Investigation the effect of electroplating and filler material on the tensile properties of wollastonite reinforced ABS composites

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Abstract: This paper deals with effects of wt. % of wollastonite (CaSiO₃) filler in acrylonitrile-butadiene-styrene (ABS) polymers prepared by injection moulding process and electroplating on the specimens. The influence of filler was examined by the different wt. % (3, 5 and 7) of wollastonite (CaSiO₃) in ABS. Filler was mixed with ABS polymer by twin screw extrusion process and pelletized. The composite pellets are used for the injection moulding process and specimens are prepared as per ASTM. The specimens are coated with nickel, copper and chromium with a thickness of 0.8 microns each by electroplating technique. The dispersion of fillers are studied by SEM. The improvements in tensile properties of 5 wt. % of filler in ABS and same wt. % of filler with electroplating components were 66% and 87 % respectively when compared with pure ABS.

Key words: Acrylonitrile butadiene styrene, Wollastonite, Composites, Injection moulding, Tensile test.

1. Introduction:

Acrylonitrile-butadiene-styrene (ABS) are the artificial thermoplastic polymers. ABS polymers are widely used engineering materials due to its good mechanical and chemical resistance properties [1]. ABS polymers are widely used in pipes, vehicles, civil structures, etc. The applications of ABS polymer depends on the applications. The fabrication and analysis the behaviour of ABS polymer is difficult and it requires the knowledge of polymer and material science [2].

The incorporation of filler material like glass fiber to the base ABS polymer to improve the thermoplastic material properties by using direct mixing techniques and processed by using injection moulding process. Combination of ABS with Poly Amide-6 (PA6) improves the bonding strength between fibre and polymer matrix. Strength and stiffness properties improvement is observed at 30 wt. % short fiber in ABS/PA6 [3].

Wollastonite has been used as functional filler in many of the plastics, ABS and wollastonite belong to fundamentally different material chemistries. ABS is a polymeric material, while wollastonite is ceramic. Therefore, their performance will be even more dissimilar than would be suggested by the difference in properties and also the two materials have significantly dissimilar densities [4].

Electroplating is the process of coating a metallic layer over a material by electrolysis process. In electrolysis process, the workpiece is fixed to cathode and acts as negative terminal. Kulkarni et al. [5-7] reported that strength is improved by electrolytic deposition of nickel, copper and chromium layers over the ABS / PA6.

F.Wang et.al [8] have discussed in their papers that a new way has been devised to modify ABS using maleican hydride (MAH) functionalized ABS and ethylene-propylene-diene rubber (EPDM) as
compatibilizer and flexibilizer so in present work an attempt have been made to investigate the changes of properties with respect to change of filler material and electroplating. The main objective of the research was to investigate wt. % of fillers in polymer prepared by twin extrusion and injection moulding process and electroplating on the specimens. The metallic moulds were used for the specimen’s preparations. The polymer and the fillers are selected for the research were ABS and wollastonite respectively. The moulded specimens are coated with nickel, copper and chromium layers. Tensile properties and SEM were studied.

2. EXPERIMENTAL DETAILS:
2.1 Specimen preparation:

The specimens were prepared as per D638-ASTM Standard (Figure 1). Initially the mixture of CaSiO$_3$ and ABS pellets were prepared using twin screw extruder (Model: TUE1, Institute of wood, Bengaluru). Pellets are used as a raw materials for injection moulding machine. The specimens were prepared by considering the process parameters of 180°-200° C barrel temperature and injection pressure of 65 kg/cm$^2$ maintained for all the samples. Whereas for pure ABS specimen directly prepared by injection mould (without twin screw extrusion). ABS and CaSiO$_3$ were used to produce composite specimens where ABS acts as matrix and wollastonite as reinforcement. The CaSiO$_3$ was varied from 3% to 7%. The composites fabricated were subjected to electroplating process.

2.2 Electroplating of Tensile Specimens
The electroplating process was carried out on the surface of ABS and ABS / wollastonite composite specimens. As the material is non-conducting the surface must be first converted into a conducting thus to increase the conductivity or to help the absorption of ions the surface is dipped in the nickel bath. Figure 3 shows the nickel solution tub. As the nickel ions are adhered on the surface the specimens are dipped in copper solution and thus copper ions are adhered making the surface more conducting. The durability of the copper is low as it fades out along with time. Figure 4 shows the copper solution bath tub. To help the long-lasting coating another layer of chrome plating is done on the surface. The durability of the chrome is high as compared to copper as it also gives a bright lustrous finish to the surface. Figure 5 shows the chrome solution tub.
2.3 Tensile Test:
The Tension test on ABS and CaSiO$_3$ reinforced composites samples are measured by using a computer controlled Universal Testing Machine (UTM) of model: KIC-2-1000-C. Initially, the test specimens are maintained at normal atmospheric condition of room temperature around 25$^\circ$C and 50% RH before undergone to the tests. The standard dimensions of each specimen are measured. Specimens are fixed to UTM, The crosshead speed is set to 1.5 mm/min and the machine is started, the software in the system records the value and plots the graph of stress vs % strain curve so that can find out the strength of the composites.

3. Results and Discussions:
The Ultimate tensile strength (UTS) is measured by load applied to a specimen until specimen break. Three different wt. % of wollastonite (3, 5 and 7 wt. %) were studied. The effect of wollastonite and electroplating on tensile strength are discussed.

3.1 Pure ABS:
The figure 6 represents the stress vs %strain relationship of pure ABS samples subjected to the tensile test. The maximum tensile stress of ABS samples is 33.7 MPa.

![Figure 6. Stress vs. strain diagram of Pure ABS Specimen.](image)

3.2 ABS+3% wollastonite:
Figure 7 corresponds to a stress vs. % strain of ABS + 3 wt. % wollastonite composites specimen subjected to tensile test. The specimens showed the improvement in tensile strength of composite specimen of 43.6MPa over 32.76 of ABS specimen and elongation percentage of the material becomes high so that it indicates that material nature was being ductile.
The SEM images of 3 wt. % reinforced composites were taken at 500X magnification. The image clearly shows the uniform distribution of the wollastonite particles. The even distribution helps the ABS matrix to gain some strength and thus increase the tensile properties.
3.3 ABS+5% wollastonite:

Figure 9 corresponds to a graph of stress vs. strain relationship of ABS + 5% wollastonite composites specimen subjected to tensile test. The average stress attained by the pure ABS specimen is 32.76 MPa as indicated in the Table 1. The inclusion of 5% of wollastonite in the ABS matrix has increased the tensile strength of 53.96 MPa that was increased by 66% and elongation percentage is decreased and material becomes more brittle and harder so that it sustains high tensile force this is may be due to proper bonding between wollastonite and ABS matrix is strong and enough to sustain external load. The fractured specimens of 5% reinforced composites were captured under SEM with 500X magnification. The images show a very homogeneous blending of the wollastonite particles with ABS matrix. This proper blending and bonding between matrix and filler leads to a remarkable increase in the tensile properties of the ABS specimen.

3.4 ABS+7% wollastonite:

Figure 11 shows to a typical stress vs. % strain relationship of ABS + 7% wollastonite composites specimen subjected to tensile test. The average stress attained by the Composites is 35.73 MPa over 32.76 of ABS (Table 1). The inclusion of 7% of wollastonite in the ABS matrix has shown only around 10% of increase in tensile strength. It was observed that there was a considerable fall in the tensile strength of these specimens as compared to the 5% and 3 % reinforced ABS but slightly increased as compare to ABS specimen. The decrease in tensile properties is found to be due to the dense powdered wollastonite makes poisoning effect in ABS. The SEM images of 7% reinforced composites were captured at 500X magnification. The image shows that, in this composition the wollastonite particles are more intensely distributed in the ABS matrix which leads to poisoning effect and due to this reason porosity in the material occurred. This weakens the matrix thus the 7% reinforced composite exhibit lower tensile strength.
Figure 11. Stress vs. strain diagram of ABS + 7% wollastonite composites.

Figure 12. SEM image of ABS+7% wollastonite Composite at 500X magnification.

3.5 Electroplated Pure ABS Samples:
Figure 13 shows the typical stress vs. strain relationship of electroplated samples of ABS. The electroplated samples has shown the maximum UTS to be 43.8 MPa over 32.76 of uncoated ABS specimen i.e., around 33% increase in the overall tensile strength. This is because of the three coatings of metallic ions that is zinc, copper and chrome. The electroplating process along with converting into a non-conductive material into a conductor also increases its mechanical strength (Figure 14).

Figure 13. Stress vs. Strain Diagram of Electroplated ABS samples.

Figure 14. Image of Electroplated Tensile Test Specimens after Fracture.

Table 1 (a). Ultimate Tensile Strength (UTS) of ABS and ABS/Wollastonite composites.

| Samples | Pure ABS UTS (MPa) | ABS+3% wollastonite UTS (MPa) | ABS+5% wollastonite UTS (MPa) | ABS+7% wollastonite UTS (MPa) |
|---------|--------------------|-------------------------------|-------------------------------|-------------------------------|
| S1      | 33.4               | 44.5                          | 58.50                         | 35.91                         |
| S2      | 33.7               | 42.83                         | 51.04                         | 36.10                         |
| S3      | 31.2               | 42.15                         | 52.35                         | 35.20                         |
| Average | 32.76              | 43.16                         | 53.96                         | 35.73                         |
Figure 15. Graphical representation of variation in UTS for different Samples

The above graph shows the comparison of tensile strength of various specimens in two different conditions like normal and Electroplated conditions. As expected, the results indicate that the mechanical strength of Electroplated-ABS samples has high compared to uncoated samples. Also, it is seen that there was an increase of 48%, 87%, and 15% in tensile strength for 3%, 5% and 7% Electroplated ABS Composites respectively when compared to pure ABS samples. The increase in mechanical properties is due to the reason that electroplated materials are composed of hybrid materials that is combination of ABS and coated material so it completely modifies the behaviour of the specimen.

Conclusion:

The 5% wollastonite reinforced composites showed a very high improvement in tensile test as compared to the ABS and the other two compositions. The average tensile strength shown for 3%, 5% and 7% composites was 43.16 MPa, 53.96 MPa and 35.73 MPa and increased in 33%, 66% and 10% respectively for normal condition evidenced by SEM.

The results of tensile test on electroplated ABS samples showed that along with inducing conductivity in the ABS polymer, the electroplated composites also shown the remarkable increased in tensile strength. The tensile strength of Electroplated composites samples are 43.83 MPa, 48.76 MPa, 61.4 MPa, 37.7 MPa increased in 48%, 87%, and 15% for pure ABS, 3%, 5% and 7% wollastonite reinforced ABS composites in electroplated condition evidenced by SEM.
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