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Validation of Tensile Test Results of Wollastonite Reinforced ABS Composites Using Finite Element Analysis

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***ABSTRACT**: In this study, raw ABS and Wollastonite reinforced ABS composites were prepared with help of Injection molding technique and specimens are fabricated and tested according to ASTM D638 Standards. The tensile test that was conducted in computer aided UTM machine. The specimens were prepared of different composition of 3%, 5% and 7% Wollastonite in to the pure ABS. the results of various composition composites and pure ABS samples are tabulate and evaluated.The evaluated values are compared with FEM results. In the other hand, A FEM model of same dimensions were designed, meshed and stress analysis were carried out using ANSYS software. The experimental results were validated with FEM results and it is noticed that results obtained is almost similar to experimental values however a small deviation was found in the results. The percentage deviations that were noticed are 9.57%, 2.15%, 4.84% and 5.50% for pure ABS, 3%, 5% and 7% composition samples respectively.*

***Key words:** Acrylonitrile butadiene styrene (ABS), Injection moulding, Tensile test, Universal Testing Machine (UTS), wollastonite ($CaSiO_3$)/ Calcium Meta silicate.*

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I. INTRODUCTION

Acrylonitrile Butadiene Styrene is one of the most widely used thermoplastic material in engineering world. Its varying composition of Styrene and Butadiene provides a variety of desired qualities according to the application. There is a flexibility in composition with regard to the amount of butadiene that provides the elasticity thus increasing the fields of application. The prime field of application for ABS material is Automobile Sector where it is used in manufacturing of parts like interiors etc. Other fields of applications involve domestic appliances such as refrigerators, sewing machines etc. However, some improvements in the mechanical properties such as tensile strength and compression strength can widen the areas of application. This can be achieved by proper addition of reinforcement material to the ABS matrix.

Polymer composite is a proper blend of a polymer material and a reinforcement material whose characteristics has to be involved in the base material. The amount of reinforcement that has to be added also has an impact on the overall properties thus has to be decided carefully. The Wollastonite is a amorphous solid with very high mechanical properties thus very suitable as reinforcement and when used with nylon 6 has given reasonably good qualities to nylon-based matrix. Thus, in this study Wollastonite has been used as reinforcement with ABS. The percentage of reinforcement used also makes a huge impact on the base matrix, therefore the percentages of reinforcement used in this process is 3%, 5% and 7% to the total weight ratio.

From past two decades extensive research has been made to improve the tensile properties of the polymers. In this study a widely used polymer (ABS) is blended with a tested reinforcement material (Wollastonite) in different compositions and test has been carried out for tensile strength. The results of the experiments are then validated with FEA model with help of ANSYS software.

II. EXPERIMENTAL METHODS

Specimen Preparation:

In this study, four different specimens were used out of which one pure ABS specimen and other three are Wollastonite reinforced ABS composites of different compositions. Pure ABS samples were prepared with Injection Molding machine whereas for the composites were premixed with the help of Twin Screw Extruder, which us carried out in Wood institute, Bengaluru and later it is taken to IM (Injection molding) machine (Fig 1). The compositions used are 3%, 5% and & 7% to the overall weight ratio. The specimen preparation for ABS and Wollastonite reinforced ABS composites of different compositions was carried out in Nagendra Enterprises, Bengaluru. The IM machine is connected with a permanent mould, when pressure and temperature developed inside the IM machine it pushes the melted ABS to cavity of the mould and after solidification the required shapes obtained.

Figure 1: Injection molding machine used in this study

Tensile Test:

The tensile test is carried out in R.V College of Engineering, Bengaluru. The test was performed according to ASTM D638 standards and the specimen used in this study is shown in fig 3. An Universal Testing Machine which is attached computer interface (fig 2). The test was carried out on three specimens for each composition and averages of three tests were taken as maximum tensile stress. The specimens were held in the grippers tightly between the grippers along the axis of the grippers. The specimens are held tightly and tensile force of the rate 1.3m/sec is applied. The force is applied till a fracture is occurred. The results and data is recorded by the computer and graphs of stress versus % strain is plotted. The Ultimate Tensile Strength (UTS) is noted from the data. Same process is repeated for all the specimens and the UTS is tabulated.

Figure 2: UTM machine used in this study

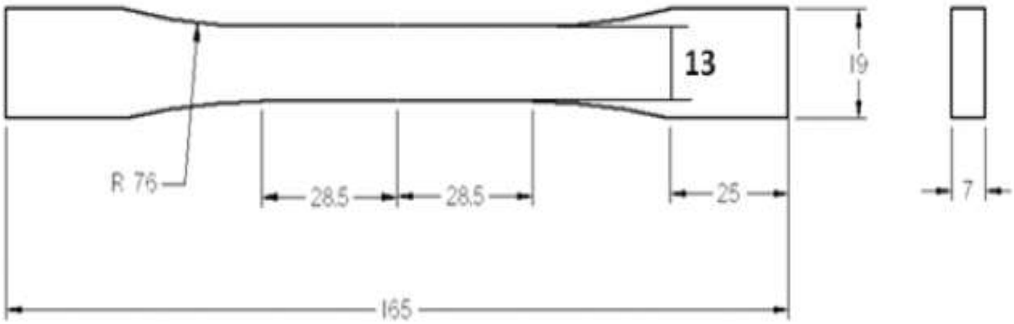

Figure 3: Tensile Test Specimen Dimensions used in the study

III. RESULTS AND DISCUSSION

Pure ABS:

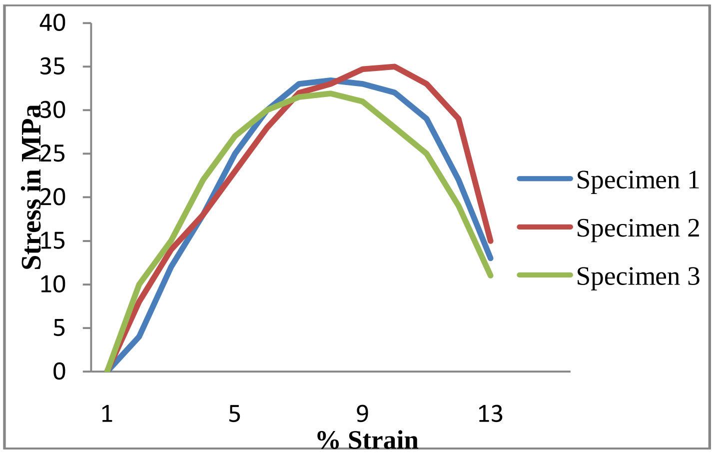

Figure 4: Stress vs. strain diagram of Pure ABS Specimen for tensile test.

The figure 4 shows the stress versus % strain graph of pure ABS sample subjected to the tensile test. The Ultimate Tensile Strength of ABS samples are found to be 33.7 MPa.

ABS/ Wollastonite ($CaSiO_3$) Composites:

From the literature survey it was found that the strength of the polymer materials can be improved with the addition of filler materials thus $CaSiO_3$ is chosen as reinforcement in this study. The reinforcement is been used in three different percentages i.e., 3, 5 and &7% and tensile test is performed on all the three sample along with the pure ABS sample. The results are tabulated below.

Table 1: Ultimate Tensile Strength (UTS) of ABS and ABS/Wollastonite composites under normal condition

Samples	Pure ABS	ABS+3% $CaSiO_3$ UTS (MPa)	ABS+5% $CaSiO_3$ UTS (MPa)	ABS+7% $CaSiO_3$ 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 value	**32.76**	**43.16**	**53.96**	**35.73**

ABS+3%$CaSiO_3$

The figure 5 shows the stress versus % strain graph of 3% $CaSiO_3$ reinforced ABS for tensile test. The inclusion of 3% of Wollastonite as reinforcement in the ABS matrix has improved its tensile properties. The 3% reinforced samples showed UTS of 43.6MPa over 32.76 of Raw ABS specimen which is a good 33% increase when compared to pure ABS. This is because of the good bonding and even distribution of Wollastonite in the matrix. The increase in sample is because the Wollastonite has higher UTS which reflects in the overall matrix.

The SEM images show the even distribution of the reinforcement in the specimen matrix. The even distribution makes the specimen homogeneous.

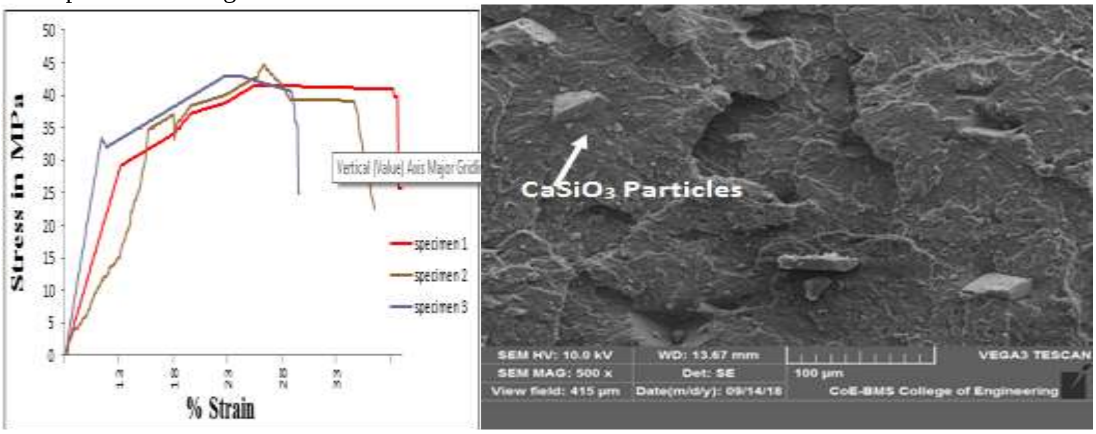

Figure 5 (a) & (b): Stress versus strain diagram of ABS+3% $CaSiO_3$composites and SEM Analysis at 500X magnification.

ABS+5%$CaSiO_3$

The figure 6 shows the stress versus % strain graph of 5% $CaSiO_3$ reinforced ABS composites sample for tensile test. The 5% inclusion of Wollastonite ($CaSiO_3$) has improved the UTS of the ABS matrix by 66% as compared to pure ABS that is 53.96MPa thus, decreasing the elongation percentage and making the material more brittle and harder so that it survives high tensile force. The sudden increase in the tensile strength is due to the excess percentage of reinforcement in the matrix. The high percentage of Wollastonite results in dense and even distribution of the $CaSiO_3$particles thus making the matrix stronger. The SEM images show the even and denser distribution of the Wollastonite in ABS matrix.

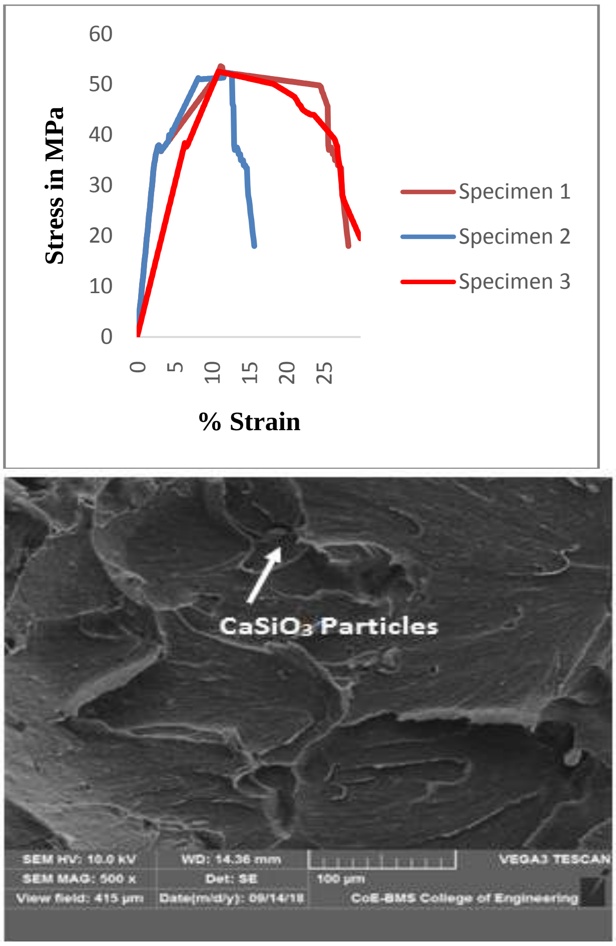

Figure 6 (a) & (b): Stress versus strain diagram of ABS+5% $CaSiO_3$composites and SEM Analysis at 500X magnification.

ABS+7%$CaSiO_3$

The above figure 7 shows a typical stress versus % strain graph of7% $CaSiO_3$ reinforced ABS composites sample tested for tensile strength. The 7% reinforced samples haven't shown very high improvements. The UTS was found to be around 35.73 MPa which is only 10% higher than pure ABS which is way less than what the 3% and 5% specimens exhibited. This maybe because of the poisoning effect caused due to the excess amount of Wollastonite present in the matrix. The increasing amount of Wollastonite induces brittles and decreases the ductility of the matrix thus making it weaker.

The SEM images of ABS+7% $CaSiO_3$ composites were obtained at a magnification of 500X. it can be seen that, in this sample the $CaSiO_3$ particles are densely distributed in the ABS matrix which may lead to cause poisoning effect in the matrix.

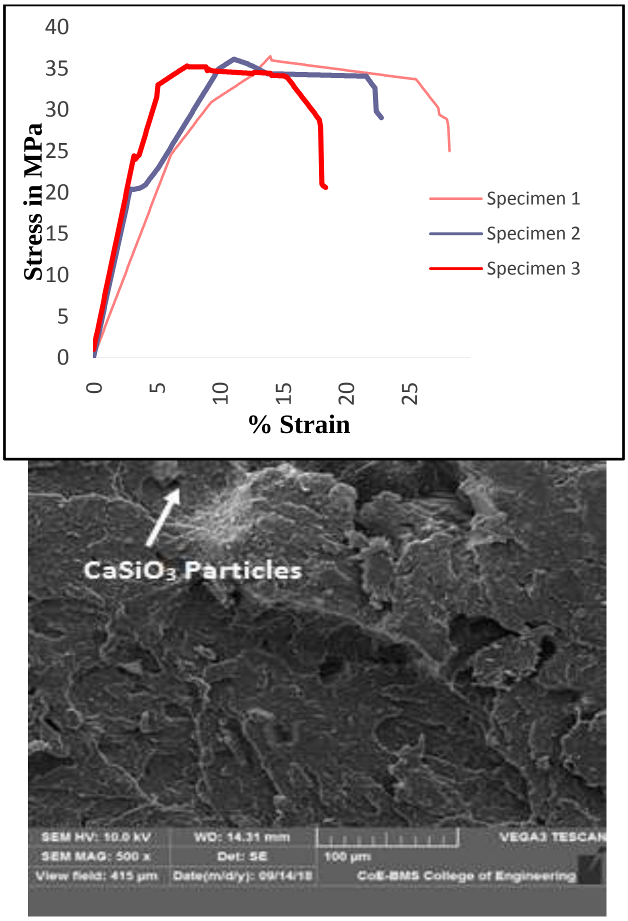

Figure 7 (a) & (b): Stress versus strain diagram of ABS+7% $CaSiO_3$composites and SEM Analysis at 500X magnification

IV. ANSYS VALIDATION:

The model is developed by using ANSYS 14 version software. It is fine meshed and boundary conditions were given to get accurate results which are shown in figure 8. Fig 13 shows the variation of experimental and ANSYS values. It is shown that ANSYS values are slightly greater than the experimental values for all the composition under normal condition and percentage deviation values are 9.57, 2.15%, 4.84% and 5.50% for Pure ABS, 3%, 5% and 7% composition respectively and these deviations are in acceptable range. It can be concluding that the carried out experimental values are correct and given valid results. The small deviation in the experimental values due to some technical issues like uneven barrel temperature of injection molding, pressure variation of IM machine, human error etc.,

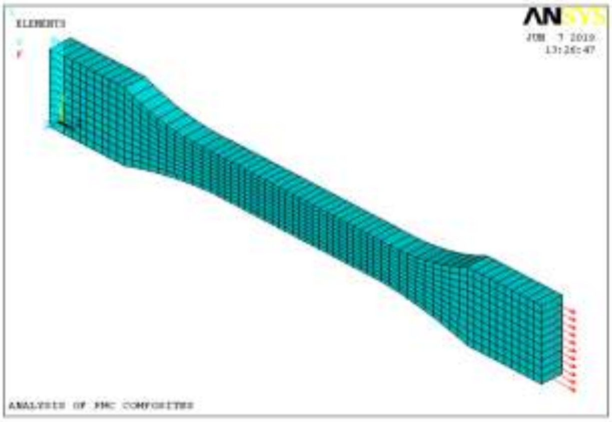

Figure 8: Meshed and boundary conditioned model of tensile specimen by using ANSYS

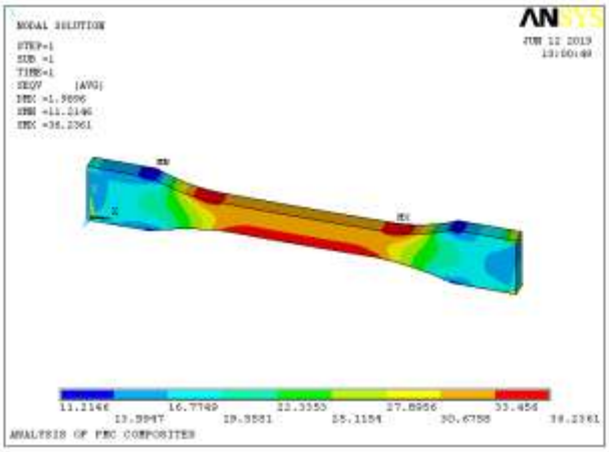

Figure 9: Tensile Stress distribution in pure ABS sample.

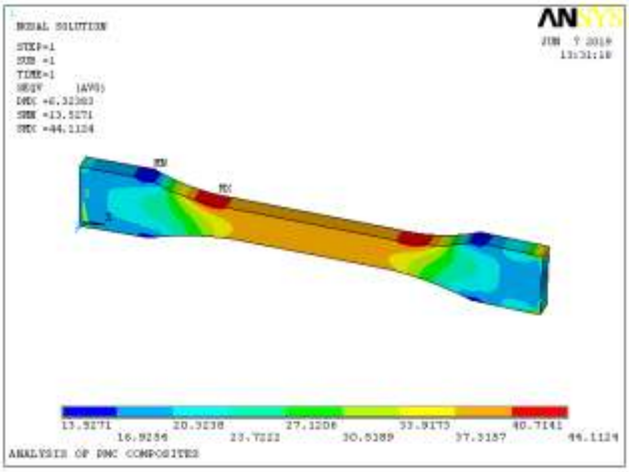

Figure 10: Tensile Stress distribution in ABS+3% $CaSiO_3$ Composition samples.

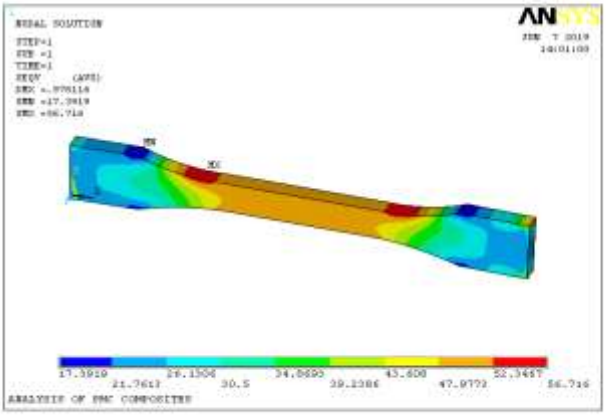

Figure 11: Tensile Stress distribution in ABS+5% $CaSiO_3$ Composition samples.

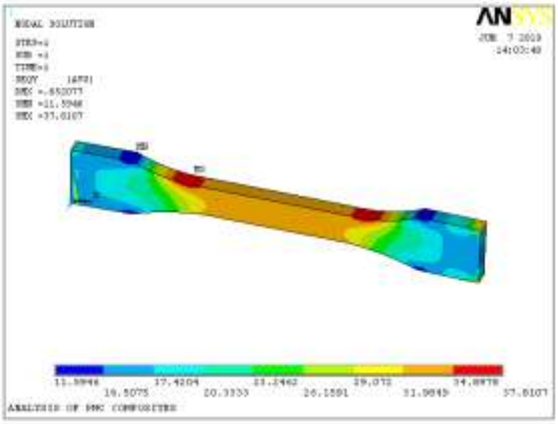

Figure 12: Tensile Stress distribution in ABS+7% $CaSiO_3$ Composition samples.

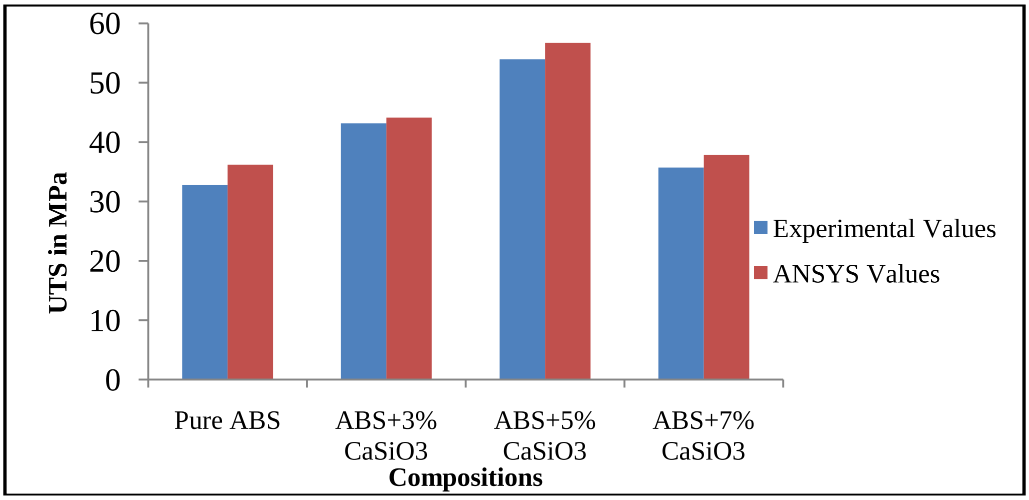

Figure 13: Deviation of Ultimate tensile test values

V. CONCLUSION:

The tensile test and Finite Element Analysis were carried out on pure, 3%, 5% and 7% reinforced composites according to the ASTM standards. The overall conclusion has shown that inclusion of Wollastonite has altered the properties of ABS positively. However, the amount of reinforcement that has to be added is also important.

The following are some derived conclusions from the obtained results:

- 3% of inclusion of the Wollastonite shows good improvement in the tensile property as the Wollastonite induces its strength in the matrix. The improvement was found to be around 33%.

- 5% inclusion of Wollastonite turned out to be the best among the all the three compositions. This composition showed a remarkable rise of tensile strength up to 66% as compared to pure ABS.
- The 7% Wollastonite inclusion improved the tensile strength slightly by 10%. Even though the amount of reinforcement was high the improvement in tensile strength wasn't as expected.
- The above results were then validated with FEM model using ANSYS software and it was found that the ANSYS results were similar and matching to the experimental results. However, there was a small deviation in experimental results as compared to ANSYS.

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