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STUDIES OF MECHANICAL PROPERTIES OF HIGH DENSITY POLY ETHYLENE/POLY PROPYLENE (HDPE/PP) BLENDS BY SMALL PUNCH TECHNIQUE

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ABSTRACT

Mechanical properties such as Compressive strength and Shear strength of High Density Poly Ethylene (HDPE) and Poly Propylene (PP) Polymer Blends have been studied by new developed punch technique, Small Punch Technique. The material properties of these blends have been studied by employing small volumes of material. The advantage of this technique is to obtain the material properties of components in service and assess the residual life of the component. This Small Punch Technique is an useful tool in assessing structural component integrity in the nuclear industries. Commodity plastics such as HDPE and PP materials are selected in these studies as their distinct properties such as hinge property, corrosion resistant, wear resistant and ease of fabrication. In order to check the competence of the developed punch dye, the mechanical properties such as Compression strength and Shear strength are tested for the injection moulded products of HDPE / PP blends and the specimens are prepared according to the standard ASTM D 732. The results are compared with existing dye punch in UTM and fabricated dye punch.

Keywords: Mechanical properties, Compressive strength, Shear strength, HDPE, PP, Small Punch Technique.

I. INTRODUCTION

High Density Polyethylene(HDPE) & Polypropylene(PP) granules are weighed each around 50 gm, then it is well mixed .The mixed granules is then fed into hopper of the injection moulding machine (TEXAR 150 ton) .The Temperature & Pressure ranges are set based on the melting point of the samples. Mould of tensile strength shaped is fixed and the specimens of standard size 6.5 mm (dia) and 0.5 mm (thickness) are prepared. The specimens for shear strength are also prepared by using blends of HDPE/PP specimens are taken out at five different formulations and the tests are carried out.

II. SELECTION OF AN MATERIAL FOR SMALL PUNCH DIE

This paper work deals with the comparative studies of HDPE/PP Blends by an different technique called small punch die technique and the existing die in an UTM Machine. For the above purpose an suitable material should be selected which exhibits some characteristics such as higher surface hardness, malleability and ductility.

III. CHARACTERISTICS AND PROPERTIES OF SUITABLE MATERIAL

Mild steel is the cheapest and most versatile form of steel. It also exhibits some of the above mentioned characteristics & distinct properties as given below in the table:-

Table

S.No.	PROPERTIES	VALUES
1.	Density	7.85 g/cm^3
2.	Young's Modulus	210,000 MPa
3.	Microhardness	53 – 54 RHN
4.	Thermal conductivity	25 – 27.7 W/m°K

- Mild steel contains 0.16–0.29% carbon. It is neither brittle nor ductile.
- Mild steel is malleable; surface hardness can be increased through carburizing.
- Carbon makes mild steel stronger and stiffer than other type of steel.

IV. SMALL PUNCH TECHNIQUE (SPT):-

The small punch test (SPT) is a mechanical testing method in which a small disk sample (for example, 8 mm diameter by 0.5 mm thickness) is clamped in a fixture and punched (up to several millimeters) with a spherical indenter. By monitoring the tip (maximum) displacement of the sample as a function of applied force, material characteristics can be assessed. The material properties cannot be extracted directly from SPT data, but an empirical relationship is used to relate the results from small punch and uniaxial tensile tests.

V. DIMENSIONS OF THE SPECIMENS:-

The miniature specimens used are disc shaped with a **diameter of 9.5mm and a thickness of 500±5µm**. Specimen preparation involves machining the discs to a thickness of 700µm followed by hand grinding in a specially designed holder to the final dimensions.

VI. EXPERIMENTAL PART

Sample preparation :

- Blends of HDPE and PP with different formulation were prepared and the mechanical
- properties were tested using UTM and small punch technique.

1.High density polyethylene (HDPE) 100% - HDPE virgin
2.Polypropylene (PP) + 100% - PP virgin
3.HDPE 20% + PP 80%
4.HDPE 40% + PP 60%
5.HDPE 60% + PP 40%
6.HDPE 80% + PP 20%

Dimensions of the specimen: 6.5 mm diameter and 0.5 mm thickness.
Sample Preparation Methodology:

- Raw materials of HDPE and PP were mixed manually & it is fed into the hopper of injection moulding machine (TEXAR 150 ton).
- The temperature and the pressure are set accordingly and the specyimens of the particular specification are prepared.
- The samples are 100 mm long, 2 mm thick and with 20 mm gauge length Moulded samples were grinded into the strip thickness of 0.5 mm in the Tool & Cutter grinder.
- A hollow punch of dia 6.5 mm was made, blanking the specimen strip for the required nos. of samples made for HDPE/ PP blends.
- The required samples of 6.5 mm diameter and 0.5 mm thickness are ready.

VII. RESULTS AND DISCUSSIONS

Compressive Testing:
The mechanical properties of HDPE/PP blends vary with respect to its compositions. Compression tests was carried out for all the samples by the small punch die(SPT technique) and the results are compared with the existing one . The test was performed at room temperature with the test speed of 5.00 mm/min. Fig. shows the compressive strength curve for HDPE/PP blends.

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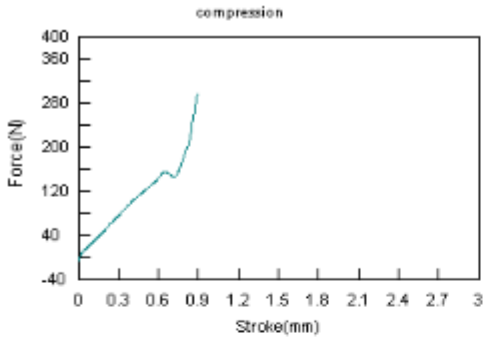
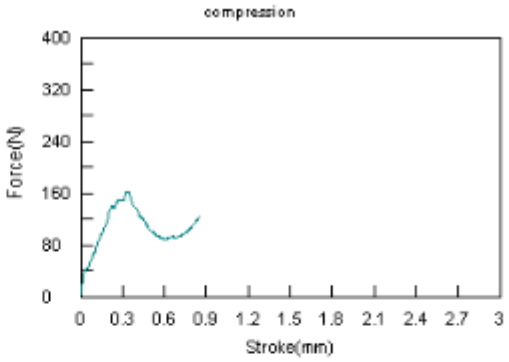
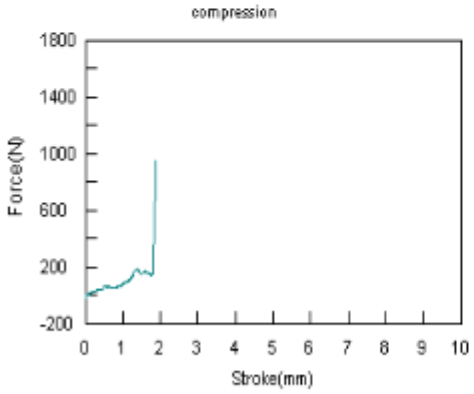


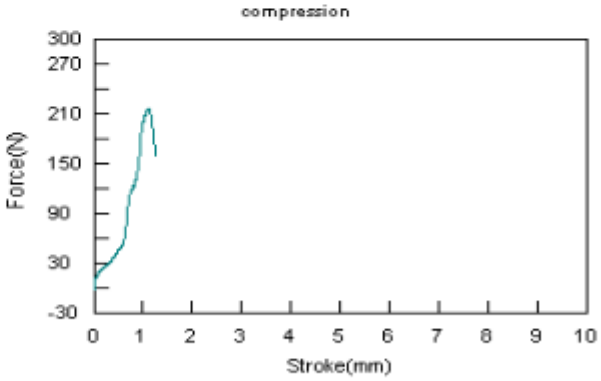
HDPE70%+PP 30%



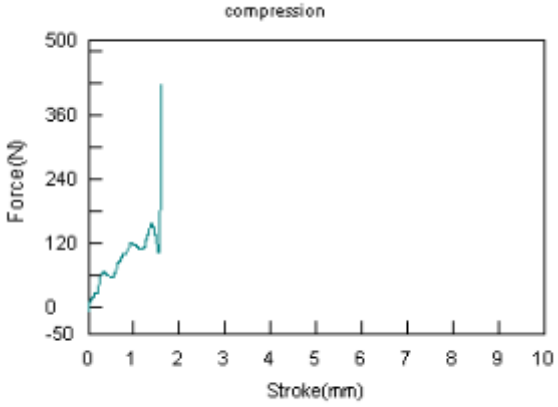
HDPE60%+PP 40%



HDPE 100%



HDPE 80%+PP 20%



HDPE 80%+PP 20%

Compressive strength for HDPE/PP blends

Fig. shows the variation of compressive strength with respect to the composition of HDPE and PP in composites. The compressive strength of 100%HDPE is 958.984 N/mm^2, whereas the compressive strength of 100%PP is 418 N/mm^2. The addition of PP with HDPE with higher composition reduces the compressive

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strength of the composites, however there is an increase in the compressive strength when the composition of HDPE is greater in the composites.

Small punch test

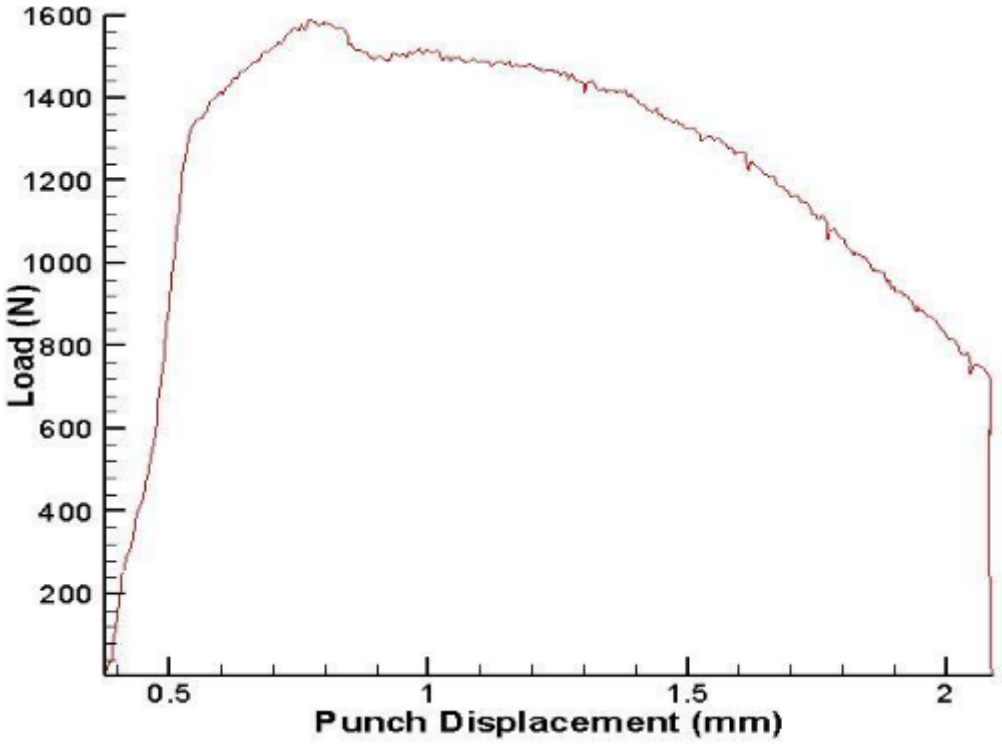
Calibration of the Experimental setup

To validate Small punch test, calibration is done by performing punching tests on Aluminium and Mild steel samples. Young's modulus, yield strength and ultimate strength obtained from experimental load-displacement curve for Aluminium and Mild steel are compared to their standard values.

- Spherical head Punch of 2.4 mm diameter and 15 mm long were used. A through hole of 2.5 mm diameter is made in die to guide the punch. The length of the hole is 10 mm and the depth of the slot made in the base to collect the specimen after the test is 5 mm. So, the punch of 15 mm length is used. Spherical head punch is used to obtain the different mechanical properties from the punch tests.

All the punching tests for calibration were performed at room temperature with loading rate of 0.5 mm/min. As the depth of slot in base is 5 mm, punch displacement of 4 mm was used as the stopping criterion of the experimen

Mild Steel Sample:-



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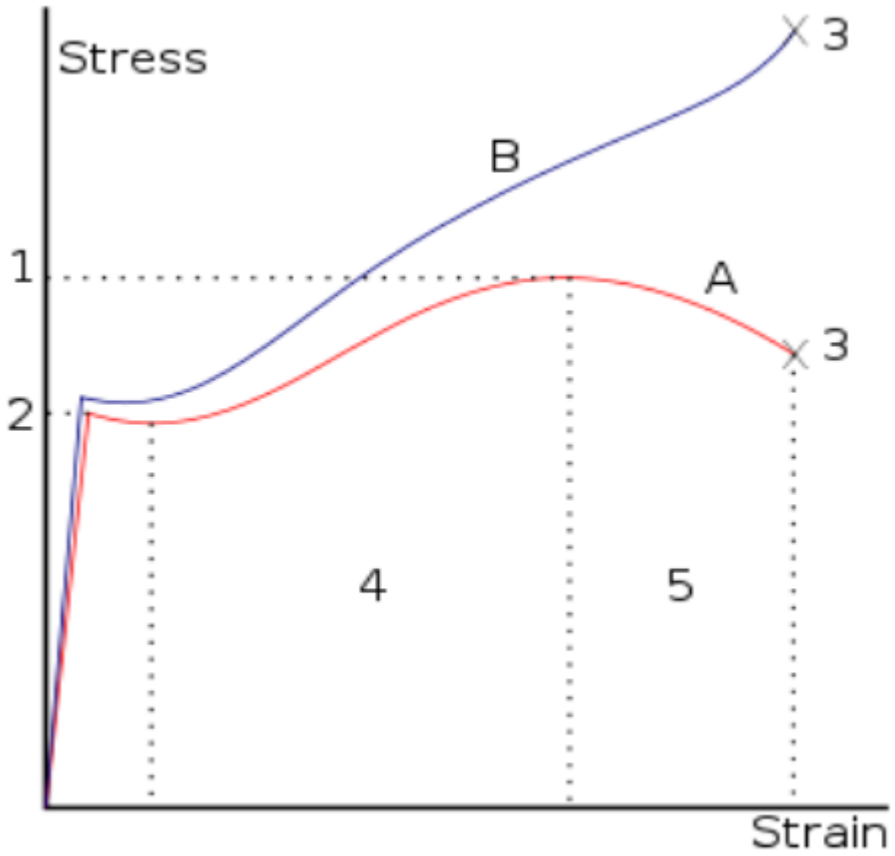

Calculation:

Diameter of punch, d = 2.4 mm

Apparent area, $A_0 = \frac{\pi}{4} d^2 = 4.5239 \ mm^2$

Stress, $\sigma = \frac{F}{A_0}$

Young's Modulus, E= 213.78 GPa

Yield Strength, $\sigma_y = \frac{383.98}{4.5239} = 84.878$ MPa

Ultimate Strength, $\sigma_u = \frac{1588.964}{4.5239} = 351.2383$ MPa

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	Young's Modulus, E (GPa)	Yield strength (MPa)	Ultimate strength (MPa)	Relative error in E (%)
Mild steel	207	70-80	380	0
Mild steel sample	213.78	84.878	351.2383	7.57

As the small punch test was successfully calibrated by using Aluminium samples, so only two samples of Mild steel were used and the table shows the average of the results obtained from the two tests. Relative error of Young's Modulus was found to be less than 10% for Mild steel sample.
The results obtained from the punch test of Mild steel samples further validate the use of small punch test for polymer composites.

Polymer and Polymer Blends (HDPE/PP):
After calibration, punching tests were performed for pure polymer (HDPE) sample and of HDPE/PP blends. Young's Modulus and peak stress were obtained from experimental Load-Displacement curve of HDPE/PP blends and compared with the pure polymer.
Dimension of test specimen used in Small punch test: 8 mm diameter and 0.5 mm thickness.

- Spherical head Punch of 2.4 mm diameter and 15 mm long are used.
- All the punch tests for polymer samples were performed at room temperature with loading rate of 0.3 mm/min.
- Maximum punch displacement of 4 mm was used as stopping criterion for the punch tests

The experimental result of the SPT is a load displacement curve, which contains information about the material strength and fracture thoughness.

Typical load-displacement curve for polymer obtained from small punch test-
Following are the mechanical properties that can be found from the load-displacement curve

- Young's Modulus: It can be found from the slope of the curve in the elastic region (Hooke's Law).
- Peak Load: It is observed as the peak of the curve.
- Ultimate Load and Displacement: It can be obtained from the curve as the point at which the polymer fails.
- Work to failure: Area under the curve gives work to failure.

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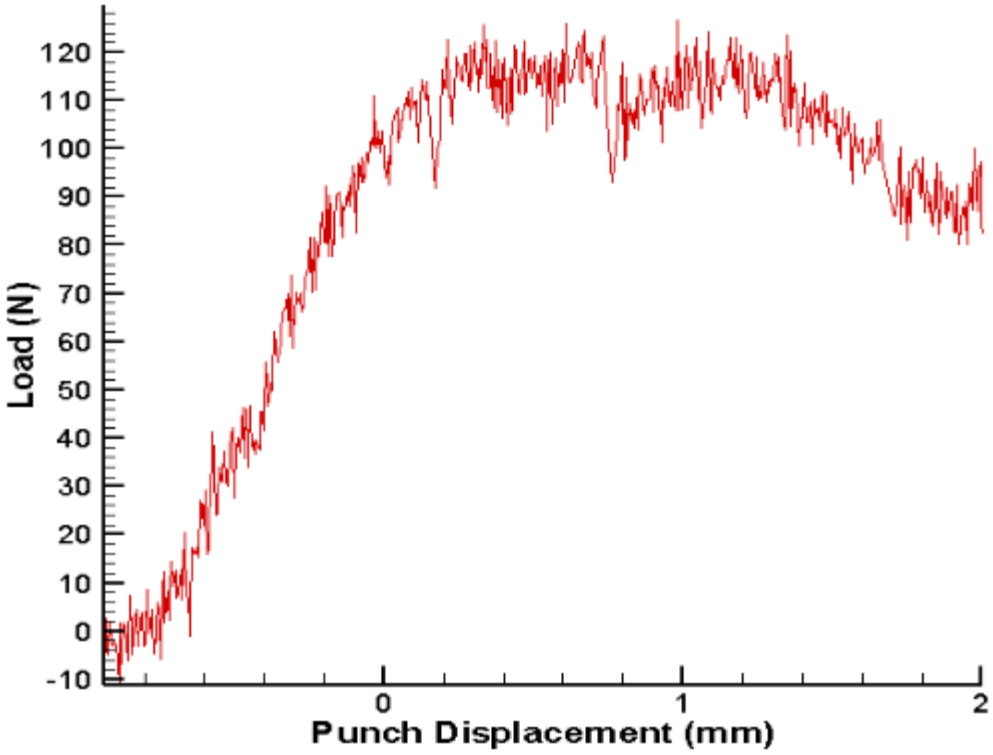

Peak Stress = 26.5 MPa
Young's Modulus, E= 1.1047 GPa

VIII. CALCULATIONS

Estimation of Young's Modulus for HDPE/PP blends:
Mechanical properties of HDPE-CNT nanocomposites:

The percentage increase of Young's Modulus starts from 0.8 Gpa--------with an increase of 1.6----------
Relative error in Young's Modulus is found out to be less than 5%.

IX. CONCLUSIONS

Small punch technique was successfully developed by performing punching tests on HDPE and HDPE/PP blends. Calibration was done on Aluminium samples. It can be concluded that small punch technique can be used to measure different mechanical properties of any material.

From the comparison of mechanical properties of HDPE/PP blends with HDPE polymer, it can be concluded that HDPE/PP show a good enhancement of mechanical properties with an increase of PP concentration

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