Tensile characteristics of HDPE/Walnut shell composites

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Abstract. Present work deals with tensile characterization of walnut shell (WS) powder (20, 40 and 60 volume %) reinforced High Density Polyethylene (HDPE) thermoplastic composites synthesized using injection molding. Composite density and tensile modulus increases with increasing WS content wherein tensile strength of composite samples is lower as compared to neat HDPE. Specific modulus and strength show increasing and decreasing trend with higher WS loading respectively.

Keywords: Walnut shell, HDPE, Injection Molding, Modulus, Strength.

1. Introduction
Environmentally friendly waste materials demand development of utilitarian composites for consumer applications. WS is reinforced in thermoset polymer using open mold process earlier[1]. The water absorption and ultimate compressive strength are observed to be increasing with WS volume percentage [2]. LDPE/WS composites show improved powder dispersion in matrix[3]. Mechanical properties are noted to be improved with increase WS content[4]. Adding coupling agent to Polypropylene and HDPE/Walnut shell powder composites enhances the mechanical properties fabricated by press mold method[5]. Incorporation of the walnut shell flour significantly improved the water resistance of the panels[6]. Rheological behavior of WS exhibits higher and steady state torque [7]. Naturally available particulate inforcements show better bonding interactions[8, 9]. Compression molding[10], injection molding [11] conventional casting [12] and most recently 3D printing [13, 14] approaches are widely explored using hollow fly ash censpheres and glass microballoons. Among these processing routes injection molding is the most promising technique as cycle time is much lower as compared to other thermoplastic processing routes enabling injection molded components to be inexpensive, durable and making them to be used in consumer utility regime.

Fillers in polymer matrix resin influence melting and crystallization temperature marginally[15]. Biodegradable and environmentally friendly composites are also developed with HDPE[3]. Present work is focused on developing HDPE/WS composites using industrial scale polymer injection molding process to characterize the tensile behavior.

2. Materials and Methods
2.1. Blend Material
HDPE thermoplastic polymer is taken as matrix material having grade of HD50MA150 (Reliance Polymers, Mumbai) as presented in(Figure 1a) having mean molecular weight 97,500 g/mol. Walnut shell powder in the form of residue (Figure 1b) procured from Palli Plaster Industries, Kashmir is used as filler having 80-100 mesh size.
2.2. Processing
Blend of HDPE/Walnut shell powder are processed using a barbender at 210 °C with twin screws (Figure 2a). Blending is carried out for all WS compositions. HDPE/WS composites are injection molded with optimized parameters as listed in Ref. [16] (Figure 2b) having dimensions as mentioned in ASTM D638-10.

2.3. Density Measurement
Density test of the prepared samples are conducted as per ASTM D792-13 and average of five samples are reported. Density of pure HDPE is measured to be 0.950±0.002g/cc.

2.4. Tensile test
A computer controlled UTM having load cell capacity of 20 kN (ZwickRoell Z020, USA) is used to conduct tensile test on injection molded composites as per ASTM D638 to analyze the tensile properties. Tests are conducted at strain rate of 5mm/min. The strain is measured using an Instron extensometer with gauge length of 30mm. Five specimens are tested for each composition and average values are reported.

3. Result and Discussion
3.1. Sample Density
Density of the HDPE/Walnut shell powder composites increases with increase in the WS content. Samples are codes following Xzz (X - HDPE, zz - WS content). The measured densities of H20, H40, and H60 are found to be 962±5, 995±7 and 1015±7kg/m³ respectively. Compare to density of pure HDPE, H20, H40 and H60 shows higher values of 1.26, 4.7 and 6.8 % respectively.
3.2. Tensile Characteristics
Representative stress-strain plots of pure HDPE and HDPE/Walnut shell composite samples are presented in Figure 3. Differential trends between the pure HDPE and HDPE/WS composites are observed. Failure strain of neat HDPE samples is over 140% [16] whereas HDPE/WS samples fail at strain in the range of 4.6-9.4% (Figure 3). Increasing WS content decreases failure strain. Figure 4a shows tensile modulus of composites is in increasing order with respect to higher filler content as compared to neat HDPE and is in the range of 153-188%. Similarly measured ultimate tensile strength of the composites shows lower value as compared to pure HDPE due to reduction in the load bearing capacity of matrix with increasing WS content (Figure 4b). Figure 4c shows specific modulus of composites increases with increasing the filler loading. Similarly, Figure 4d represents the decreasing trend of specific strength with increasing volume percentage of WS content. The measured values of tensile modulus, ultimate tensile strength, percentage elongation, failure strength and failure strain are reported in Table 1.

![Figure 3. Representative tensile behavior of HDPE/WS composites.](image)

![Figure 4a. Tensile modulus vs. Walnut shell volume.](image)

![Figure 4b. Tensile strength vs. Walnut shell volume.](image)
Figure 4. Tensile (a) modulus (b) strength (c) specific modulus and (d) specific strength of HDPE and their composites.

Table 1. Mechanical Properties of HDPE and their Composites

| Sample | WS (volume %) | Tensile modulus (MPa) | Ultimate tensile strength (MPa) | Ultimate tensile strain (%) |
|--------|---------------|-----------------------|-------------------------------|----------------------------|
| H      | 0             | 530                   | 19.5                          | 10.2                       |
| H<sub>20</sub> | 20           | 1340                  | 13.4                          | 7.3                        |
| H<sub>40</sub> | 40           | 1460                  | 12.8                          | 4.8                        |
| H<sub>60</sub> | 60           | 1530                  | 11.6                          | 4                          |

4. Conclusion

The present study focused on utilizing environmentally friendly and waste material (Walnut shell powder) for reinforcing in thermoplastic matrix (HDPE) to fabricate composites using rapid manufacturing process. The tensile behavior of composite samples is compared with pure HDPE. The results are concluded as follows.

- Density of composites having 20, 40 and 60 volume % walnut shell powder increases as compared to pure HDPE.
- Tensile modulus of HDPE/Walnut shell powder composites shows increasing trend with increasing volume % of filler content whereas strength of the composites decreases.
- Values of specific modulus and specific strength of composites shows increasing and decreasing trends respectively with increase in filler content.

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