Welding Behaviour of Graphene Oxide Reinforced High Density Polyethylene Nanocomposites

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Abstract: ***Welding is used to produce bonded joints with technical properties to the base material. The thermoplastic nanocomposites are more familiar in recent days due to their excessive automotive applications. The specimens were prepared by pure HDPE and various weight ratios HDPE with nanofiller composites by melt mixing method and required shape produced by using compression moulding. The nanofiller will be chosen in this study is Graphene oxide. The main scope of using Graphene oxide was to enhance the mechanical properties of the prepared specimens. In this work, Ultrasonic welding had been used to carry out the test on both pure HDPE and HDPE with grapheme oxide. Mechanical properties were analyzed for both pure HDPE and grapheme oxide filled HDPE of both body part and welded part joints are compared.The mechanical properties of tensile strength and youngs modulus and elongation of the body part for graphene oxide filled HDPE was substantially increased due to the presence of compatabilizer.Thus the result improves the weld strength of the nanofilled polymer matrix with compatabilizer***

Keywords: ***Nanocomposites, ultrasonic welding, HDPE nanocomposites Compatibiliser***

I. INTRODUCTION

In a single manufacturing process the joining of materials is mainly done at the places where the product cannot be fabricated. The process of joining materials may be mechanical fastening, and physical and chemical bonding studied[1] Welding is used to produce joining of parent material that which approach the mechanical properties. Plastic welding is performed in thermoplastic polymers, mainly they softened by heat. The Plastic welding processes can be submerged into two types. The first type process involves external heating, and the second type is mechanical movement. Ultrasonic welding, that involves external heating has been applied to join plastic nanocomposites investigated [2].

Zhang et. al. stated at Nanocomposites are new developed composites which are having in nanometer range at least one dimension of the dispersed particles. Polyethylene (PE) is the largest sales turnover than other plastics. Ultrasonic welding is easy reliability, ease of operation, high production, and economic feasibility [3]. This paper deals with the far field welding of semicrystalline polymer/high-density polyethylene (HDPE). The amplitude is important in welding parameters in plastics are discussed [4]. C. Das et.al stated that the composites were prepared both in presence and absence of compatibilizer. The presence of compatibilizers having high performance while compared to absence of compatibilizers [5,6]. The compatibilizer helps to improve the bonding of nanoclay in base polymer matrix. The adding compatibilizer agent EP presented a sticking effect can promoting their mechanical properties of PBT/RCF composites is investigated [7]. The PP/ TIO2 nanocomposites using vibration welding the tensile testing was carried out by with welding and without welding. The nano fillers added to PP slightly increase their strength. But the welding pressure exceed to maximum level the weld thickness will be less.so the tensile strength will be decreasing are studied [8].

Rudolf R et.al was stated in the method mainly including the welding the plastics depends on the main parameters like the type of materials to be joined, size of the joining area, production rate, constant pressure, welding rate, cost, etc[9]. The plastic welding can be divided into two types. The first one mechanical movement and the second involve external heating. Welding of plastics involves their hold the plastics parts in gripper, position to weld the plastics at the joining portion, constant pressure, and removal of the welded specimen from the welding tool [10]. The USW of plastics can heating parts at site of their parts.so the USW welding can possible even at low temperature than other methods.in some situation welding can apply energy [11]. In this study the HDPE/graphene oxide nanocomposites mixed with compatabilizer. The ultrasonic welding used to welding the pure HDPE and HDPE/graphene oxide samples prepared different percentage in the with and without adding compatabilizer. The different mechanical properties were analyzed with and without welding part.

II. MATERIALS AND METHODS

The methodology of this research work has been depicted in Fig.1.

The following materials were used in this study,

(i) HDPE,

(ii) Graphene oxide,

(iii) Maleic anhydride [C2H2 (CO)2 O]

High Density Polyethylene

HDPE is known for its large strength-to-density ratio. The density of HDPE can range from

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0.93 to 0.97 g/cm3 or 970 kg/m3. Although the density of HDPE is only marginally higher than that of low-density polyethylene, HDPE has little branching, giving it stronger intermolecular forces and tensile strength than LDPE. The difference in strength exceeds the difference in density, giving HDPE a higher strength.

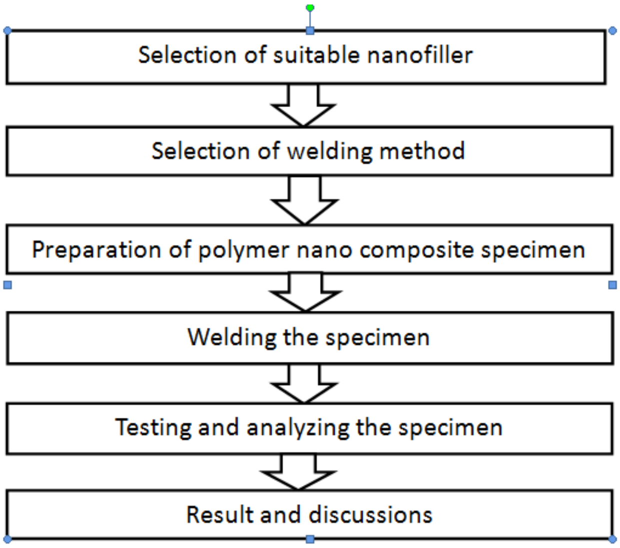
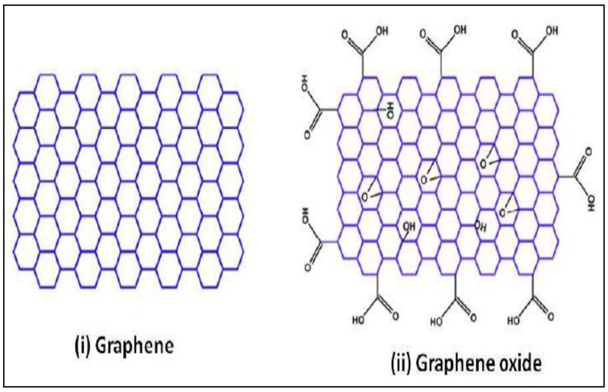


Fig. 1 Methodology

Graphene Oxide

Graphene was first reported in 2004, made using mechanical exfoliation from graphite, graphite oxide as attracted a great deal of interest, as researches have explored



simpler, more efficient cheaper and better yielding methods of synthesizing graphene, which can be scaled up easily and retain commercially viable properties for industrial applications.

Fig. 2 Chemical structure of graphene and graphene oxide

Maleic Anhydride`

Maleic anhydride is an organic compound with the formula $C_2H_2\ (CO)_2\ O$. it is the acid anhydride of maleic acid. It is a colorless or white solid with an acrid odor. It is produced industrially on a large scale for applications in coatings and polymers. Fig. 2 shows the picture of maleic anhydride

A. Preparation of nanocomposites

Melt mixing method

The mixing sample preparation formulation is shown in Table- I. For the preparation of nanocomposites, the graphene oxide placed in melt mixer and HDPE directly mixed to the melt mixer with two Sigma type counter rotating rotors. The mixing was done by at 200°C at 50 rev min^{-1}.After mixing the HDPE/graphene oxide, the compatibiliser added to melt blending at 200°C.

Compression moulding

The required shape of prepared nanocomposites were by using compression molding method under constant pressure of 10 MPa at 200°C for 10 min after cool down in room temperature. As per the sample preparation the ultrasonic welding was done of both the Pure and nanofilled composites.

Table- I Sample preparation of nanocomposites

S. No	*HDPE (g)*	*Graphene Oxide*	*Maleic Anhydride*	*Total*	*Composition*
1	30	-	-	30	HDPE
2	29.7	0.3 g (1%)	-	30	HDGO2
3	29.55	0.45 g (1.5%)	-	30	HDG03
4	29.4	0.6 g (2%)	-	30	HDGO4
5	28.8	0.3 g (1%)	0.9 g (3%)	30	HDCGO2
6	27.75	0.45 g (1.5%)	1.8 g (6%)	30	HDCGO3
7	26.7	0.6 g (2%)	2.7 g (9%)	30	HDCGO4
8	29.1	-	0.9 g (3%)	30	HDC4

Ultrasonic plastic welding is the joining or reforming of thermoplastics through the use of heat generated from high-frequency mechanical motion. It is accomplished by converting high-frequency electrical energy into high-frequency mechanical motion. That mechanical motion, along with applied force, creates frictional heat at the plastics components mating surfaces. So the plastic material will melt and form a molecular bond between the parts.

Table- II Ultrasonic Welding Properties

Parameters	Values
Weld pressure	4bar
Weld delay time	3sec
Welding time	3sec
Hold time	5sec

All the specimens were welded by using same constant parameters. The ultrasonic welding machine was shown in the Fig.3. The two specimens were to be welded by lab joint held by two clams, under constant parameters like 4bar welding pressure; 3 sec weld time, 3sec delay time and 5sec hold time as listed in Table- II. The thermoplastic polymer welded at the welding area by the heat generated due to the energy produced by ultrasonic wave.

Fig. 3 Ultrasonic welding machine

B. Mechanical testing

Tensile testing was performed in a universal testing tester machine, as shown in Fig. 4 operated at room temperature at an initial gauge length of 40 mm with an extension speed of

5 mm/min. The each specimen test values were noted directly from the digital display and the system.

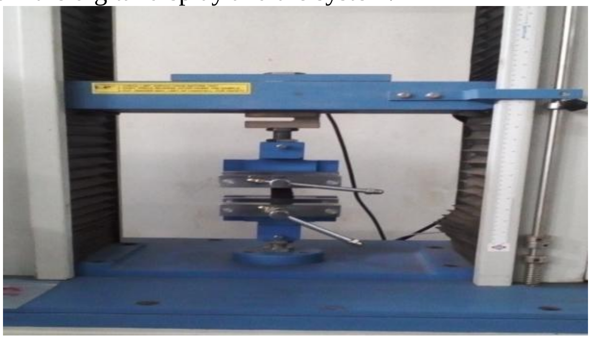


Fig. 4 Tensile testing machine

III. RESULT AND DISCUSSION

A. Tensile Strength

The mechanical properties of pure HDPE, HDPE/graphene oxide without and with adding compatabilizer specimens were tested .In the Fig. 5 and 7 shows the specimen of without welding Tensile strength and Young Modulus respectively and in the Fig. 6, 8 which refers the welding specimen of both Tensile strength and Young Modulus respectively. The tensile strength and modulus were increased with adding compatabilizer when compared to pure HDPE, HDPE/Graphene oxide without adding compatabilizer. The presence of compatabilizer is used to increase their mechanical properties.

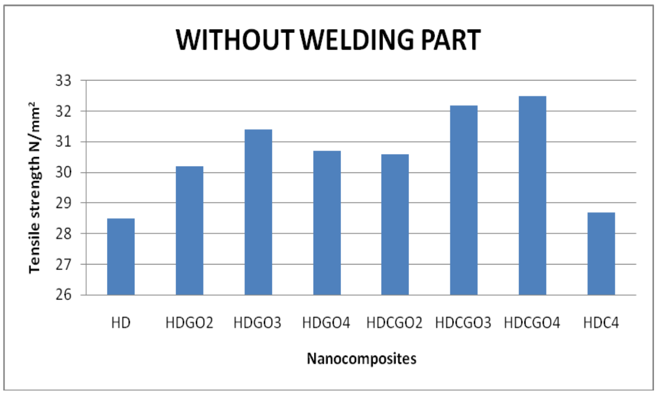


Fig. 5 Tensile strength of Pure and nanofilled composites

In this fig.5 shows the tensile strength of pure HDPE were less. The HDPE/graphene oxide without compatabilizer having problem with incorporation of mixing. So the tensile strength of without adding compatabilizer is not good but better than pure HDPE. The adding of compatabilizer in HDPE/graphene oxide to reduce their incorporation and mixing well. The adding 3%, 6%, 9% compatabilizer increases their tensile strength respectively. The 9% of adding compatabilizer having high tensile strength of others. The compatabilizer added to pure HDPE without nanofiller having low tensile strength than others.

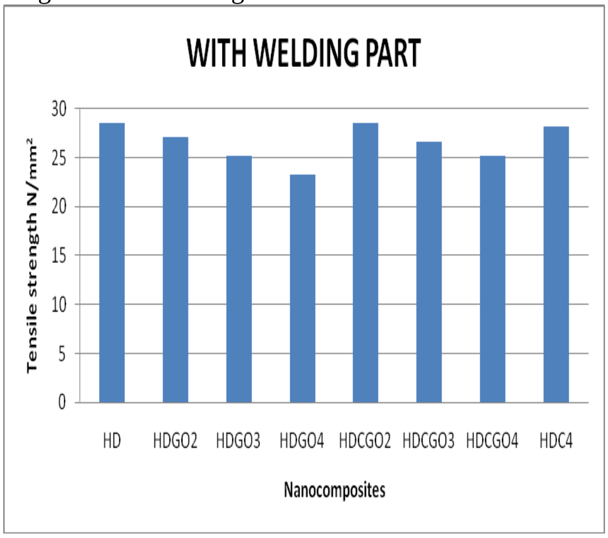


Fig. 6 Tensile strength of Pure and HDPE with Graphene oxide

In this fig.6 shows the tensile strength of welded pure HDPE is high. The mixing of graphene oxide of 1%, 1.5%, 2% in HDPE to be welded. By the welding of high temperature the specimens were agglomerated. So the tensile strength of HDPE/graphene oxide decreasing by welding. The adding compatabilizer specimens also agglomerated and decreasing their tensile strength. But the 3% , 6%, 9% of adding compatabilizer having high tensile strength when compared to pure HDPE and HDPE/graphene oxide without adding compatabilizer.

B. Young's Modulus

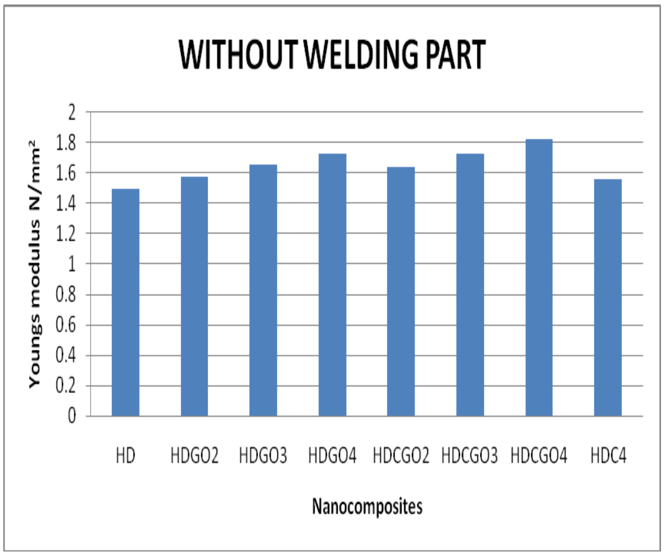


Fig. 7 Young's modulus of Pure HDPE and Nanocomposites

In this fig.7 shows the pure HDPE young's modulus were less. The mixing of graphene oxide in HDPE young's modulus was better than pure one. The adding 1%, 1.5%, 2% graphene oxide to HDPE increases their young's modulus. The adding compatabilizer to HDPE/graphene oxide increasing their young's modulus when compared to pure HDPE and without adding compatabilizer. The compatabilizer added pure HDPE are less modulus.

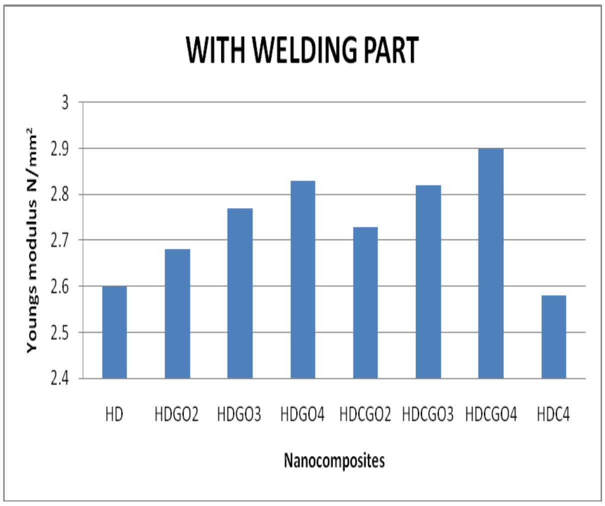


Fig. 8 Young's modulus of Pure and nanofilled composites

In this fig.8 shows the young's modulus with welding part. The welded specimens having high modulus when compared to without welded specimens. The pure HDPE having with low modulus. Then the HDPE without compatabilizer adding 1%, 1.5%, 2% graphene oxide respectively the modulus were increased while compared pure one. The HDPE/graphene oxide adding 3%, 6%, and 9% compatabilizer respectively the modulus was increased when compared to without compatabilizer and pure one. The pure HDPE added compatabilizer modulus was less.

C. Comparison of Unwelded and Welded Specimens of Elongation

The unwelded specimen's elongation result should be higher than when compared to welded specimen. The welded specimens have agglomerated. So the welded specimen's elongation result will be obtained less.

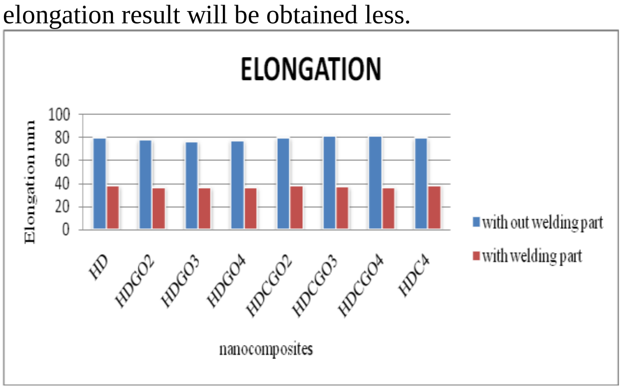


Fig. 9 Elongation of pure and welded part

D. High Resolution TEM Analysis

- Low content of graphene oxide
- High content of graphene oxide

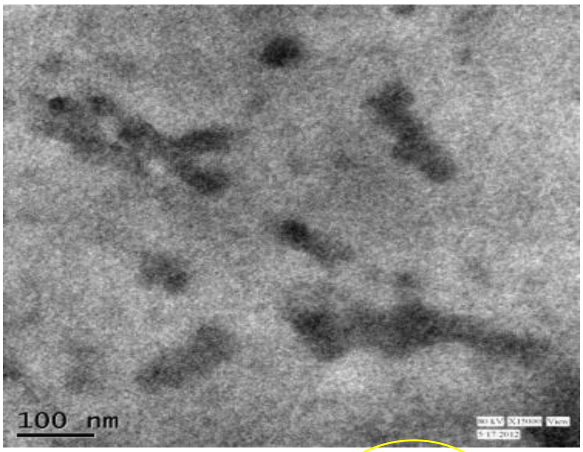


Fig. 10 Low content graphene oxide

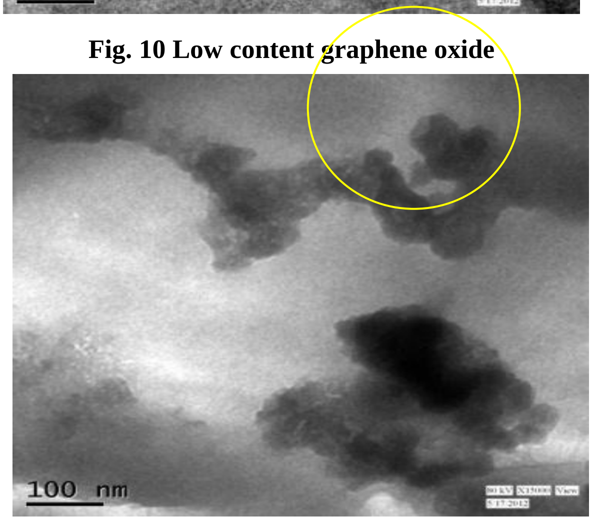


Fig. 11 High content graphene oxide

Fig. 10 shows the low content of graphene oxide in HDPE better homogenous and distribution of nanofillers throughout the HDPE matrix. The homogenous distribution is used to decrease their agglomeration and improves their mechanical properties. This proves that the low content added nanofiller dispersion was improved in the HDPE matrix. Fig. 11 shows the high content of graphene oxide in HDPE the formation of agglomeration of nanofiller in the HDPE matrix. The high content of added, shows the homogenous distribution is not well. This proves that the high content added nanofiller increasing agglomeration and decreasing the mechanical properties

IV. CONCLUSION

Uncompatibilized nanocomposites shows slightly increase in mechanical properties compared to pure HDPE. This may be due to physical interaction between the GO and HDPE. The improvement in mechanical properties of compatibilized nanocomposites may be due to the better compatibility between GO and HDPE in presence of Maleic Anhydride. HG3, HG4 and HCG3, HCG4 shows slender drop in tensile strength compared to low loaded GO nanocomposites. This may be due to the higher loading of GO, which leads to agglomeration of GO sheets in the HDPE matrix. The presence of compatibilizer plays a great role in improving the mechanical properties of HDPE nanocomposite than uncompatibilized HDPE nanocomposite. The improvement in properties

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may be due to polar-polar interaction between the nanofiller and compatibilizer. The tensile strength and modulus of the compatibilized system is found superior compared to pure HDPE and uncompatibilized systems. In summary, the best result of mechanical properties is high for HCG of tensile strength 28.5 N/mm^2 and Young modulus 2.72N/mm^2.

REFERENCES

1. Patham B and Foss, H.P, "Thermoplastic vibration welding: review of process phenomenology and processing structure property interrelationships". *Polymer Engineering and Science*, (2011) DOI: 10.1002-pen.21784.
2. Stokes, and V.K, "Joining methods for plastics and plastic composites: An overview". *Polymer Engineering Science*, (1989), 29, 1310–1324.
3. Zhang, and J. Manias, E, Charles, "An effective route to nanocomposites" ,*A polymerically modified layered silicates* (2008*)*. .
4. M.Roopa, and K. Prakasan, R. Rudramoorthy "Studies on *High Density Polyethylene in the Far-field Region in Ultrasonic Welding of Plastics"*, (2008) , 47: 762–770.
5. C. Das, R. Rajasekar, S. Friedrich, and M. gehde. "Effect of nanoclay on welding of LLDPE nanocomposites in presence and absence of compatibilizer". *Science and Technology of Welding and Joining*, vol. (2014),16, pp. 199-203.
6. C.Das, and R. Rajasekar, S. Friedrich, M. gehde, "Vibration welding of amorphous thermoplastic nano composites", *Materials and Manufacturing Processes*, (2012),vol. 27, pp. 786-790.
7. Minggang and Li Siqi, Li Jie, Liu, "striking effect of epoxy resin on improving mechanical properties of poly (butylenes terepthalate)/recycled carbon fibre composites". (2016).
8. Leyu Lin and Alois, K. Schlarb, "Vibration Welding of Nano-TiO2 Filled Polypropylene". (2014).
9. Rudolf R and Mitschang P, Neitzel M, Rueckert C, "Welding of high-performance thermoplastic composites, Polymers and Polymer Composites". (1999).
10. Kagan and V.A, "Optimizing welding temperatures of semi- crystalline thermoplastics–Memory effectsofnylon".InANTEC Proceedings, Orlando, FL, May 2000. 4. Stokes, V.K. Joining methods for plastics and plastic compo- sites: An overview. *Polymer Engineering Science*, (1989), 29, 1310–1324.
11. V.G.Gutnik and N.V.Gorbach, A.V.Dashkov, "some charecteristics of ultrasonic welding of polymers", (2002) , vol. 34, no. 6.

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