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Design Of Mechanical Mixer for Synthetization Of Polymer Matrix Composites

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Abstract: Polymer nanoparticle composites present industrial potential in many applications. However, some limitations for the application of these composites are due to the non-uniformity of their mechanical properties. One of the main issues of that drawback is the lack of uniform distribution of the nanoparticle's reinforcement inside the polymer matrix. In other words, uniform distribution of nanoparticles throughout polymer matrices presents a crucial issue for obtaining sound parts of fair enough mechanical properties. That would present a limitation for use in different areas of applications. A mechanical mixer with a special design has been developed during the present work. A prototype mixer has been carried out, and used for the synthetization of polystyrene carbon nanoparticles, (CNP's) composites. The design of the developed mechanical mixer is based on the principle of subjecting the mixture of CNP's and Polymer to multi-shearing strokes in a bi-directions extrusion die during heating at appropriate temperature for a specific time. The produced composites have been subjected to metallographic examination, and mechanical testing to investigate the effectiveness of using the developed mechanical mixture. Metallographic examination of specimens of the produced composites parts using SEM have shown fair enough distribution of the carbon nanoparticles throughout the polymer matrix. The mechanical properties of the produced composites have been evaluated, and the results showed comparable values with respect to those dismantled in publications.

Keywords: Mechanical Mixer; Mechanical Properties; Nanocomposite; Polystyrene; Carbon Nano Particles.

1. Introduction

Matrix nanocomposites reinforcement by carbon nanoparticles (CNP's are frequently used in packaging, safety, transportation, military systems, electromagnetic shielding, sensors, catalysis, and the information sector [1-3]. They are significant materials for both industrial and scientific reasons.

Polymer nanocomposites provide enormous possibilities for the future of these materials by providing solutions to several real-world issues and everyday difficulties.

The nanocomposite often has superior characteristics than pure polymers and/or polymer composites. Depending on the intended usage, a variety of natural, synthetic, biopolymer, and elastomer polymers have been employed to create these materials, which may include varying percentages of nanoparticles [5–13].

Nanocomposites may be synthesized by several techniques. However, regardless of the method, the final morphology of all polymer nanocomposites is dependent on interactions between polymers and nanoparticles that will provide good dispersion and distribution of the nanoparticles within the polymer matrix [14–18].

The hot melt extrusion (HME) method figure (1) is the most extensively utilized processing technology in the plastic, rubber, and food manufacturing sectors. Hot melt extrusion entails compaction well as the conversion of powdered components into a product of consistent density and shape. For example, when rubber is used in a hot melt extrusion process, spinning screws motivate the rubber and active substances, including any additives such as carbon nanofillers, forward toward the die at specified temperatures, pressures, feeding rates, and screw speeds. [19].

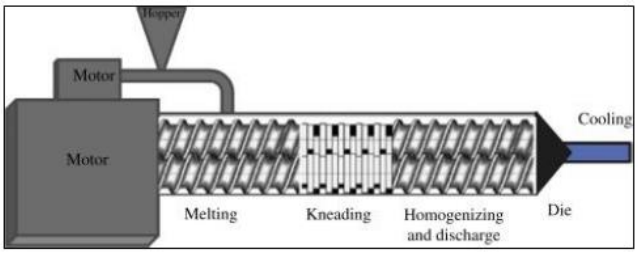

FIGURE 1. Hot Melt Extrusion Method [19]

As the HME has its disadvantages like thermal degradation is possible for sensitive materials, High start-up costs and specialized knowledge also required complexity design and manufacturing of mixing screw. To facilitate the mixing process a new mechanical mixer has been developed.

2. THE MAIN IDEA OF MIXING

The main idea of the developed mixing method depends on subjecting the constitutes of the mixture to shearing forces in two opposite direction (back and forth) , for specific interval of time at appropriate temperature until a homogenize mixture is obtained.

3. DESIGN OF MECHANICAL MIXER:

The developed mechanical mixer consists of the elements as described in Figure 2-a.

The constituents of the mixture are placed inside the cylinder # 6, via the opening # 3, after it has been heated to an appropriate temperature via an electric heater # 5, that temperature depends on the constituents' type. The temperature is controlled via a temperature controller # 13.

The pistons # 7(a & b) are moved back and forth for a specific interval of time via the handle # 1.

After completion of mixing, the pistons # (7 a& b), which consist of two pistons, one inside the other as shown in Figure 2b , are rotated by handle # 1, at an angle of 30 degrees w. r. t. each other in such a way to make the holes close and allowing the mixture to moved forward towards the exit opening # 10, under the application of axial force via the handle # 1

Each of the pistons # 7 (a& b) has 12 holes arranged at an angle of 30∘, to facilitate:1-the translation of the mixture during the back-and-forth movement, 2-the closure between the holes during the exit stroke.

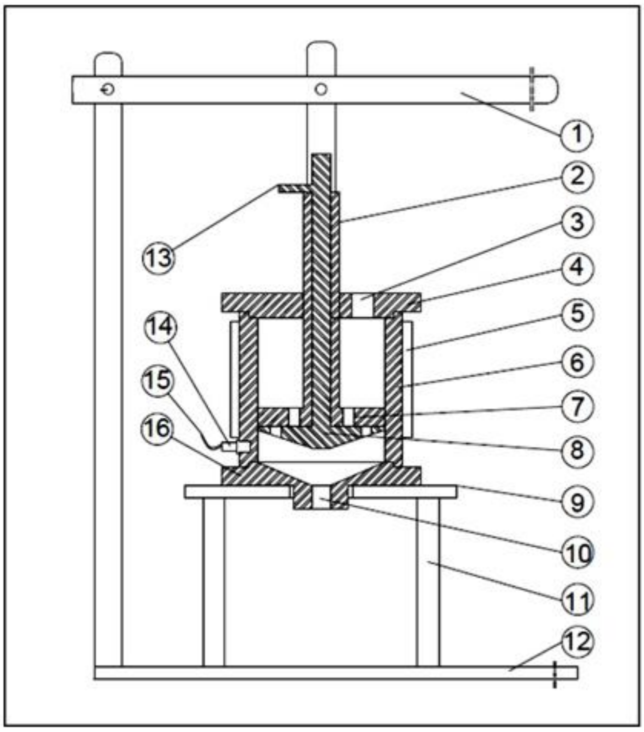

FIGURE 2a. Section sketch of the developed Mechanical Mixer

Key Features

1 Handle	9 Upper Base
2 Pistons rods	10 Composite output holes
3 Raw material holes	11 Spacers
4 Upper cover	12 Machine base
5 Electric Heater	13 Rotating handle
6 Cylinder (mixing room)	14 Thermocouple
7 Upper pistons	15 To temperature controller
8 Lower pistons	16 Lower cover

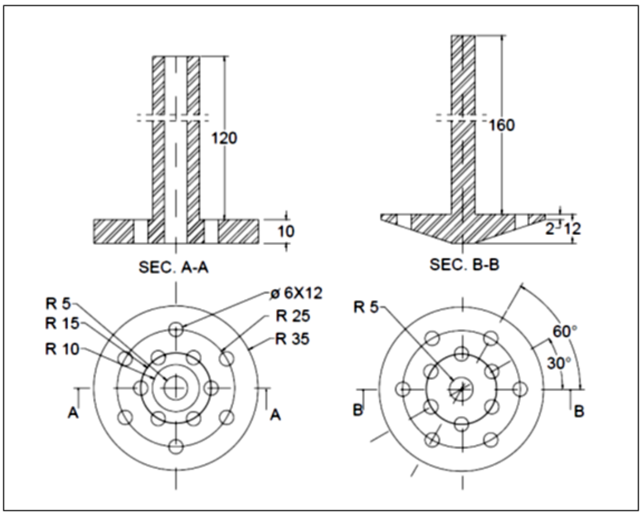

FIGURE 2b. Upper and Lower Pistons.

4. EXPERIMENTAL WORK:

The mixture consists of CNP, and polystyrene was introduced inside the mixing room of the cylinder # 6, that has been heated to appropriate temperature of about 240 ± 5 ℃. Then the pistons # 7 (a & b) moved up and down together serval times during a specific interval of time of about 5 minutes, for the mixing process. During the mixing time, the mixture passes through the piston holes. subjected to shearing forces in bidirectional enabling the mixing process.

After the completion of mixing process, the piston # 7.b (the inside piston) is rotated at an angle of 30 degrees, so that the holes for the two pistons are closed by each other. An axial force is applied by the handle # 1 to force the mixture to exit from the die opening # 10, in the form of longitudinal rods of about 8 mm and of different lengths, depending on the amount of the materials introduced in the mixer.

The produced mixture is used as a preform, for the fabrication of composite components via a vertical extrusion device, for further details it would retune to reference [20].

5. RESULTS

The mixed Polystyrene and carbon nanoparticles nanocomposite., produced using the developed mechanical mixer have been subjected to SEM investigation. Fig. 3 shows one picture for nanocomposites containing Carbon nano particle of about 0.025 mass %. It is obvious from the figure, that the nanocarbon particles are distributed throughout the polystyrene matrix with the absence of agglomeration, clusters and no voids or porosity [21].

CONCLUSION

It is worth mentioning that using the developed mechanical mixing method has successfully produced nanocomposites preforms of faire enough distribution of the nano particles size. That would enhance the mechanical properties of the fabrication of the nanocomposites and widen its field of applications in different industrial areas.

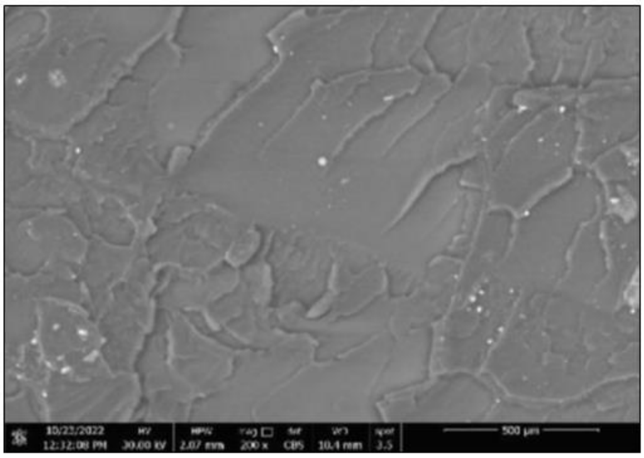

Figure 3. SEM Photo Shows Mixed Compound (CNP'S + Polystyrene)

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