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Fabrication and testing of PVC composites with flyash and mica as hybrid reinforcements

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ABSTRACT

Polyvinyl chloride (PVC) is a well-known plastic and it is widely used because of its low cost and easy formability. Despite its great potential, virgin PVC is not bio-degradable and incineration of post consumed PVC products will release carcinogenic gases. In the current work, the main focus is done on preparing a new polymer composite by reducing the amount of virgin PVC just by adding low cost reinforcements.

Particulate polymer composites have wide applications due to easy formability and slow cost. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for wide spread applications in automotive and small engine applications. Muscovite Powder (MICA) is widely used as filler because of its functional morphological and surface characteristics. In the current research work flyash and mica filled PVC composites of different concentrations were prepared using Injection Moulding process. To find the potentials of composites, samples were tested for water solubility, flammability, chemical resistance, density and adhesive property. Mechanical properties were evaluated as per ASTM standards. The results shows enhancement in tensile property, Chemical resistance, flammability, but little reduction in shore D hardness.

KEY WORDS: PVC, Mica, Flyash, Injection Moulding.

1. INTRODUCTION

Polyvinyl chloride (PVC) is now the second most commonly used plastic material globally in terms of volume. It is mainly used for fabricating pipes, sheets, wires, etc. It is also the easiest to mould and is very compatible with other polymers. However PVC is nontoxic during usage but it creates complications while disposal. PVC is not a biodegradable plastic in addition burning of used PVC products leads to carcinogenic gases due to presence of chlorine.

PVC products also often contain dangerous toxic additives such as mercury, dioxins, lead and phthalates (used as softeners) which can leach out and pose dangers to consumers. PVC is dangerous to human health and the environment throughout its entire life cycle at the factory, in our homes, and in the trash. The dangers of PVC are from the persistent pollutants it releases and the toxic additives used to produce PVC products.

In India many towns and cities contribute post-consumer PVC as a municipal solid waste (MSW). Due to the ignorance of either consumers or municipal workers, under current conditions 82% of waste PVC goes to landfill and 15% to incineration.

Particulate filled polymer composites are becoming attractive because of their wide applications and low cost. There has been an increasing interest in composites containing low density and low cost reinforcements. In practical it is difficult to avoid total PVC usage but there is a need to reduce the quantity of virgin PVC by adding other low cost reinforcements

Now a day's more research is concentrated in preparation of polymer composites with different reinforcements. Most of the research is aiming to improve the properties of material without badly effecting the environment. Wear resistance of PVC composites was improved with the addition of fillers like SiC, Al_2O_3, $CaCO_3$, Flyash and B_4C to PVC (Fenglin Yang, 1999). Jitendra Gummadi (2012), evaluated the flexural properties of fly ash filled polypropylene composites. Wong (1994) added flyash at 20wt% to polypropylene and an ethylene/propylene with and without the addition of maleic anhydride grafted polypropylene coupling agent. The tensile property and the fracture toughness was measured using notched impact specimens.

Manoj Singal (2010) added varying weight percentages of flyash into epoxy resins. On testing found that compressive strength is increased, Impact strength is decreased. Rahail Parvaiz (2010) fabricated Polyetheretherketone (PEEK) composites using fly ash and mica as fillers. On testing, found that the tensile strength, tensile modulus and flexural modulus have increased. The tensile modulus of PEEK fly ash composites was found to be higher than PEEK mica composites.

Sreekanth (2009) prepared composites of polyester thermoplastic elastomers with varying concentrations of fly ash using twin screw extrusion. They tested for mechanical properties such as flexural strength, tensile strength and dielectric strength. Deepthi (2010) used Fly ash Cenospheres as reinforcing filler in HDPE to develop lightweight composites.

Deshmukh (2010) have done a study of the mica filled PVC composites prepared from mica of different particle size and with different filler concentration. Tests were conducted on the composites. The Economic Evaluation of PVC Waste Management report given by the European Commission Environment Directorate has

discussed about the wastage of PVC and its detrimental effects in the future. Ma (1994) used flyash as the reinforcement for formamide and urea plasticized thermoplastic starch (FUPTPS) and glycerol-plasticized thermoplastic starch (GPTPS).They tested for its Young's Modulus and Tensile stress.

In this study, PVC is used as the main matrix with mica and fly ash as reinforcement. The weight percentage of reinforcements is kept in the range of 5%-20%. The use of fillers will not only bring down the overall wastage amount of post consumed PVC by 20%, but will also have the additional function of improving the physical properties of the material. The increased use of fillers is projected to conserve up to 1 to 2 million tons of PVC waste every year.

2. EXPERIMENTAL

Materials Used: Composites of five different combinations of matrix and reinforcement were prepared by injection moulding process. Proper quantities of stabilizer, plasticizer (ABS) and steric acid as a lubricant were used in preparation of composite samples. Silquest 11009(3-aminopropyltriethoxysilane) silane coupling agent, was used for Surface treatment of mica. A test sample (S1) without reinforcement (mica and flyash) were prepared by adding additives such as stabilizer, lubricant and plasticizer for comparative studies. New hybrid composites with different combinations of reinforcement, with varying weight percentages were produced using injection moulding process and sample list is shown in table 1.

Table.1. Weight percentages of composite samples

Sample No	Composition	Weight Percentage %			
		PVC	FLYASH	MICA	ABS
S1	PVC+ABS	90		-	10
S2	PVC+ABS+FLYASH	82	10	-	8
S3	PVC+ABS+MICA	85	-	3	12
S4	PVC+ABS+MICA+ FLYASH	85	5	3	7

Injection moulding: The PVC, Fly Ash, Mica and the compounding agent were taken and mixed in four different combinations. The composite mixture was dry blended using high-speed mixer for five minutes and the process was repeated for four times. The blended powder was poured in hopper of injection moulding machine. The induction is heated up to 140°C temperature which is near the melting point of PVC. After, the machine setup is completed as shown in figure.1 the first combination's material is put in the hopper. It is then left to melt due to the coil for 2-3 minutes. After which the side handle is rotated for the plunger to push the material through the barrel. The material is squeezed out of the barrel through the nozzle into the die.

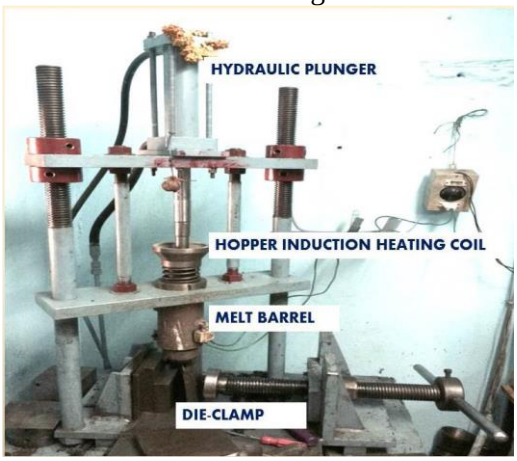
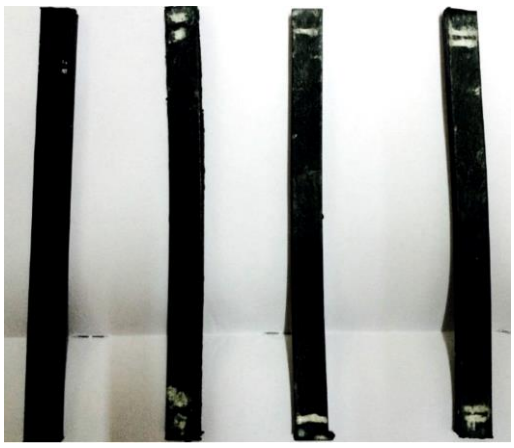


Figure.1. Injection moulding machine



S1 S2 S3 S4

Figure.2. Composite samples

Above said process was carried out to produce composites samples of different composition and individual naming was given as S1, S2, S3,S4 and S5 as shown in figure.2.

3. RESULTS & DISCUSSION

Tensile Test: Mechanical properties of the test specimen were evaluated as per ASTM D412 using universal testing machine (UTS 40) from Omega inspection and analytical laboratory, Guindy, Chennai. Virgin PVC and four different samples of varying filler combinations have been tested for finding the tensile strength the results are tabulated in the table.2. The samples shown in figure.3 have been used to find that tensile strength for PVC (S1) is having a maximum tensile strength of 11.18 MPa and least tensile strength of 4.06 MPa is found for PVC + MICA (S4).

Table.2. Tensile strength of composite samples

Sample N0	Sample Name	Tensile strength (Mpa)
S1	PVC+ABS	4.35
S2	PVC+FLYASH+ABS	4.38
S3	PVC+MICA+ABS	4.06
S4	PVC+FLYASH+MICA+ABS	4.38

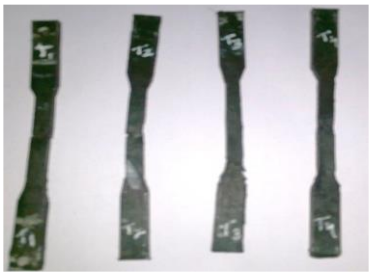


Figure.3. Samples after tensile test

So, tensile test report concludes that by adding fillers as flyash and mica the tensile strength is slightly increased when comparing with PVC.

Hardness Test: Mechanical properties of the test specimen were evaluated as per ASTM D2240 using Shore hardness testing Machine from Omega inspection and analytical laboratory, Guindy, Chennai. Four different samples of varying filler combinations have been tested for finding the shore hardness.

Table.3. Hardness Test

Sample Number	Sample Name	Hardness (Shore A°)	Hardness Average (Shore A°)
S1	PVC+ABS	91,89,92	90
S2	PVC+FLYASH+ABS	85,87,87	86
S3	PVC+MICA+ABS	85,86,84	85
S4	PVC+MICA+FLYASH+ABS	84,79,83	85

Hardness test for the samples have been found that shore- A hardness value for all the samples is listed in the above table 3. The hardness value of PVC+ABS (S1) is 90 shore A°. The hardness value for other samples is reduced. So, the test concludes that on adding fillers the hardness value is slightly reduced.

Chemical Resistance Test: Chemical properties of the test specimen were evaluated using chemical test with both acid and base from Omega inspection and analytical laboratory, Guindy, Chennai. Four different samples of varying filler combinations have been tested for finding the chemical resistance.

Table.4. Chemical resistance test – Acid

Sample No.	Sample Name	Initial Weight (g)	Final Weight (g)	Weight Difference	
				(g)	(%)
S1	PVC+ABS	3.6578	3.6704	0.0126	0.344
S2	PVC+FLYASH +ABS	3.7007	3.7165	0.0158	0.427
S3	PVC+MICA+ABS	3.2567	3.2702	0.0135	0.414
S4	PVC+FLYASH+MICA+ABS	2.8572	2.8808	0.0236	0.826

Chemical resistance test for the following samples have been found that when reaction takes place with an acid the weight of the samples are increased. The values are displayed in the above table 4. The percentage increase in the weight is less than 0.5% for samples S1, S2, S3. The percentage increase in the weight is less than 1% for sample S4. So, chemical resistance test concludes that PVC+FLYASH+MICA+ABS (S4) is having 0.826 which is a high value when compared to the other samples.

Table.5.Chemical resistant test – Base

Sample No.	Sample Name	Initial Weight (g)	Final Weight (g)	Weight Difference	
				(g)	(%)
S1	PVC+ABS	3.4491	3.4505	0.0014	0.040
S2	PVC+FLYASH+ABS	3.4938	3.4956	0.0018	0.051
S3	PVC+MICA+ABS	3.2936	3.2950	0.0314	0.953
S4	PVC+FLYASH+MICA+ABS	3.3463	3.3475	0.0012	0.036

Chemical resistance test for the following samples have been found that when reaction takes place with a base the weight of the samples are increased. The values are displayed in the above table 5. Chemical resistance test

concludes that percentage difference for PVC+MICA+ABS (S3) is having high value of 0.953 when compared to other samples.

Water Absorption Test: Chemical properties of the test specimen were evaluated using water at room temperature for time of 24 hours from Omega inspection and Analytical laboratory, Guindy, Chennai. Four different samples of varying filler combinations have been tested for finding the water absorption test.

Table.6.Values of water absorption test

Sample No	Sample Name	Water absorption (24 hours at room temperature)
S1	PVC+ABS	0.081
S2	PVC+FLYASH+ABS	0.102
S3	PVC+MICA+ABS	0.087
S4	PVC+FLYASH+MICA+ABS	0.053

Water absorption test is done by placing the samples in the water for 24 hours at room temperature. The test results say that there is water absorption for all the samples when placed in water. The results are shown above in table 6. Hence the water absorption test concludes that the absorption rate for PVC+FLYASH+MICA+ABS (S4) is having least value when compared to the other samples.

Flammability Test: Physical properties of the test specimen were evaluated using burning flame from Omega inspection and analytical laboratory, Guindy, Chennai. Four different samples of varying filler combinations have been tested for finding the flammability test. The results are tabulated below in the table 7.

Table.7.Flammability Test

Sample No	Sample Name	Flammability (Burning Rate) (cm/min)
S1	PVC+ABS	SELF EXTINGUISH
S2	PVC+FLYASH+ABS	SELF EXTINGUISH
S3	PVC+MICA+ABS	SELF EXTINGUISH
S4	PVC+FLYASH+MICA+ABS	SELF EXTINGUISH

Flammability test is done for the samples at 200°C of burning flame. So, the test reports conclude that there is a self-extinguishing nature for all the samples.

Density Calculation: Densities for all the samples have been calculated using rule of mixture formula. The density values vary from sample to sample.

Table.8.Density Calculation

Sample No	Sample Name	Density(gm/cm^3)
S1	PVC+ABS	1.27
S2	PVC+FLYASH+ABS	1.28
S3	PVC+MICA+ABS	1.26
S4	PVC+FLYASH+MICA+ABS	1.33

So, the density calculation concludes that the density of sample PVC+FLYASH+MICA+ABS (S4) is high when compared to other samples because of hybrid reiforcements. The densities are listed above in table 8.

Adhesive Test: The adhesive test is done by using PVC&UPVC solvent (a).First, the two sample specimens are taken (b) and solvent is applied on both of the samples (c) on to the specimen and placing another on it to check the adhesive property of the sample (d).

Figure.4. Adhesive test

4. CONCLUSION

The current work study was done on the effect of adding different proportions of reinforcement particles in virgin flexible PVC material. Several tests have been done to determine the potential and limitations. The tensile strength of the composite material has been slightly increased. This composites can be used in several other applications where lower tensile strength isn't an issue. The use of filler material will reduce the overall amount of virgin PVC wastage. Hardness of the PVC composite material has been slightly decreased. PVC, Mica and Fly ash composite sample has more resistance to acids when compared to the rest of the samples while PVC and Mica composite sample is more resistant towards bases when compared to the rest of the samples. These resistance property can be utilized for the purpose of storing chemicals and to develop chemical resistant coating.

Water absorption percentage of PVC, Fly ash and Mica composite sample is lowest (0.053) compared to the remaining composites samples which is good development. It can be used for water proofing purpose also. Virgin flexible PVC's decomposition temperature is 140-160°C range, the composite samples have been seen to exceed that range of the decomposition range and has self-extinguished. Densities of all the composites are almost same in the range of 1.3 gm/cm^3. It shows that despite the addition of fillers there is little change in density which is an appreciable development. The samples have shown good adhesive properties.

Hence the results clearly shows that there is a little reduction in the hardness property but there is a great improvement in the remaining properties. And it can be used as an alternative material in place of flexible virgin PVC products. Globally, there is a great demand for bio-degradable plastics based on conserving and protecting the environment for the future generations and the prepared composite meets that requirement. By using these composites, there will be a 20% reduction in the post-consumer products.

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