Influence of Copper Filled Acrylonitrile Butadiene Styrene Composite's on Mechanical Properties in Injection Molding Process

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Abstract
Acrylonitrile Butadiene Styrene (ABS) is one of the ideal material for direct digital, functional prototyping and conceptual modeling manufacturing. The manufacturers are different technologies and the methods to enhance the properties of the product. The focus is shifted from the pure material to the composites for the designing the product. The objective of the present study was to investigate the effect of different composition of copper (Cu) powder on the mechanical properties of the ABS-Cu composites. Different compositions of ABS-Cu composite with different weight percentage of specific material were prepared using Injection Molding machine. Specimens of ABS-Cu composite were made for the dry sliding wear test and hardness test as per ASTM standard. Result shows that, with increase in copper percentage in the composite, there is a decrease in surface hardness and coefficient of friction in ABS-Cu composite. These conclusions will be consider in engineering designs and will give improvement towards the mechanical properties of the material.

***Keywords:** Injection molding,* Acrylonitrile butadiene styrene, *ABS-Cu composite,Dry wear test and Vickers Hardness Test.*

INTRODUCTION
Nowadays many technological processes require materials with unusual combinations of properties that cannot be aqquired by the traditional Composites, and metal alloys. For example, aerospace industry is increasingly looking for structural materials with low density, high strength, stiffness, and abrasion as well as impact resistance properties. The combination of these characteristics brings an extremely challenging front for engineers and materials scientists. Polymers are classified in two subdivisions of thermoplastic and thermosetting based on their response to the mechanical forces at elevated temperatures. Filler materials have been used to improve thermal and electrical properties as well as increasing the density, inducing magnetism, and thermal stability. Various kinds of metals used in injection molding process. Gungor studied the mechanical properties of Fe powder fillers in the HDPE polymer matrix based on vol. % (5, 10, 15 vol. %). They concluded that an additional 5 vol. % of Fe reduced the impact strength of HDPE 40% and reduced 90% of elongation respectively. When vol. % of Fe increase of 10 vol. % and 15 vol. %, the impact strength and % elongation values decrease proportionally. For additional 5 vol. % Fe composite in HDPE, the modulus of elasticity was 31% higher than unfilled HDPE. Nikzad et al. investigated the thermal and mechanical properties of new metal-particle filled acrylonitrile butadiene styrene composites ations in fused deposition modeling rapid prototyping process. Ahn et al. developed

a polymer matrix composite feedstock material by the injection moulding machine. And they studied the effect of powder loading and binder content on the mechanical properties. Masood and Song developed and discussed the thermal characterization of new metal/polymer composite material for use in fused deposition modelling (FDM) rapid prototyping process with the aim of application to direct rapid tooling. Kumar and Kruth furnished succinct notes on the composites formed by rapid prototyping processes such as selective laser sintering/melting, laser engineered net shaping, laminated object manufacturing, stereo lithography, fused deposition modeling, three dimensional printing and ultrasonic consolidation. Moballegh et al. synthesized different feedstocks from gas atomized copper powder and a thermoplastic binder based on paraffin wax. The optimum formulation of 95 / 5 wt (copper powder / binder) was selected from rheological investigation and then the suitable feedstock was injected successfully at low pressure. Nikzad et al., showed 2D and 3D numerical analysis of melt flow behavior of representative ABS-iron composite through the 90 degree bend tube of the liquefier head of the fused deposition modeling process using ANSYS FLOTRAN and CFX finite element packages. Masood and Song developed a new metal/polymer composite material for use in fused deposition modeling (FDM) process with the aim of application to direct rapid tooling. The material consists of iron particles in a nylon type matrix. The detailed formulation and characterization of the tensile properties of the various combinations of the new composites are investigated experimentally.

Aim of the present study was to investigate the effect of different composition of copper (Cu) powder on ABS-Cu composite material on the mechanical properties of the material.

Material and Methods

To study the effect of metal powder on mechanical properties of composite material, three different composition of main material and the metallic powder in weight percentage were taken. In this the surfactant material is used to improve the covalent bonding and the flow ability between the ABS and the metallic copper powder. The table1 shows the Weight percentage of composite compounding. Dry wear test specimens were prepared as per ASTM G99- 95. Vertical hand operated injection moulding machine is used to fabricate this specimens. Aluminium die was used for the fabrication of the ABS/ABS composite pins for the dry wear test. In this the dimension of the cavity is maintain at 10 mm in diameter at one end with little diversion angle for easy removal of pin from the die with 35 mm length of the die. Dry wear test specimen first of all took out from the aluminium mould and then shaped as per the ASTM standard using lathe machine. Vickers Hardness Testing machine were used to conduct hardness test. Figure 1 shows the setup diagram for dry wear test (Pin on disk test) and Vickers hardness test. Figure 2 shows the specimens of four different composition of plain ABS and Cu-ABS composite material for tests. Table 2 shows the process parameters and their values for the pin on disk test.

Table 1: *Weight percentage of composite compounding*

Composition	ABS (wt. %)	Copper (99.9% pure) (wt. %)	Noninphinoethoxylate (Surfactant material) (wt. %)
Composition A	65	30	5
Composition B	44	50	6
Composition C	23	70	7
Plain ABS	100	0	0

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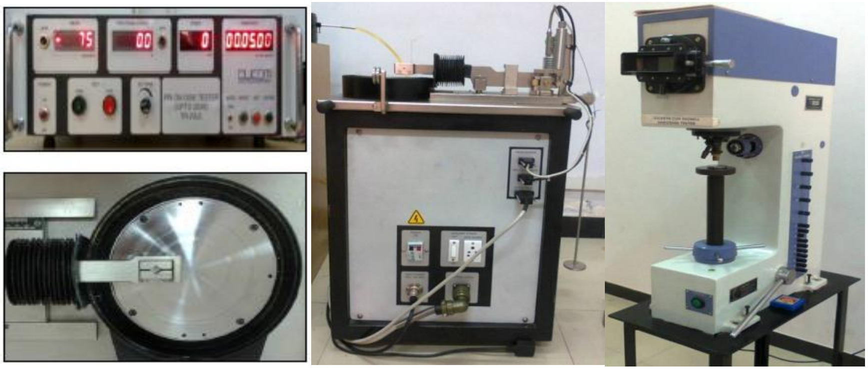

Figure 1: *Machine set up for dry wera test and Vickers hardness test*

Figure 2: *Specimens for Pin on disk Test and Vickers hardness Test.*

Table 2: *Process parameters with their values for Pin on Disk Test*

Composition	Sliding speed (m/s)	Load (N)	Sliding distance (mm)	Time (min)	Wt% Cu
Composition A	350	9.81	100	5	30
Composition B	350	9.81	100	5	50
Composition C	350	9.81	100	5	70
Plain ABS	350	9.81	100	5	0

RESULTS AND DISCUSSIONS

The dry wear test and hardness test data for each type of composite samples and the plain ABS are shown in table 3 and table 4 respectively. As in case of the dry wear test the standard dimension pin are prepared with ǿ8 mm × 32 mm cylindrical shape and an aluminium die is used to take out the mould from the injection moulding machine of each specimen. In this the sliding track diameter is set at 75 mm with the load of 5 Kg and the speed of the disk is maintained at 350 rpm for 5 min. And in case of Vickers hardness test 5 kg load is applied for the given PMC material and the plain ABS polymer. The three Vicker's numbers (HV) are calculated by taking three impressions at three different locations on the specimen. In this the average HV values were calculated by taking average of d1 & d2 and the results are tabulated in table no. 4.

Table 3: *Process parameters with their values and result for Pin on Disk Test*

Composition	Sliding speed (m/s)	Load (N)	Sliding distance (mm)	Time (min)	Wt% Cu	Wear rate	C.O.F
Composition A	350	9.81	100	5	30	146	0.433
Composition B	350	9.81	100	5	50	109	0.320
Composition C	350	9.81	100	5	70	89	0.313
Plain ABS	350	9.81	100	5	0	65	0.221

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Table 4: *Vicker's hardness test results*

Type of material	D1	HV1	D2	HV2	D3	HV3	Avg. HV
Composition A	0.4685	42.2429	0.4725	41.5307	0.483	39.7446	41.1727
Composition B	0.4745	41.18	0.483	39.7446	0.491	38.46	39.7949
Composition C	0.5045	36.4293	0.5545	30.1557	0.4927	38.1957	34.9269
Plain ABS	0.463	43.2525	0.4215	42.1529	0.4015	40.1593	41.8549

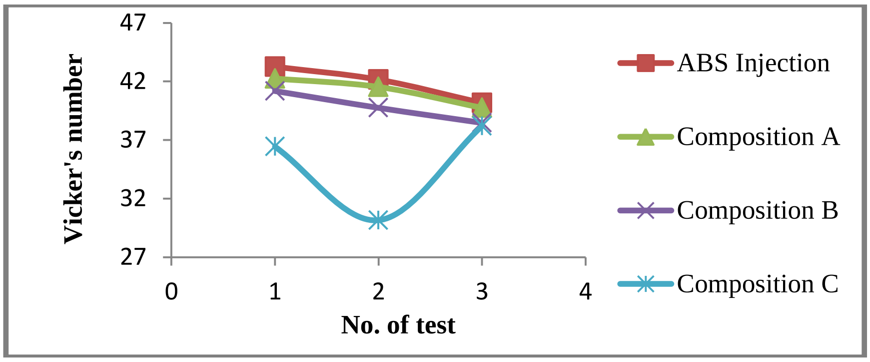

Figure 3: *Hardness test: Vicker's number vs. number of test of each material.*

The Table 3 shows that as the copper percentage increases in the composite the wear rate and the coefficient of friction decreases varies from 0.433 to 0.313 and the plain ABS having the coefficient of friction 0.221. It indicates that in ABS with Cu affects the wear properties of the composition.

Table 4 and figure 3 shows that the injection moulded specimen fabricated with the ABS material have the highest surface hardness among all the composite material with HV number 41.8549. In the composite material, composition A shows the high HV number i.e. 41.1727 which is higher than composition B and composition C which is also nearer to the HV number of plain ABS material.

CONCLUSIONS

The present study was to investigate the effect of different composition of copper powder on the mechanical properties of the ABS-Cu composites. Three different compositions of ABS-Cu composite with different weight percentage of surfactant material were prepared using injection moulding machine. Dry were test specimens were prepared as per the ASTM standard and the same specimens were used to carried out hardness test. The specimens made up of pure ABS shows good mechanical properties within the test observation. With increase in copper percentage in the composite, there is a decrease in surface hardness and coefficient of friction in ABS-Cu composite. From the results we can also conclude that instead of using only ABS or copper we can use the ABS-Cu composite material for different application where surface hardness and the wear rate of the material consider on priority basis with respect to the other mechanical properties. This will help in material characterization to identifying the best composition of the material for given requirement and create optimal process planning.

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