Print ISSN : 0022-2755
Journal of Mines, Metals and Fuels
Contents available at: www.informaticsjournals.com/index.php/jmmf

Comparison of Mechanical Properties of ABS and ABS/Wollastonite ($CaSiO_3$) Composites

Prapul Chandra AC[1*], Gangadhar TG[2], Mahantesh M Math[1], Gurupavan HR[3] and Roopa TS[1]

[1]RV College of Engineering, Department of Mechanical Engineering, Bengaluru, Karnataka.
E-mail: prapulchandraac@rvce.edu.in / Mahanteshm@rvce.edu.in / roopats@rvce.edu.in
[2]SJBIT, Department of Mechanical Engineering, Bengaluru, Karnataka. E-mail: tggangsadi@gmail.com
[3]PESCE, Department of Mechanical Engineering, Mandya. E-mail: gurupavanhr@pesce.ac.in

Abstract

This paper deals with the effect of filler material on the tensile and compression strength of Acrylonitrile-Butadiene-Styrene (ABS) and its composites filled with wollastonite ($CaSiO_3$) were investigated. In present study, the filler material $CaSiO_3$ is an inorganic compound which is mixed with the organic ABS. $CaSiO_3$ is mixed with ABS in varying percentages ranging from 3-7 wt% and the proper mixing of composition is ensured by twin screw extrusion process. Later, the mixture is taken into injection moulding machine and prepared specimen as per the ASTM standards. The prepared specimens are subjected to tensile and compression test using Universal Testing Machine (UTM). The 5% composition samples show more improvement in both tensile and compression strength and it is enhanced by 66% and 77.20% respectively compare to pure ABS samples under normal load condition. The presence of wollastonite ($CaSiO_3$) in ABS is examined using SEM analysis.

Keywords: *Acrylonitrile butadiene styrene, Composites, Injection moulding, Tensile test, Universal Testing Machine (UTS), wollastonite ($CaSiO_3$)*

1.0 Introduction

Polymer matrix composite material is the one that uses organic polymer as matrix and fiber as reinforcement. However, there should be a matrix with good bonding properties to held reinforced material together. On the other hand, the matrix material should be served as force distributer when the load applied. In some cases, the properties of composites are mainly depends on the nature and types of the matrix material. Due to which in composite materials, the performance of fiber, matrix and the interface between them directly impact on the performance of composite materials[1].

Among all the plastics, ABS has been in much use for its wide range of applications. ABS is a two-phase polymer blend. A continuous phase of styrene-acrylonitrile copolymer (SAN) gives the materials rigidity, hardness and heat resistance. The toughness of ABS is the result of sub microscopically fine polybutadiene rubber particles uniformly distributed in the SAN matrix[2].

Filler materials are the small particles which act as reinforced added to resins that can enhance the material properties. Most of the filler materials used in polymers composites are glass or mineral based type. Some of the filler materials used in the polymer composites are calcium carbonate, calcium silicate, glass fibre and carbon black etc. In some cases, organic matrix is mixed with inorganic type of filler material to form hybrid nanocomposites. The inorganic silica nanoparticles are mixed with the organic ABS and both the material encapsulation by coagulation process. Due to addition of Silicon Dioxide (SiO_2) nano particles, enhanced in impact, tensile and hardness strength; this was because of proper bonding between

*Corresponding Author

ABS and SiO_2 nanoparticles and also it controlled the microstructure properties of material.

Wollastonite – A versatile industrial mineral with many unique characteristics has become one of the most versatile functional fillers in the marketplace. Wollastonite increases the performance of many products including plastics, paints and coatings, construction materials, friction, ceramic and metallurgical applications to name a few. Wollastonite is a natural mineral comprised chemically of calcium, silicon and oxygen. Its molecular formula is $CaSiO_3$ and its theoretical composition consists of 48.28% CaO and 51.72% SiO_2. Natural wollastonite may contain trace or minor amounts of various metal ions such as aluminum, iron, magnesium, potassium and sodium. Wollastonite is rarely found by itself and generally contains other minerals like calcite, garnet and diopside that are removed during processing. In plastics, wollastonite improves the durability of the composite due to its acicular or needle-like structure. It also enhances electrical insulating properties, adds fire resistance, and improves dimensional stability. Finer particle size grades provide improved scratch and impact resistance compared to other materials. The application of surface treatments like silanes on the wollastonite substrate changes the mineral from utilitarian filler to a functional component of a polymer composite. This in turn adds performance values which the base resin alone does not possess. Optimum performance is created by properly matching the correct coupling agent at the right concentration level to the polymer system. Overall, the benefits of a surface modified wollastonite are improved physical properties, improved processing along with improved dispersion of the resin[3].

The inclusion of Wollastonite in ABS matrix improves the tensile modulus and impact strength of ABS as a result of good interfacial interaction between the Wollastonite and ABS. Further, the mixing mechanism has significant effect on mechanical properties[5]. However the proper mixing of the compounds is generally achieved in twin screw extruder. The flexibility and ease of working (like clockwise and anti-clock wise rotation of the screws) in the twin screw extruder equipment allow operation to be designed for the formulation being processed[6]. Sometimes in order to achieve some difficult mixing characteristics, the screw configuration itself maybe varied using forward and backward conveying element[7].

2.0 Experimental Details

2.1 Specimen Preparation

The specimens for tensile and compression tests are prepared according to ASTMD 638 and D695 Standard. In the beginning, the mixtures of Wollastonite ($CaSiO_3$) and ABS pellets are mixed by using the twin extruder. The long pellet of mixture obtained from the extruder is taken out and allowed to cool for 15 minutes and upon those long pellets of mixture is cut in to small pellets and maintained pellets in hot oven for 24 hours and this avoids the presence of moisture particle in it. Then after taken in to injection mold machine which is fitted with master molds. The temperature around 180°-200°C and injection pressure of 65 kg/cm^2 are maintained as process parameters while fabricating the specimens. Whereas for pure ABS specimens the pellets of ABS is dried at 80°C for 24 hours in hot air oven before it is processing are directly taken in to the injection molding for the fabrication of specimens [8].

2.2 Tensile and Compression Tests

Tensile and compression samples were obtained from injection mold. The test of each samples are conducted at ambient temperature, by using computerized Universal Testing Machine (UTM). The test specimens are fixed to UTM machine at a cross-head speed of 1.5mm/min and the software in the system records the value and plotted the graph of stress-strain curve so that it indicates the strength of the tested samples. The three specimens were tested in each composition and taken the average value.

ABS and its composites specimen'sfractured surface were examined by Scanning Electron Microscopy (SEM). The morphological structures of ABS reinforced Wollastonite specimens were carried out to check surface fractured specimens crystallization and to ensure the distribution of Wollastonite particle in ABS matrix.

3.0 Results and Discussions

ABS reinforced Wollastonite specimens were subjected to tensile and compression tests and these are the most important mechanical tests for the material. The specifications of the specimens for both the tests are shown in Figure 1 and

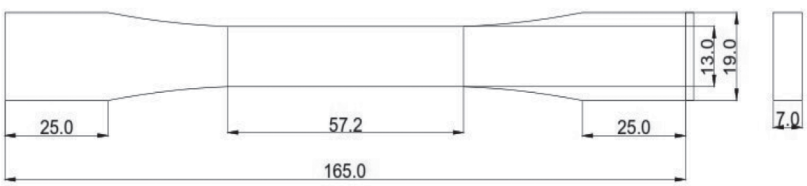

Figure 1: Tensile test specimen specification

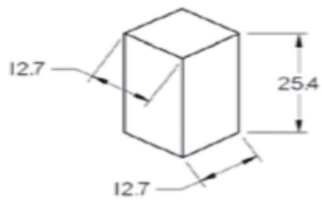

Figure 2: Compression test specimen specification

Table 1: Properties and its strength of ABS and composites samples

Properties	ASTM standards	ABS (standard data)	ABS (Tested data)	ABS+3% $CaSiO_3$	ABS+5% $CaSiO_3$	ABS+7% $CaSiO_3$
Tensile strength (MPa)	D638	36	32.76	43.6	53.96	35.73
Compressive strength (MPa)	D695	58.62	59.16	64.17	103.9	77.3

2 respectively. The obtained experimental results for different compositions are analyzed and compared in the graph. The ultimate stresses are determined from the load displacement curves i.e. by plotting the graph of stress Vs strain for different compositions (3, 5 and 7 wt.%) and are listed in Table 1.

Pure ABS

The pure ABS samples are prepared by injection molded machine as per the ASTM standards. Mechanical properties (tensile and compression) results are as discussed in the Table 1. The Figure 3(a) and (b) indicates the stress vs. strain relationship of ABS subjected to the tensile and compression test. The maximum stress of ABS samples is 33.7 Mpa and 59.16 Mpa and it is decreases 6.38% and 3.87% compared to standard values respectively for tensile and compression test. The diverted values are in the specific ranges as seen from the Table 1. It is observed that the pure ABS tested samples indicate a brittle mode of fracture and that failure of ABS samples indicates reduced matrix elongation without the neck formation. The results of the tests indicate that there is a marginal drop in strength, Also the loss in the strength can be attributed to the use of hand operated IM machine which lacks the necessary raw material drying facility (hopper drying), mould/die heating facility, maintaining the necessary injection pressure, effective raw material melting facility etc. that the sophisticated IM machines

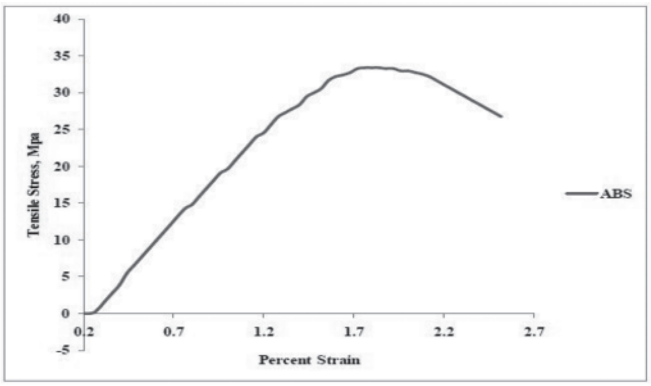

Figure 3(a): Stress versus strain diagram of raw ABS Specimen for tensile strength

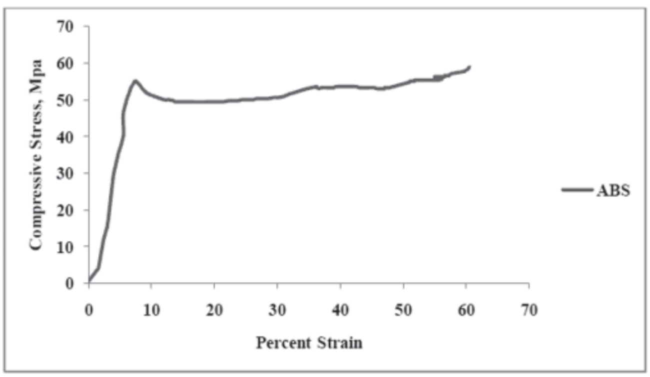

Figure 3(b): Stress versus strain diagram of raw ABS Specimen for Compression strength

ABS+3% Wollastonite

Figure 4(a) and (b) indicates the stress vs. % strain of ABS +3wt.% wollastonite composites specimen subjected to tensile and compression test. From the graph it is observed that there is slightly improvement in UTS for ABS+3%

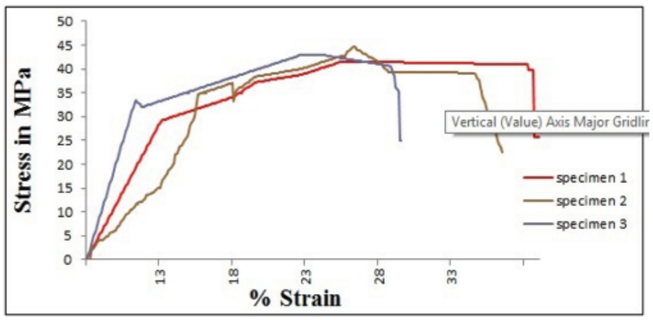

Figure 4(a): Stress versus strain diagram of ABS+3% wollastonite composites Specimen for Tensile strength

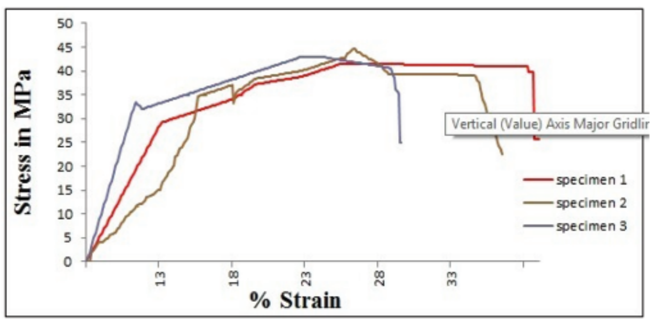

Figure 4(b): Stress versus strain diagram of ABS+3% wollastonite composites Specimen for compression strength

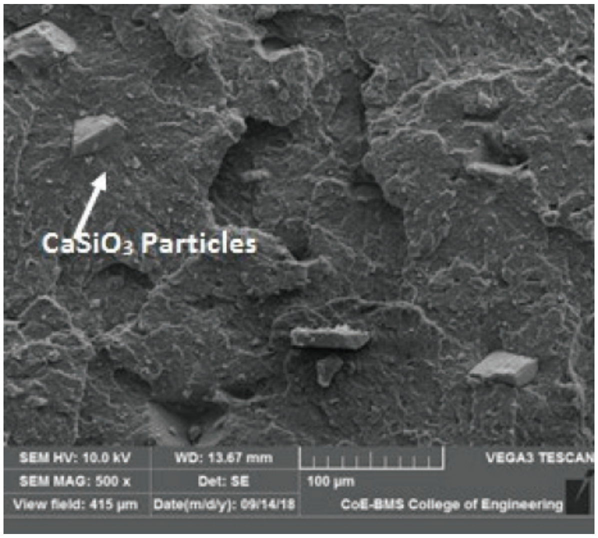

Figure 4(c): The SEM images of 3 wt.% reinforced composites at 500X magnification

wollastonite composite specimen of 43.6Mpa over 32.76 of pure ABS specimen and strength is increased by 33.08%. The percentage of elongation of this composites is slightly high and that indicates that material is attained the ductile nature. The Figure 4(c) shows SEM images of ABS+3% wollastonite composites were taken at 500X magnification. The image clearly indicates the even distribution of the wollastonite particles in ABS matrix and this helps the ABS matrix to gain some strength and thus increase the tensile properties

In the other hand, the addition of 3% wollastonite into the ABS matrix shows marginal increase in the compression strength of composites and it is 64.17 Mpa against 59.16 Mpa of pure ABS and it is increased by 7.80%.

ABS+5% Wollastonite

It is clear from the Table 1 that 5% reinforced ABS composites exhibit a higher load carrying capability than the normal, 1% and 7% wollastonite reinforced ABS composites under normal conditions. The addition of 5% of wollastonite into the ABS matrix has increased the tensile and compression strength of 53.96 Mpa and 103.9 Mpa and it is increased by 64.71% and 75.62% respectively over pure ABS so the percentage of elongation becomes low hence material becomes more brittle and harder so that it sustains high force. The enhancement in the tensile strength of 5% samples indicates that, the bonding between $CaSiO_3$ and ABS matrix is strong enough to withstand the externally load applied during tensile loading and this is evident from the Fig.5(c), which is a Scanning Electron Micrograph (SEM) 5% tensile fractured sample. The micrograph indicates finely distributed $CaSiO_3$ particles in a matrix of ABS.

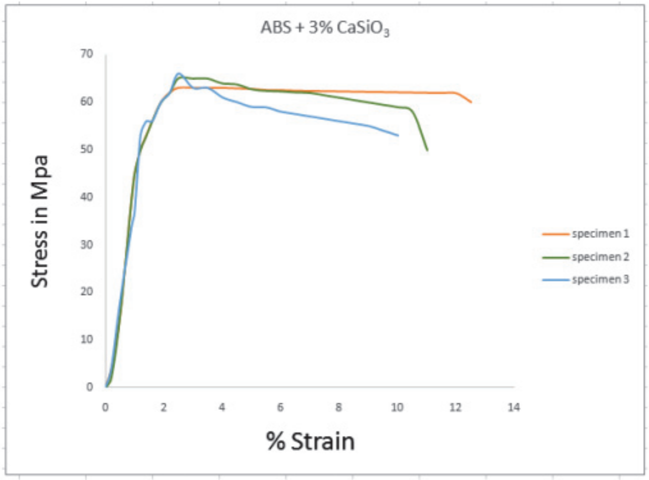

Figure 5 (a): Stress versus strain diagram of ABS+5% wollastonite composites specimen for tensile strength

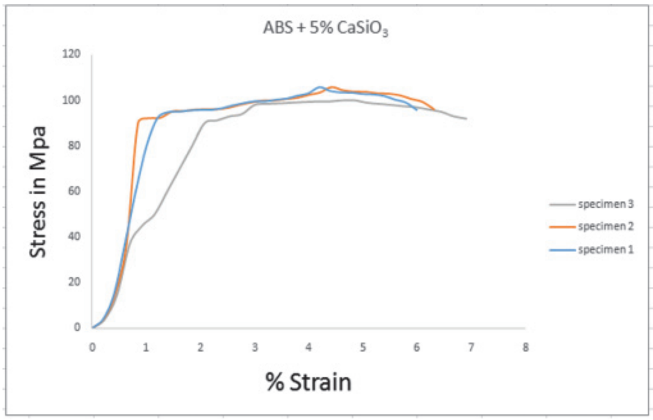

Figure 5 (b): Stress versus strain diagram of ABS+5% wollastonite composites specimen for compression strength

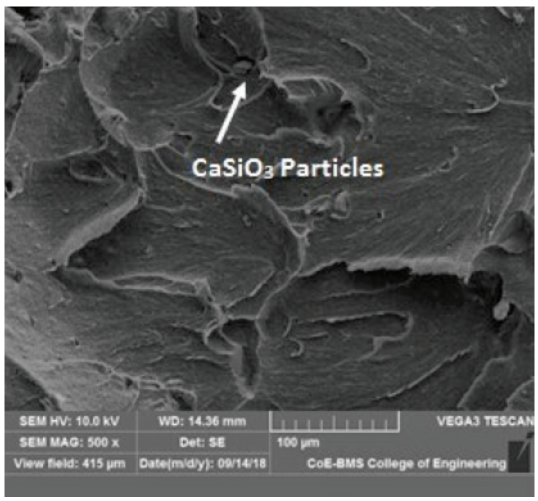

Figure 5(c): The SEM images of ABS+5% wollastonite composites at 500X magnification

ABS+7% Wollastonite

Figure 6 (a) and (b) shows to a typical stress versus. % strain relationship of ABS + 7% wollastonite composites specimen subjected to tensile and compression test. The maximum tensile and compression stress attained by the composites is 35.73 MPa and 77.3 Mpa that is 9.06% and 26.20% respectively compared pure ABS samples. From the graph it is observed that there is considerable fall in the strength of these composition as compared to remaining composition but there is slightly higher in the strength as when compared to pure ABS specimen. The reason behind to decrease in strength may be due to the dense powdered wollastonite makes poisoning effect in ABS i.e. at lower percentages wollastonite acts a reinforcing material but as the percentage increases the same wollastonite particles acts as the sites of imperfections and porosity in the material occurred thus decreasing the strength. Also, this decrease in strength could be attributed to the tendency of wollastonite to form agglomerates at higher percentages, as proved by SEM study. The Figure 6(c) shows SEM images of ABS+7% wollastonite

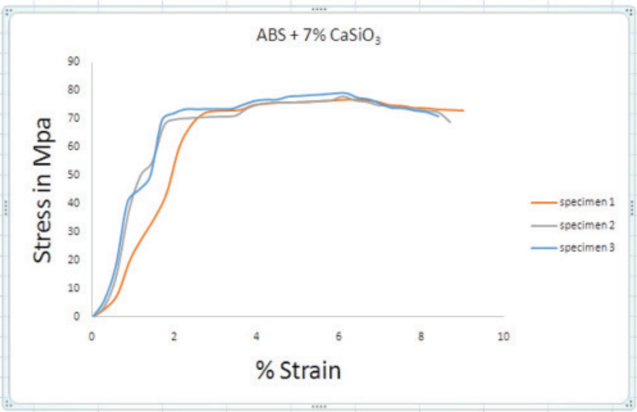

Figure 6(a): Stress versus strain diagram of ABS+7% wollastonite composites specimen for Tensile strength

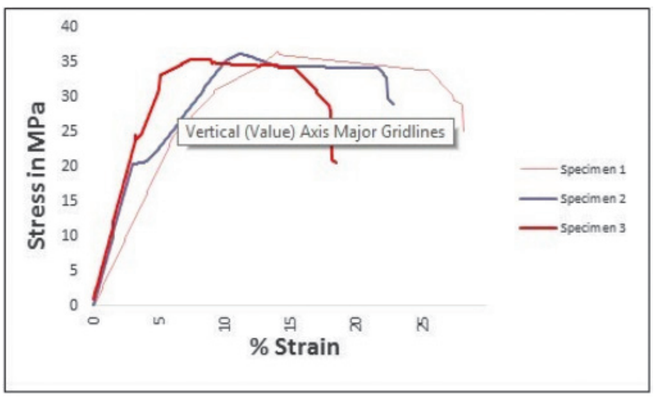

Figure 6(b): The SEM images of ABS+7% wollastonite composites at 500X magnification

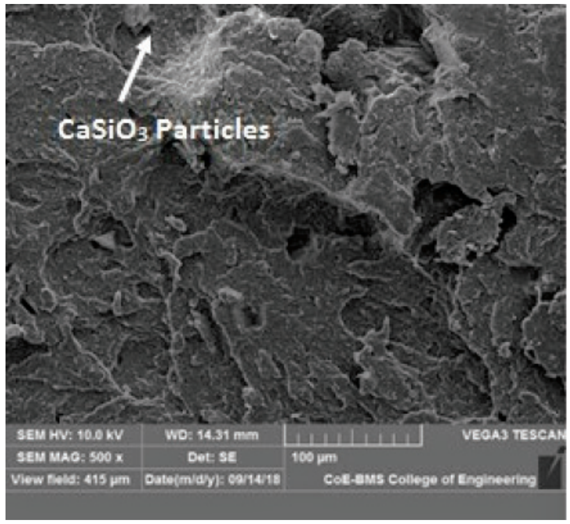

Figure 6(c):The SEM images of ABS+7% wollastonite composites at 500X magnification

composites were taken at 500X magnification. This figure clearly shows the dense distribution of wollastonite particles and which leads to poisoning effect in ABS.

4.0 Conclusions

From the graph (Figure 7) it can be understood that the addition of 5% wollastonite in ABS matrix sample given a very appreciable improvement in tensile and compression strength compared to the pure ABS specimen, 3% and 7% compositions samples. The average tensile strength shown for 3%, 5% and 7% composites is 43.16 Mpa, 53.96 Mpa and 35.73 Mpa and exhibit increased by 33.08%, 66% and 9.06% respectively. The maximum strength for the compression tests are 64.70Mpa, 105.56 Mpa, 77.73 Mpa and increased by 10%, 77.20% and 26.20% respectively for 3%, 5% and 7% compositions samples.

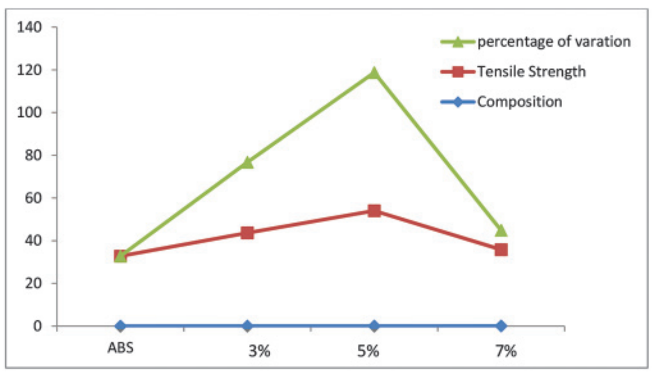

Figure 7: Variation of strength for different compositions of ABS reinforced wollastonite composites

The strength increased in 5% composition is due to the fact that even distribution of wollastonite in ABS and acts as good reinforcement for the matrix of ABS which gives inner support to matrix of ABS and hence 5% composition samples bear the external load but where in 7% composition samples decreased in strength is noticed because large lumps of wollastonite distributions are visible, which actually leads to poisonous effect thus brings down the strength of the composites and this is evidenced by SEM analysis.

5.0 References

1. Ru Min Wang and Shui Rong Zheng, (2011): Polymer matrix composites and technology, Book-Wood head Publishing.
2. http://www.bpf.co.uk/plastipedia/polymers/ABS and Other Specialist_Styrenics.aspx (accessed on 21-05-2016), British Plastic federation.
3. I.J. Kimo, S. Kwon, J.B. Park and H. Joo (2006): Synthesis and characterization of ABS/silica hybrid nano composites, *Current Applied Physics*, Vol 6, (pp 43-47).
4. K. P. Ashik and Ramesh S. Sharma (2015): A Review on Mechanical Properties of Natural Fiber Reinforced Hybrid Polymer Composites, *Journal of Minerals and Materials Characterization and Engineering*, Vol 3, (pp 420-426).
5. http://www.imana.org/?page=what_is_Wollastonite (accessed on 21-05-2016), Industrial Minerals Association-North America, 2016
6. Garcia A, Berthelot T, Viel P, Mesnage A, Je'gou P, Nekelson F, Roussel S and Palacin S (2010): ABS polymer electroless plating through a one-step poly (acrylic acid) covalent grafting. *Journal paper ACS Appl Mater Interfaces,* vol 2 1177–1183.
7. White, J.L. and Kim, E.K (2010): Twin Screw Extrusion, Technology and Principles, 2nd Edition, Hanser Publications, Munich.
8. Prapul Chandra A C, Dr. H V Byregowda (2018): Investigation of Compressive Properties of Wollastonite ($CaSiO_3$) reinforced Acrylonitrile Butadiene Styrene composites *International Journal of Engineering and Technical Research* Vol.8, pp 2454-4698
9. Leong YW, Bakar A, Ishak ZA, Ariffin A and Pukanszky B. (2004): Comparison of the mechanical properties and interfacial interactions between talc, kaolin, and calcium carbonate filled polypropylene composites. *J Appl PolymSci*; Vol.91, pp 3315-3326.
10. Unal H, Findik F and Mimaroglu A (2003): Mechanical behaviour of nylon composites containing talc and kaolin. *J Appl PolymSci.* Vol 88, pp 1694-97.
11. S. R. Owen and J.F Harper (1998): Mechanical, Microscopical and fire retardant studies of ABS Polymers, *Polymer Degradation and Stability* vol. 64, pp. 449-45.