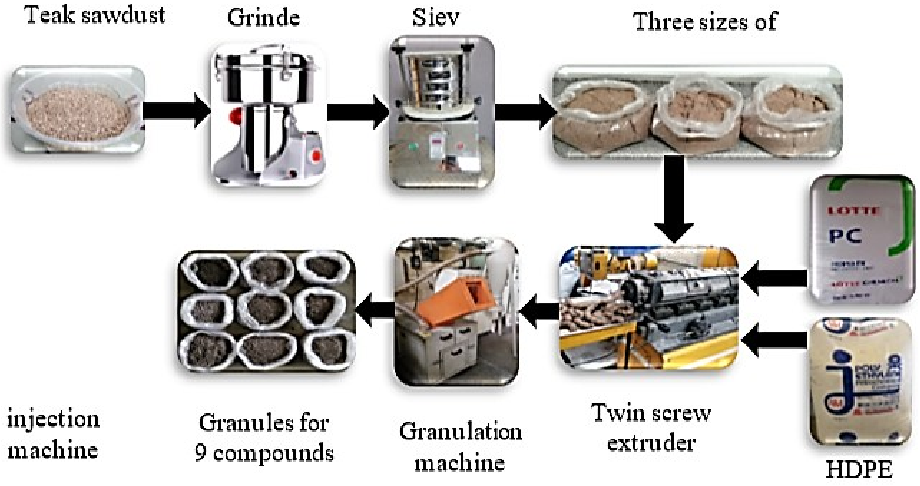

Fig. 1. Experimental procedure diagram

2.4. Characterization methods

Standard bending samples in accordance with ASTM D790 were utilized for these experiments, as illustrated in Fig. 2. The hardness of the samples was measured with a Shore D durometer. The weight was then measured with a precision balance (weight accuracy to 0.001 g) and thickness with a digital diameter gauge (0.01 mm). Samples were soaked in water for 24 h according to ASTM D570, and their weight and thickness were re-measured to evaluate water absorption. This process was followed by the Taguchi method analysis of the results to identify key indicators and optimal conditions for performance.

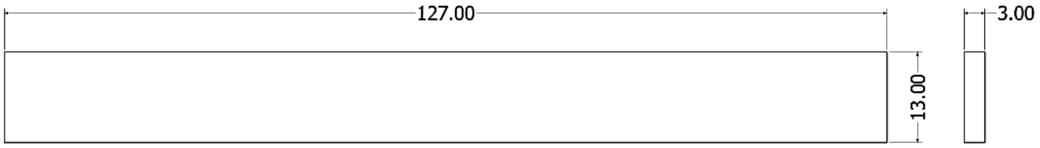

Fig. 2. The standard dimensions for ASTM D790

3. Results and discussion

3.1. Water absorption and swelling thickness

Water absorption is the ability of a material to absorb moisture from its surrounding environment, thus directly influencing physical and mechanical characteristics. Thickness swelling, resulting from water absorption, tends to be more important in wood and composite materials because it can result in dimensional change and influence mechanical performance. These two properties are usually evaluated according to standards like EN 317. Here, samples were immersed in water for 24 h, and measurements on weight and thickness were recorded to determine the effects of absorption. Water absorption, along with thickness swelling are evaluated using Eqs. 3 and 4, respectively.

$$WA = \frac{m_t - m_o}{m_o} * 100\% \tag{3}$$

$$TS = \frac{T_t - T_o}{T_o} * 100\% \tag{4}$$

The initial mass of the sample is (m_o) and the mass as (m_t): both measured in grams. T_0 and T_t are the initial and final sample thicknesses (mm) and thickness following immersion, respectively. The sample was weighed pre-immersion and post-immersion using a precision balance with an accuracy of 0.001 g. Fig. 3 shows the change in water absorption after 24 hours, while Fig. 4 shows the change in swelling thickness over the same period. The results demonstrate a direct relationship between water absorption and increased swelling thickness. Samples L2 and L3 recorded the highest values for water absorption and swelling thickness, indicating that the absence of PC can lead to increased moisture absorption. In contrast, sample L7 exhibited the best performance, achieving the lowest values for water absorption and swelling thickness. This is attributed to its 15% PC content with a minimum wood content of 20%. Increasing the wood content can also lead to higher water absorption and swelling, a predictable behavior given the hygroscopic nature of wood fibers. Furthermore, the smallest wood grain size ranged between 0.6 to 0.8 mm. Pure HDPE showed no measurable water absorption within the accuracy limits adopted in this study, with a measurement accuracy of 0.01%. Therefore, the water absorption rate was recorded as 0%. This result is consistent with ASTM D570, which indicates that HDPE's water absorption is very low, typically between 0.005% and 0.01%.

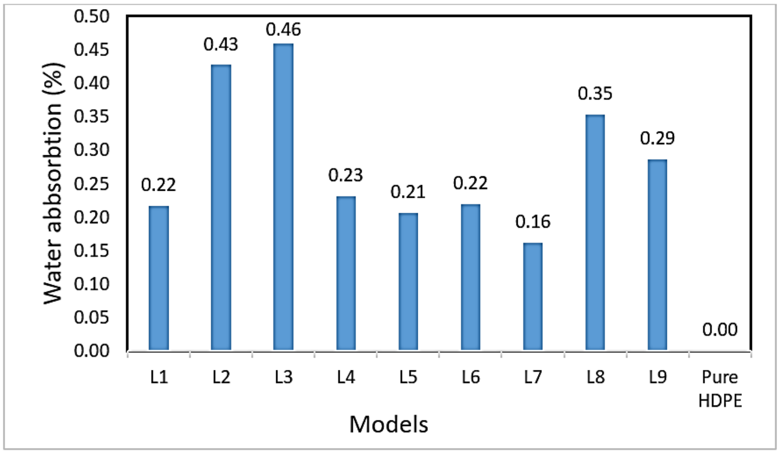

Fig. 3. Changes in weight after 24 hours

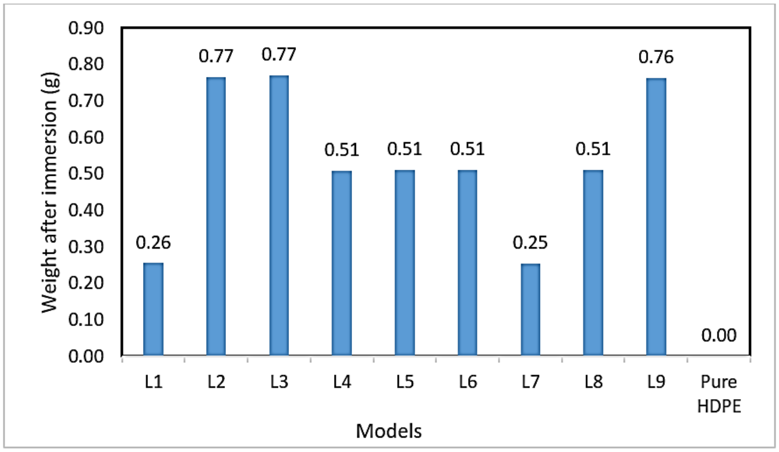

Fig. 4. Changes in thickness after 24 hours

In Taguchi's analysis of water absorption and swelling thickness, the "smaller is better" criterion was selected. Fig. 5 illustrates the main effects plot for the signal-to-noise (S/N) ratio regarding water absorption. The wood percentage has the most significant impact among all the parameters, with 20% yielding the best results. Additionally, it can be observed that increasing the wood percentage leads to higher water absorption and swelling thickness.

The addition of PC demonstrates the second most significant effect, with 7.5% being the optimal ratio. In contrast, grain size has the least impact among the parameters studied, with the smallest grain size producing the best outcomes.

The significant impact of teak wood content on water absorption in the Taguchi method can be attributed to the hydrophilic nature of lignocellulose materials. Teak wood contains active hydroxyl groups (-OH) in its cellulose and hemicellulose, which enhances its ability to form capillary pathways and absorb moisture as the wood content increases. Additionally, a higher wood content leads to the formation of microscopic pores at the interface, which further improves water permeability within the structure. This explains why teak wood content has a greater influence than grain size and PC content in the Taguchi arrangement [25].

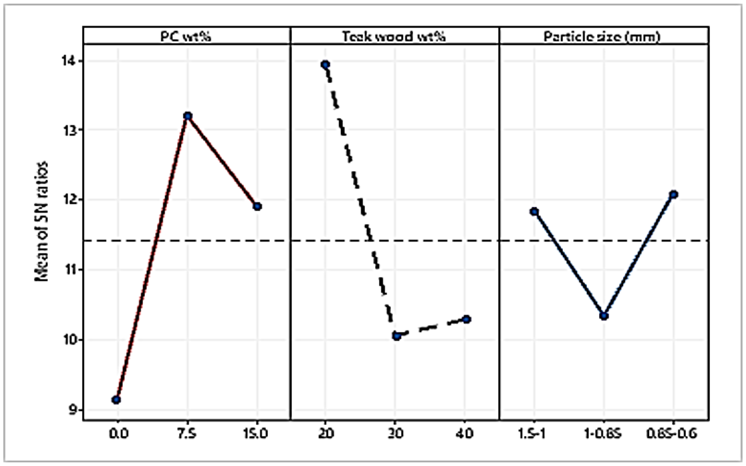

Fig. 5. Main effects plot for S/N ratio for water absorption

3.2. Density

When wood fiber is added to the polymers for the making of WPCs, this would help to minimize the total density of the end product, as is the case with most of the extruded materials. However, when it comes to injection molding, the final composite density may be significantly affected by the type of materials and processes such as the temperature and the injection pressure [26]. The density of the samples was measured using Archimedes' principle of water displacement. The volume of each sample was determined using a graduated tube, and the density was calculated by dividing the mass of the sample by the measured volume. As the system contains a PC component at a maximum temperature of up to 185 °C and an injection pressure of 120 MPa, these values were considered necessary to obtain the desired bonding of the PC in the matrix. It is made despite the low degree of tolerance of wood fibers to such high-temperature activities. Based on Fig. 6, it is clear that the best model is L1, which has the lowest density at 0.975 g/cm³. Conversely, Models L9 and L3 show the highest density in the presence of high wood content. This increase in the density is due to the injection pressure during injection, which results in the gain of the density in samples with more wood content. L1 also has the lowest density in a comparison to the other samples, as it has the lowest percentage of wood (20%) and is non-PC (0%).

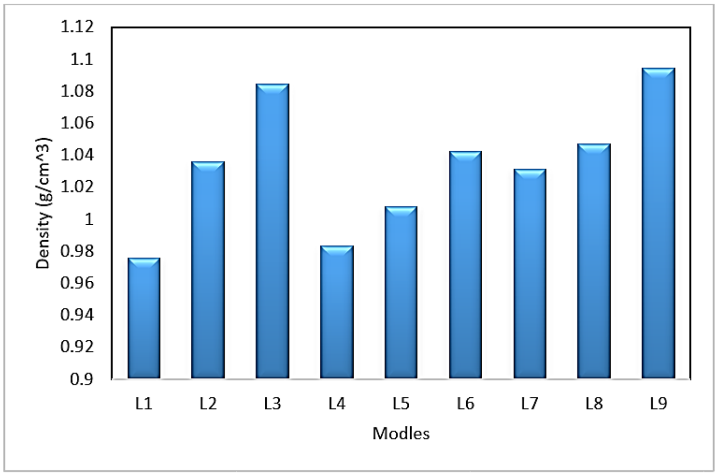

Fig. 6. Density of nine compounds

In Taguchi's analysis of density, the criterion chosen was "smaller is better". Referring to Fig. 7, it is evident that the wood weight ratio has the most significant impact on the density of the other parameters. Specifically, a wood of 20 wt.% has the greatest influence on density, which then gradually decreases as the wood percentage increases. Following wood, the PC ratio also affects density, with 7.5% of its weight having the most considerable impact. In contrast, grain size has the least effect on density, with a range of 1.5% to 1% showing the best influence on the density of the other parameters. The limited impact of particle size on the studied properties is due to its secondary physical factor status if compared to the wood and PC percentages. Additionally, the signal-to-noise ratio plots showed consistent trends across the applied manufacturing conditions. Taguchi's findings suggest that the teak wood content is the primary factor influencing density. This is because it directly affects the composite's volumetric structure and component distribution. As the teak content increases, the filler-to-polymer matrix ratio changes, which, in turn, affects the filler uniformity and the compression ratio during injection molding. Additionally, the difference in density between the wood and the polymers used significantly affects the overall density of the composite. This underscores the importance of teak wood content as a determining factor compared to other variables [27].

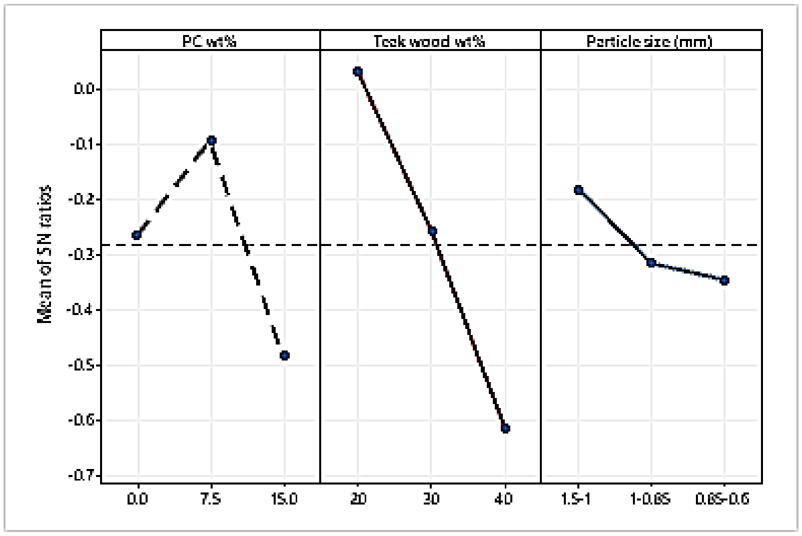

Fig. 7. Main effects plot for S/N ratio for density

3.3. Durometer shore hardness

The Shore D hardness test is utilized to determine the extent to which hard and rubbery polymeric materials are resistant to penetration or surface deformation with a durometer. This fast and precise procedure is suitable for investigating the properties of a material without damaging or altering its structure and is suitable for both industrial and lab applications. The hardness was measured following the ASTM D2240 standard, using bending samples (as depicted in Fig. 2) with an effective thickness of 6 mm. This was achieved by stacking two samples, each 3 mm thick, to ensure compliance with test requirements and accuracy of the results. All composites have hardness levels higher than pure HDPE, as depicted in Fig. 8. Specifically, an increase in the proportion of wood in the composite results in an increase in the hardness, in which case, model L6 demonstrates the highest hardness compared to the other models.

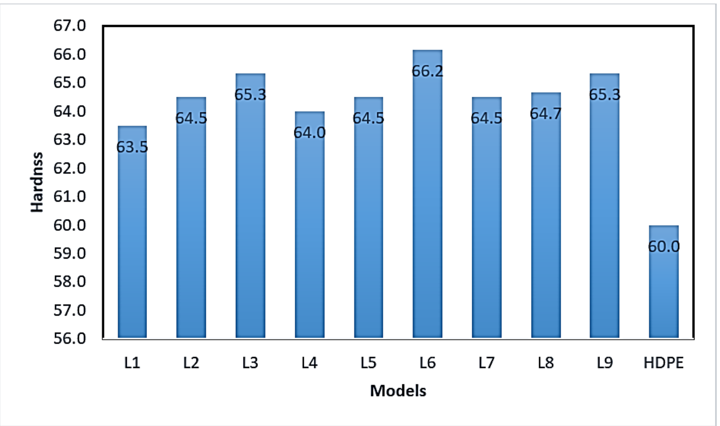

Fig. 8. Column chart for hardness

Fig. 9 illustrates the main effects plot for hardness factors using the Taguchi method, based on the principle of "larger is better." The effects of three main factors on the composite's stiffness were analyzed: PC content (PC wt.%), teak wood content (Teak wood wt.%), and particle size, with the levels of each factor shown in Fig. 9. Fig. 9 shows that teak wood content has the greatest impact on stiffness, with a maximum at 40%. This is followed by PC, which has a moderate effect, reaching its highest value at 7.5%. Particle size has the least impact among the three factors studied, showing limited changes compared to the other factors.

The high hardness of teak wood, as demonstrated by Taguchi's results, can be attributed to the role of wood particles acting as rigid fillers that limit the movement of polymer chains. Increasing the wood content enhances the material's resistance to localized deformation and improves surface hardness. This effect is especially pronounced when there is good cohesion between the components, aided by the MA-PE compatibility factor. However, the influence of grain size and PC content is less significant than that of wood content, which aligns with the ranking of factors determined statistically by Taguchi's method [28]. The limited impact of grain size on the Taguchi method results is due to its secondary role within the range of sizes considered. This contrasts with the significant effect of the wood ratio. The results demonstrated consistent trends with little variation, confirming the validity of this effect under the manufacturing conditions employed.

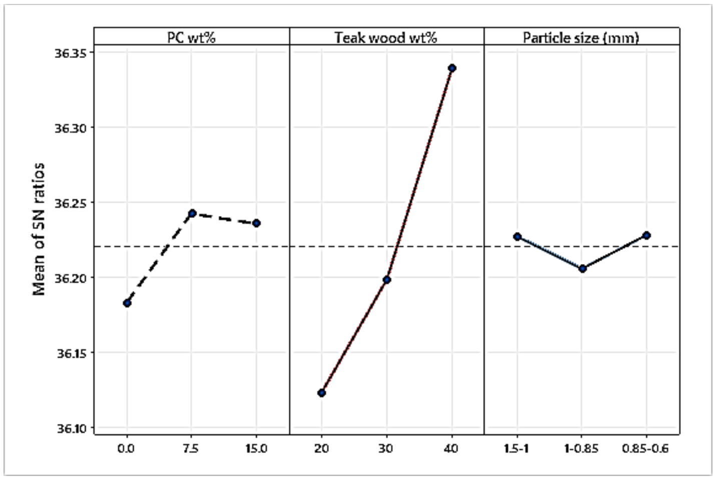

Fig. 9. Main effects plot for S/N ratio for hardness

4. Conclusions

The current study used teak wood as a natural filler in a polymer matrix to improve the mechanical and physical properties of the resulting polymer composites. The results ascertained that an increase in the teak wood content can lead to higher water absorption and swelling thickness due to the porous nature of the fibers, while adding 7.5–15% PC reduced water absorption and improved dimensional stability. Measurements showed that samples L2 and L3 can exhibit the highest water absorption and swelling thickness values, while sample L7, containing 15% PC and 20% teak wood, achieved the lowest values. No water absorption was recorded in pure HDPE within the 0.01% accuracy limit according to ASTM D570. Regarding density, the L1 sample, containing the lowest wood content (20%) and lacking PC, exhibited the lowest density at 0.975 g/cm³. Conversely, the density increased in samples with higher wood content due to injection pressure during molding. Taguchi analysis revealed that teak wood content had the greatest impact on density, followed by 7.5% PC, while grain size had a limited effect. Surface hardness was also associated with increasing teak wood content, with further improvement observed upon the addition of 7.5% PC. Furthermore, Taguchi analysis showed that teak was the most influential factor on hardness, followed by PC content, while grain size had the least impact. L7 was identified as the optimal compound. It demonstrated the lowest water absorption and the thinnest swelling, while also exhibiting suitable hardness and density. These conclusions are based on the results of the S/N Ratio analysis conducted on all properties. This makes it more suitable for moisture-resistant, high-surface-toughness applications. Besides, it indicates a reasonable approach to changing the values of Teak Wood, PC, and particle size, resulting in high-performance wood-plastic composites for environmentally friendly engineering and construction products. However, it should be noted that MA-PE was used as a fixed compatibilizer based on established literature, and therefore, the effectiveness of the compatibilizer in the present composite system was assumed. This would be a limitation of this study that should be addressed in future research.

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