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Effect of Notches and Evaluation of Material Performance of a Cement Filled Composite Material for Fabrication of Non-metallic Parts

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Abstract

A cement filled polypropylene composite material designed and developed for fabrication of various nonmetallic automotive and mechanical parts. The composite is fabricated using Portland pozzolana cement (PPC) particles as filler material into the polypropylene (PP) matrix followed by Injection molding process. The geometrical structure of the product developed, and presence of cracks or any kind of deformities severely affect the material performance and shortens the product life. To evaluate this, specimens of variable notch size are prepared and experiments are conducted to study and investigate the material performance. It is observed that due to variation of stress concentration around the circular notch, stiffness of the material changes significantly results in fast failure of the deformed material. In addition, damping properties and vibration characteristics of the material also changes significantly owing to the deformations.

Keywords: Mechanical properties, fatigue, circular holes, bending, reinforcement factor.

1. Introduction

In the past various filler materials such as montmorillonite nanoclay, Indian Bentonite clay, phosphate glass, aluminum oxide (Al_2O_3), synthetic Na^+ saponite clay, carbon black etc. were successfully used with polypropylene (PP) to develop thermoplastic composites for soft industrial applications (Gupta *et al*, 2010; Groner *et al*, 2006; Tetsuka *et al*, 2007; Sarkar *et al*, 2008; Kashiwagi *et al*, 2004; Golebiewski and Galeski, 2007). It is observed that mechanical, electrical, thermal and magnetic properties of the composite materials mostly depend on the filler materials and the dispersion method throughout the polymer. Therefore, dispersion of the filler materials and its subsequent effect on the composite materials serves the purpose to characterize the polymer composite. Further, enhancement and improvement of bonding between non-polar PP matrix and filler materials are achieved by using maleic anhydride-grafted PP (Raka *et al*, 2009; Gutiérrez *et al*, 2010; Fung *et al*, 2003), because grafted PP initiates strong bonding between filler materials and pure PP.

In the present work, cement based composite material is developed and fabricated using polypropylene with portland pozzolanic cement as filler materials followed by Injection Molding technique. The composite is suitable for industrial application such as in automobile, building shade, rotor, propeller blades and also for various mechanical parts. However, geometrical structure of the product developed depends on material deformities, presence of cracks, cavities that severely affects the material performance and ultimately leads to material failure. **Several experiments are conducted to study and investigate the material performance with notches. Samples of various notch sizes are prepared and tensile properties of the composite material are studied by conducting experiment using Instron Universal testing machine. It is observed that tensile properties of the composite material significantly changes owing to the presence of notches and percentage variation of the cement fillers.**

2. Materials and Methods

Cement filled Polypropylene (CPP) composites are first fabricated using graded PP homopolymer (H110MA), purchased from the Reliance Industries Limited. The polymer is having the characteristic melt flow index (MFI) (at 230° C / 2.16kg) 11/10 (g/min) while the heat deflection temperature (at 455 kPa) is 104^0 C. Further, the grafted PP, OPTIM-P-425 is purchased from Pluss Polymers, Gurgaon, India, used for **improvement of bonding strength** [10] between the PP matrix and cement particles. Before **the** fabrication, PPC solution is prepared using distilled water with water to cement is taken 3:1 proportion. The solution is then kept in an ultrasonic chamber for 45 min and mechanically stirred up continuously. PPC solution is then piled up with the PP matrix in a steel bowl for 30 min. In the follow up, cement solution and the PP granules are cooked at 100^0C until the cement particles are fully coated on the surface of granules of PP matrix. The processed materials are then dehydrated at room temperature for 120 h in order to remove the entrapped moisture in the materials (Sardar and Bandopadhya 2010). The dried cement coated PP granules are then used for injection molding (JTS 40, TEXAIR- Plastics & Hydraulics, Coimbatore, India) for sample preparation. Temperatures at the three consecutive heaters are maintained at 220^0C, 225^0C and 230^0C from the access to the sprue accordingly and while the sprue (nozzle) temperature is kept at 50^0C. Injection shot capacity is adjusted to 100 g/s. Much more details on the fabrication procedure can found in the literature (Sardar and Bandopadhya 2010). Photograph of the fabricated composite sample is shown in Fig. 1.

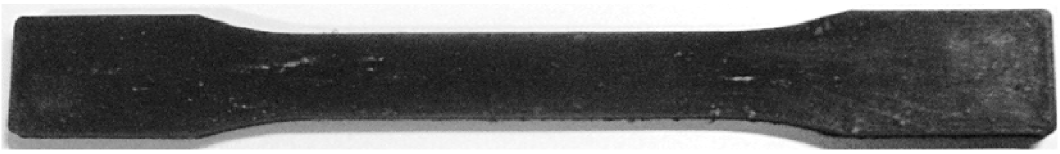

Fig. 1: Fabricated PP composite sample (Injection molded).

3. Tensile Mechanical Behavior of the Composites with Various Notch Sizes

The tensile mechanical properties of cement filled composite materials with notches are obtained following the ASTM standard D638. Universal testing machine digitally controlled by the closed loop servo hydraulic 100kN dynamic testing machine (maker: Instron, model no: 8801) is used for experimentation. The circular notches are drilled at the middle of the sample anticipating uniform affect on variation of stress level in either side of the samples. The test is carried out at a cross head speed of 2 mm/min at room temperature. The mechanical properties of the composites obtained experimentally and tensile true stress-strain graphs are shown in the Figures 2(a), (b), (c) and (d).

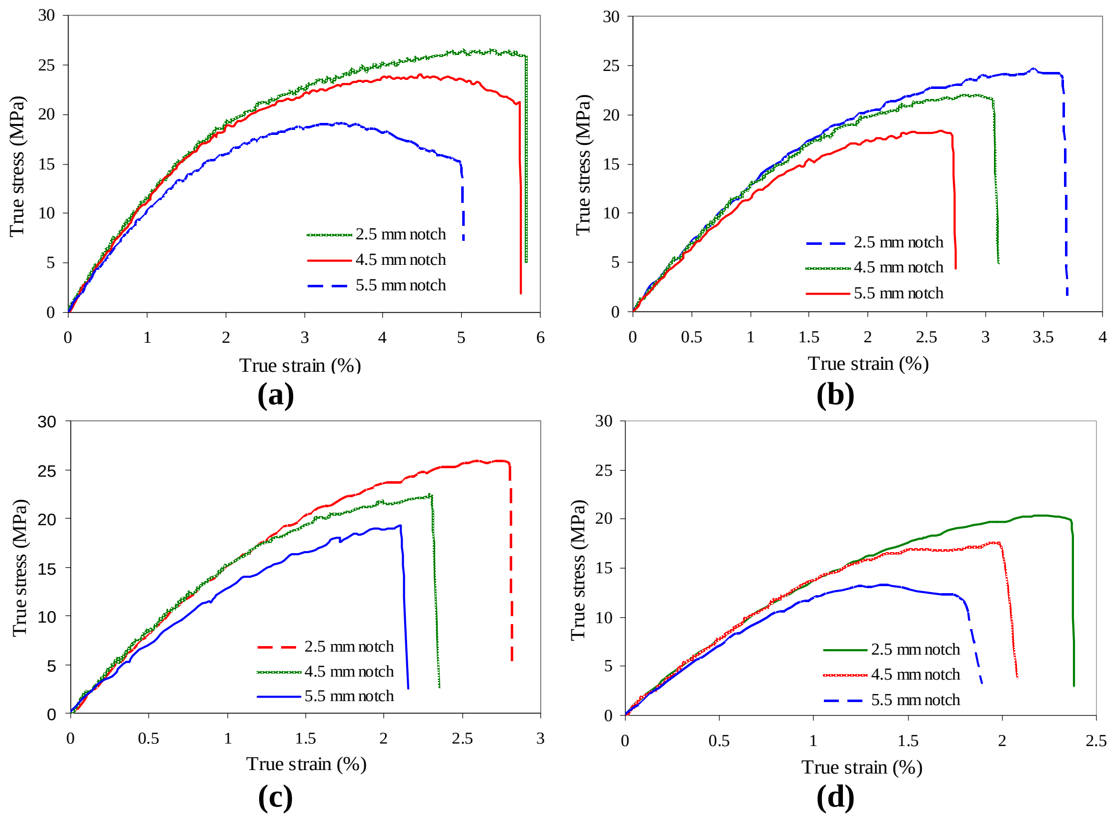

Fig. 2: True stress-true strain behavior of (a) PP, (b) 5% CPP, (c) 10% CPP and (d) 15% CPP with varying hole size.

Samples are prepared keeping the width constant while the hole diameter is selected as 2.5, 4.5 and 5.5 mm where diameter to width ratio varies as 0.192, 0.346 and 0.424. The tensile strength of the composites with respect to hole-to-width ratio for notched and un-notched conditions is shown in the Fig. 3. Fig. 4 shows the variation of work-of-rupture strength for both notched and un-notched condition as the filler percentages varies from 0 % to 15 %. It is clearly observed that with notches, the tensile strength of the composite significantly decreases in addition to the percentage increase of cement materials. Further, decrease in notched strength with increase in notch size corresponds to the stress concentration factor around the vicinity of the hole.

Table 1: The tensile strength of notched and unnotched specimens [MPa]

Notch (mm)	100% PP	5% CPP	10% CPP	15% CPP
0	29.44	30.65	31.52	24.07
2.5	25.05	25.81	26.19	19.94
4.5	22.97	23.4	24.23	16.63
5.5	18.48	18.89	19.58	13.06

Prabhakaran (Prabhakaran, 1979) reported the experimental analysis for the isotropic composite materials on gross stress and the two-parameter analysis, where the net stress for the specimens with holes tends to level off when the notched strength reaching a limiting value. In this research work, it is seen that, the notched strength does not reaching a limiting value and shows that the net stress with hole size decreases because of the sample width is kept constant for all the specimens (Fig. 3).

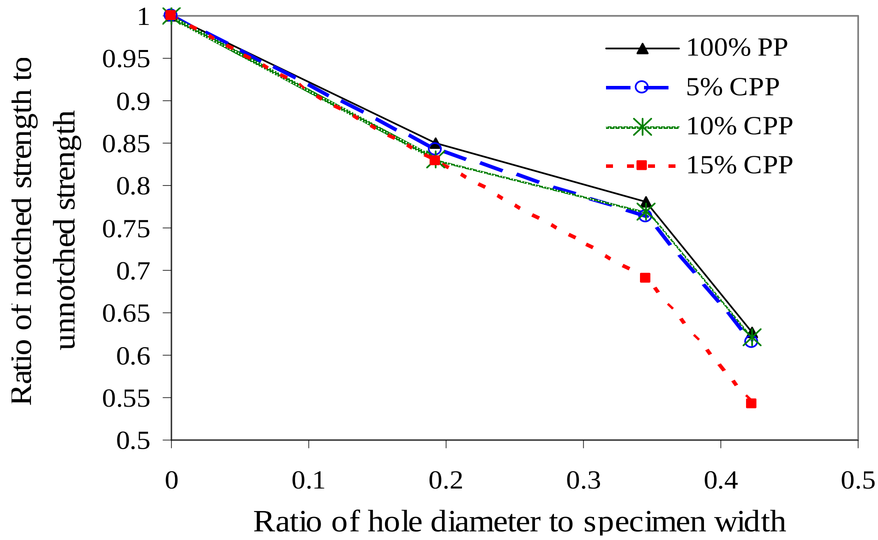

Fig. 3: Variation of net notched strength with hole size.

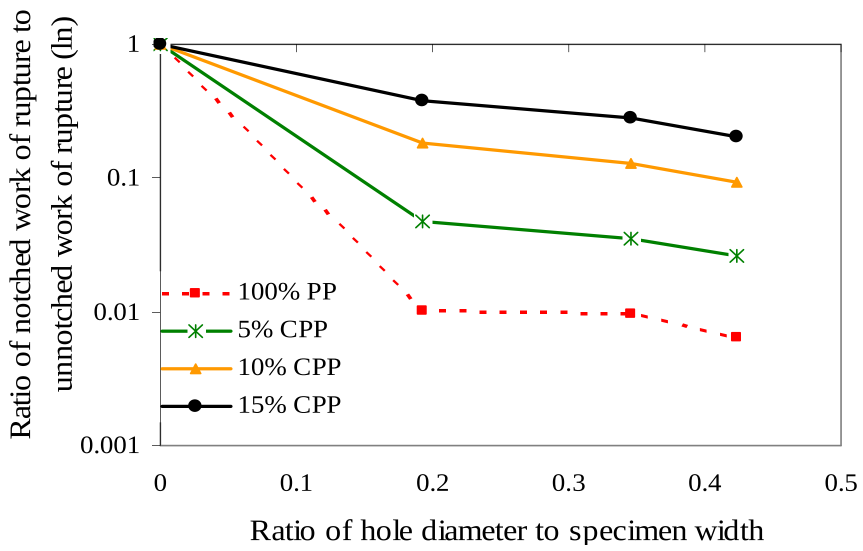

Fig. 4. Variation of work of fracture with hole size.

The experimental work of rupture of the fabricated composite samples and pure PP are evaluated by calculating the area under the curve up to the fracture point of the specimens. It is seen from the analysis that, the work of rupture is a function of the ratio of hole diameter to the specimen width which shown in the Fig. 4. In the course of this investigation an important analysis is taken into account that net work of rupture of the specimen with variation of hole diameter tends to level off and reaching a limiting value though the specimen width is constant for all the cases.

4. Conclusion

Inexpensive polypropylene and cement materials are used for design and development of a thermoplastic composite material. The composite is suitable for fabrication of nonmetallic mechanical and automotive parts through batch production. Tensile strength of the composite is evaluated and studied with notches in order to assess the affect of cracks, cavities etc on the product life of the composite material. It is observed that with notches, tensile strength of the composite material significantly decreases in addition to the percentage increase of filler materials.

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