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Fabrication and Design of a Mechanical Polymer Mixer

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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 Mixing, nanocomposite, polystyrene, polymer, mechanical mixing, Nano Carbon Particles

I. INTRODUCTION

Polymer nanocomposites are frequently used in packaging, energy, 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 idea behind Polymer nanocomposite design is that surface area and size are linked to much increased reactivity [4].

Because of the novel design, polymer nanocomposites have moved rapidly in manufacturing. These new materials often have 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 amounts of nanoparticles [5–13]. The novel design depends on selecting the appropriate polymer-nanoparticle combination and preparation method to produce these new materials with desirable properties. The most popular techniques for obtaining these materials are melt extrusion, solution dispersion (which includes spray drying and nanoprecipitation), and in situ polymerization. Every procedure is unique. The final morphology of polymer nanocomposites is crucial, regardless of the method, and is determined by interactions between polymers and nanoparticles that provide optimal dispersion and distribution of the nanoparticles inside the polymer matrix [10–14]. The technique used to create the polymer nanocomposite affects the final morphology as well.

These materials may be generated by several techniques, the most popular being melt extrusion, solution dispersion (which includes spray drying and nanoprecipitation), and in situ polymerization. Every procedure is unique. However, regardless of the method, the ultimate morphology of all polymer nanocomposites is dependent on interactions between polymers and nanoparticles that will provide optimal dispersion and distribution of the nanoparticles within the polymer matrix [14–18].

Since its inception in the early 1930s, the hot melt extrusion method has quickly become the most extensively utilized processing technology in the plastic, rubber, and food manufacturing sectors. Hot melt extrusion entails many compaction phases as well as the conversion of powdered components into a product of consistent density and shape. 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.

The theoretical approach to comprehending the hot melt extrusion process is depicted in Figure 1 [19].

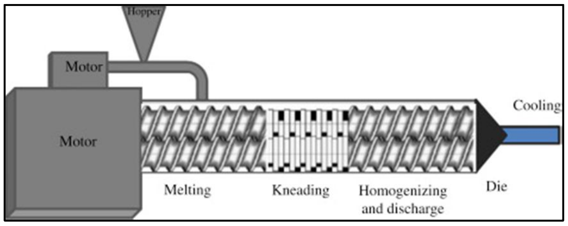

FIGURE 1. Hot melt extrusion method.[19]

In the Solution method, excellent solvent-polymer interaction allows for the dispersion of varying numbers of nanoparticles. This is the simplest way to create high-quality nanocomposites. Since the solvent must be totally removed afterwards, some caution must be used when manipulating it [20:23]. The required equipment (Figure 1) is basic.

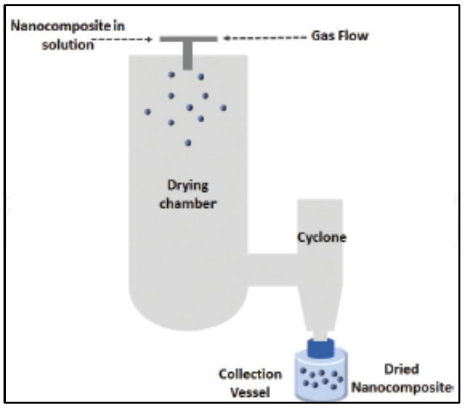

FIGURE 2. Scheme of obtaining polymer nanocomposites by spray drying.[24]

In-situ polymerization has been frequently used to create nanocomposites with insoluble and thermally unstable matrices (insulating polymers) that cannot be created using solution/melting procedures. Figure 3

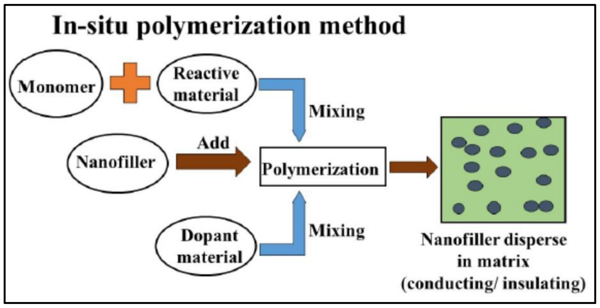

FIGURE 3. In-situ polymerization method of preparation of conductive and insulating polymers. [25]

A new mechanical mixer has been designed and fabricated to facilitate mixing nanoparticles with polymers in the injection molding industry.

II. RESEARCH PROBLEMS

Shortage of finding nanocomposites in Egyptian market, Difficulties in mixing process in premixing and long loop process, the need to enhance used polymers properties by nanoparticles, and All polymers’ nanocomposites materials in Egypt are imported.

Research Objectives and Importance:

1) Developing an entirely novel mechanical mixer.
2) Making improvements to the characteristics of recycled polymers by incorporating nanoparticles.

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III. MIXING DEVICE

Figures 4 & 5 show a 3D model and sectional 3D model of the designed and fabricated mechanical mixer respectively, the developed mechanical mixer consists of the elements as described in Figure 6-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 6b , 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^o, to facilitate:1-the translation of the mixture during the back-and-forth movement, 2-the closure between the holes during the exit stroke.

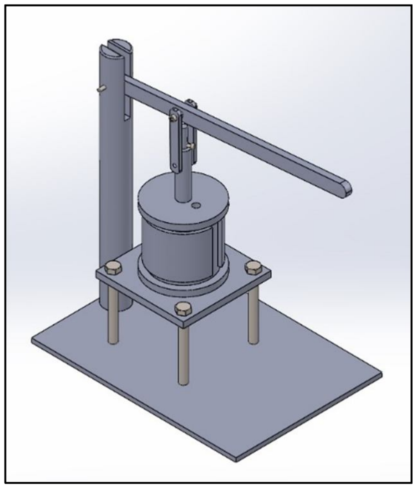

FIGURE 4. A 3 D model of the designed and fabricated mixer

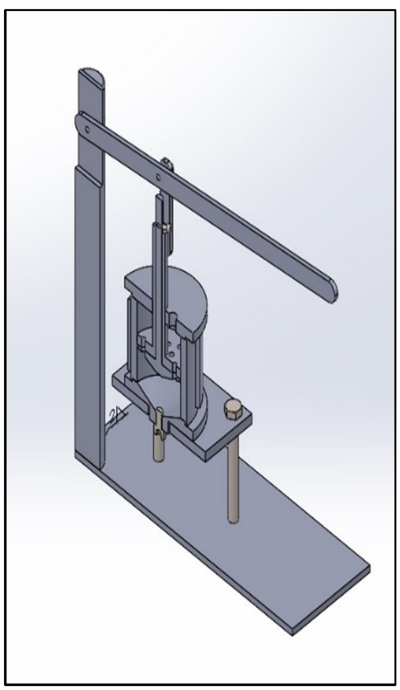

FIGURE 5. A sectional 3 D model of the designed and fabricated mixer.

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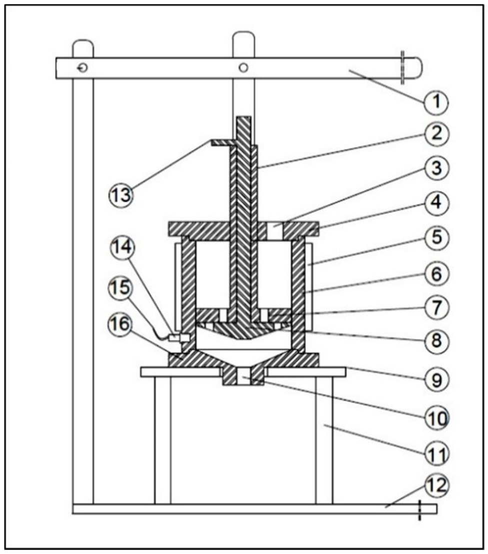

FIGURE 6a. Section sketch of the developed Mechanical Mixer

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

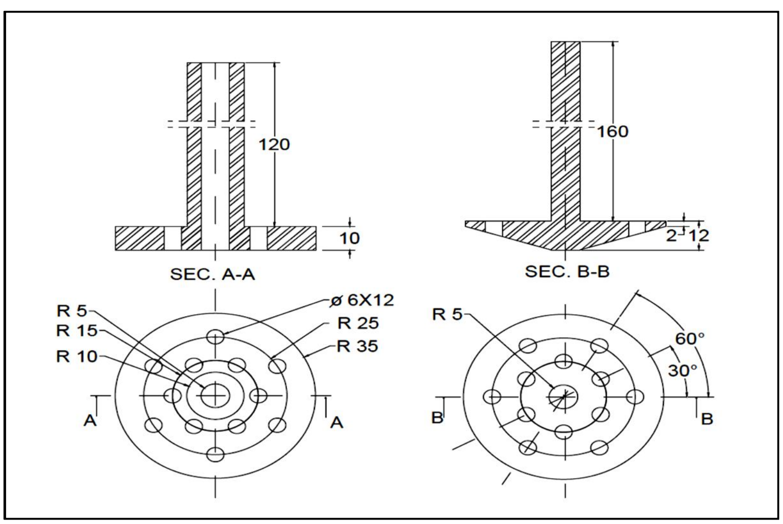

FIGURE 6b. Upper and Lower Pistons.

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IV. EXPERIMENTAL WORK

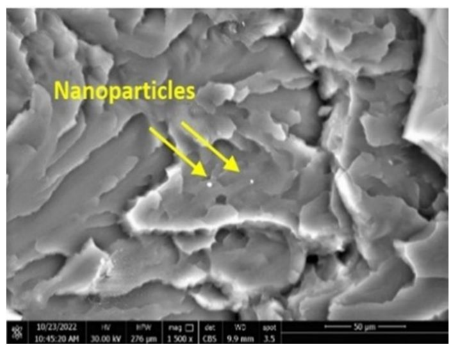
The mixture consists of CNP, and polystyrene was introduced inside the mixing room of the cylinder # 6, that has been heated to appropriate temperature of about 240 ± 5 °C. Then the pistons # 7 (a & b) moved up and down together serval times during a specific interval of time of about 5 minutes, for 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.

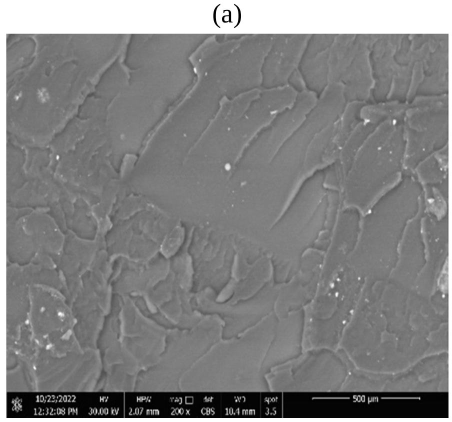
The produced mixture is used as a preform, for the fabrication of composite components via a vertical extrusion device, for further details it would retune to reference [20].

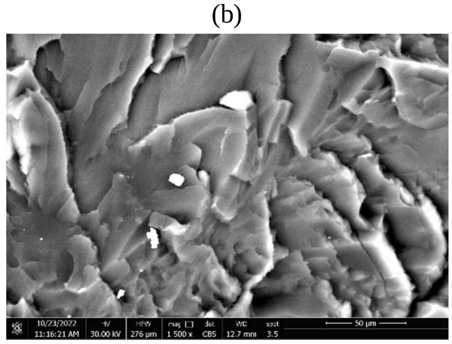
V. RESULTS

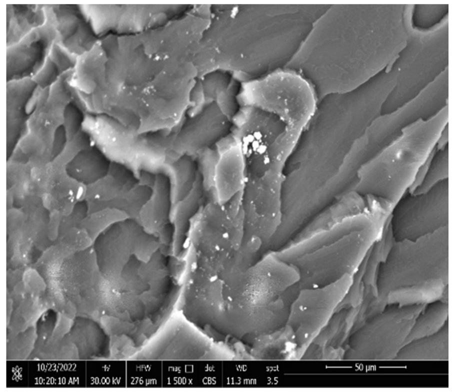
Polystyrene polymer granules and carbon nanoparticles were prepared with a weight percent of 0.025 wt. % nanoparticles. Figure 7 (a : f) show SEM investigation of mixed polystyrene and nanoparticles, SEM reveals no agglomeration and acceptable distribution.



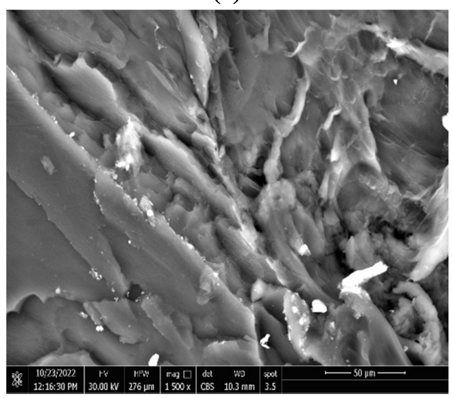
(a)


(b)

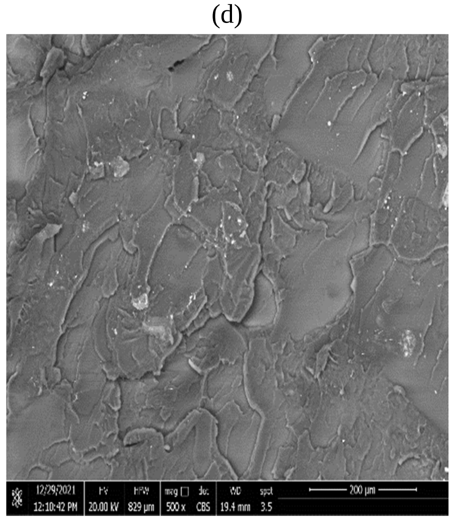

(c)



(e)



(d)



(f)

FIGURE 5 (a & b) SEM photos shows mixed compound (CNP + Polystyrene) [26]

VI. 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.

VII. ACKNOWLEDGEMENT

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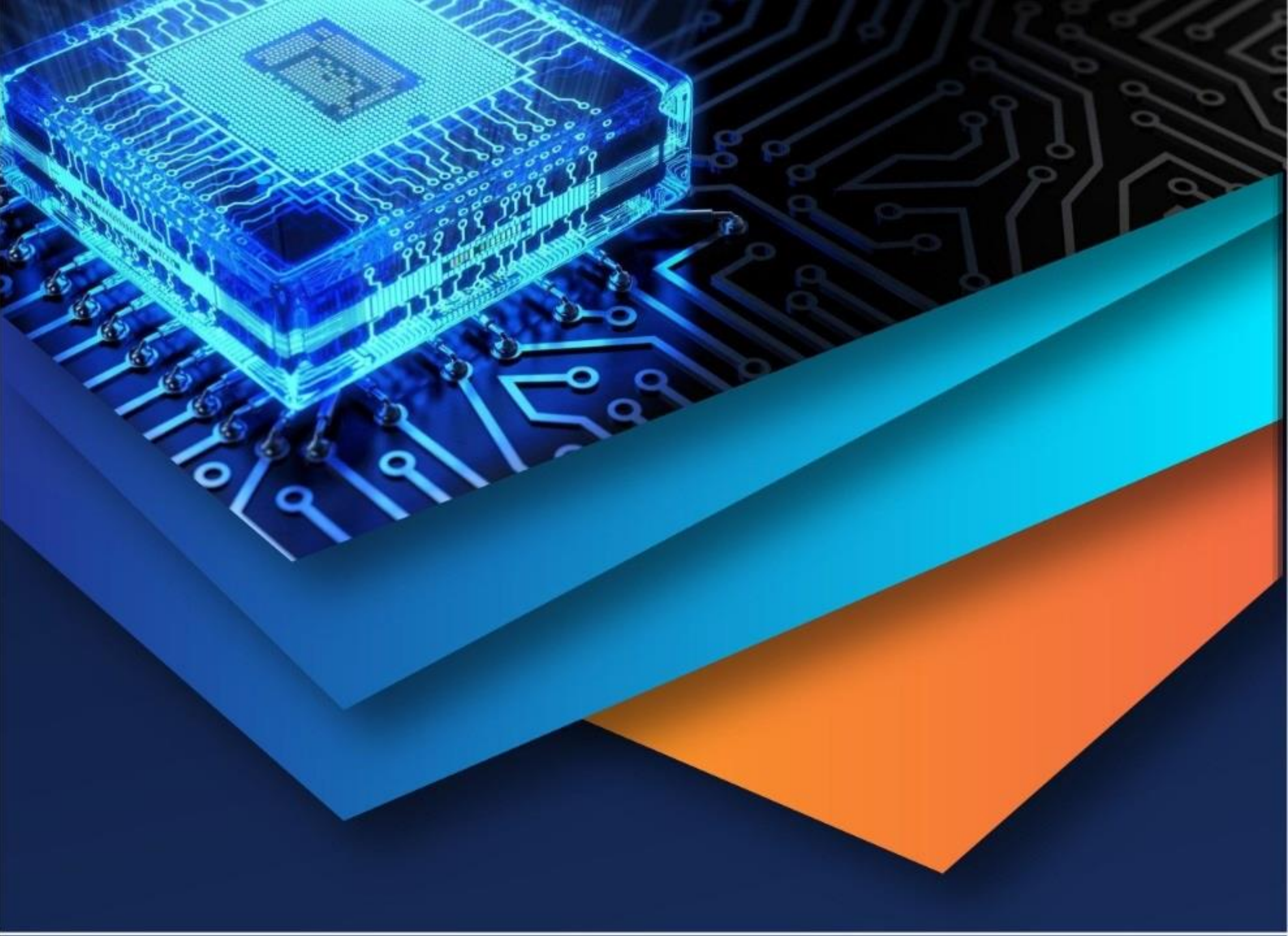

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