Journal of University of Babylon, Engineering Sciences, Vol. (26), No. (5): 2018.

Investigation of Flexural Strength and Impact Strength of Binary Polymer Blends Fabricated by Friction Stir Processing

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Abstract

In the past few years, there has been an increase in the demand for polymer blends to obtain the desired properties that it could not obtain from individual polymer. And to obtain surface or local polymer blends and in a specific place on the surface of the matrix for the purpose of improving the different characteristics required and according to the specific use, an attempt was made to manufacture binary polymers blends [(HDPE:PVC), (HDPE:PP) and (HDPE:SAN)] by using the friction stir processing (FSP) method on the surface of the matrix (HDPE) at depth 3 mm from the surface and with different percentages (10, 15, 20 and 25 %) for each of (PVC),(SAN), (PP) polymeric materials added to the matrix (HDPE). From the mechanical tests which included bending and impact tests it was obtained values indicating a marked increase in mechanical properties at percentages (85% and 34%) from the results achieved for the polymer blends (85%HDPE: 15%PP) and (85% HDPE: 15 % PVC) Respectively. Based on the results obtained, and this demonstrate the success of the FSP method to preparation of different polymer blends and most of these polymers have high efficiency and without have any internal or external defects.

Keywords: Polymer blends, Friction Stir Processing (FSP), Mechanical properties.

الخلاصة

في السنوات القليلة الماضية، كان هناك زيادة في الطلب على الخلائط البوليميرية للحصول على الخصائص المرغوبة التي لا يمكن الحصول عليها من البوليمر بصورة منفردة. وللحصول على خلائط بوليميرية سطحية أو موقعيه وفي مكان محدد على سطح المادة الاساس بغرض تحسين الخصائص المختلفة المطلوبة ووفقاً للاستخدام المعين، جرت محاولة لتصنيع خلائط بوليميرية ثنائية لكل من {(البولي أثيلين عالي الكثافة: البولي فينيل كلوريد)، (البولي أثيلين عالي الكثافة :بولي ستيرين أكريلونيتريت) و (البولي أثيلين عالي الكثافة : بولي بروبلين)} باستخدام طريقة الاحتكاك و الخلط (FSP) ، بعمق 3 مم من السطح وبنسب مئوية مختلفة (10، 15، 20، 25 ٪) لكل من المواد البوليميرية (بولي فينيل كلوريد)، (بولي ستيرين أكريلونيتريت) و(بولي بروبلين) تضاف إلى المادة الاساس (البولي أثيلين عالي الكثافة). أجريت الاختبارات الميكانيكية على العينات المحضرة التي شملت اختبارات الانحناء ومقاومة الصدمة، تم الحصول على قيم تشير إلى زيادة ملحوظة في الخواص الميكانيكية بنسب مئوية (85٪ و34٪) من النتائج المحققة لكل من {(البولي أثيلين عالي الكثافة: البولي فينيل كلوريد) و (البولي أثيلين عالي الكثافة : بولي بروبلين)}على التوالي. استناداً إلى النتائج التي تم الحصول عليها، وهذا يدل على نجاح طريقة الاحتكاك والخلط (FSP) لإعداد الخلائط البوليميرية المختلفة، ذات كفاءة عالية وبدون أي عيوب داخلية أو خارجية.

الكلمات المفتاحية: الخلائط البوليميرية، طريقة الاحتكاك والخلط، الخواص الميكانيكية.

1. Introduction

Polymers have a main part in the modern applications, however the expanding interest of materials for cutting edge applications or portrayed by particular mix of properties can't be fulfilled by straightforward homopolymers. Hence, there are extensive exploratory and mechanical interests in blending these polymers. Polymer blends are capable of providing materials with extended useful properties beyond the range that can be obtained from single polymer (Sihama *et.al.*, 2015). Mixing diverse polymers and keeping their individual properties in the last blend is an appealing and reasonable method for acquiring new polymeric materials (Hajnalka *et.al.*, 2013). Planning polymer blends– a blend of no less than two macromolecular substances – is a powerful approach to grow new raw materials (Dobrovszky *et.al.*, 2015). The accompanying material-related advantages can be referred to: (a) Providing materials with full arrangement of coveted properties at the most minimal cost. (b) Expansion the building saps' execution. (c) Improving particular properties, viz. sway quality or dissolvable resistance. (d) Offering the methods for mechanical and/or civil plastics waste reusing. Mixing additionally benefits the producer by offering: (1) Improved procedure capacity, item consistency, and scrap diminishment. (2) Quick shape changes. (3) Reduction of the quantity of evaluations that should be fabricated and stored. (4) Inherent recyclability, and so on (Utracki, 2003). For genuine applications, polyblends are for the most part made by physical mixing of melt handling, which mixes different polymers on an extruder, compounder and blender (Jia-Horng *et.al.*, 2015). Polymer blend has been a typical and financial technique to grow new polymer materials for some years (Hua-Yong *et.al.*, 2016). In the current study, an attempt was made to use FSP technique to make surface or local polymer blends. This technique is of great importance for improving the various properties of the material surface by making surface composites and grain refinement, for this has been given a great importance by researchers in the last few years. (FSP) has been developed from the friction stir welding, which is a solid-state welding process of metallic materials. (FSP) of polymeric materials is not a solid-state method because polymers do not have a single melting point, but melting ranges due to having molecules of different lengths. Thus, shorter chains reach their melting point while longer chains do not (Shahram *et.al.*, 2012). Figure (1) shows the image of the friction stir processing. The objective of this work, an attempt was made to manufacture binary polymer blends [(HDPE: PVC), (HDPE: PP) and (HDPE: SAN)] by using the friction stir processing (FSP) method on the surface of the matrix (HDPE), to use for repair cracks and defects that are formed in polymeric materials.

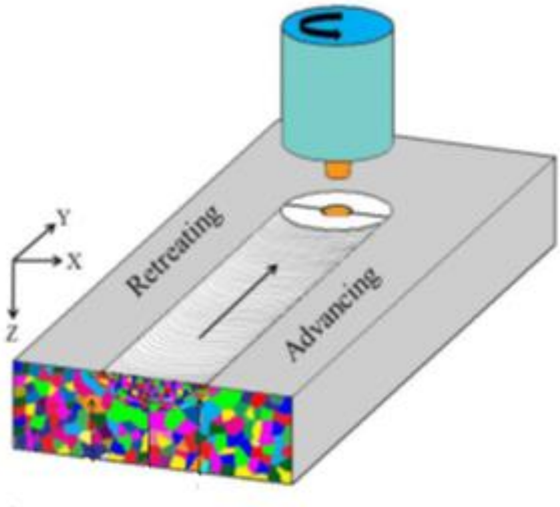

Fig. 1 image of the friction stir processing Technique (Yadav and Baur, 2015).

2. Materials and Methods

I. Materials Used

The material selected in the present study was high density polyethylene (HDPE) as a matrix phase and polyvinyl chloride (PVC), styrene acrylonitrile (SAN) and polypropylene (PP) as added phase, these materials provided by the general Company of Chemical Industries in Zafarania/Baghdad.

II. Experimental Step

In order to produce binary polymer blends [(HDPE: PVC) , (HDPE :SAN) and (HDPE: PP)], at first; a special slot with different depths (0.9 mm, 1.1 mm, 1.3 mm, 1.5 mm) was processed in the middle of HDPE sheet, each one have the same surface area (8 mm width, 150 mm Length). Second; slices of the same dimensions mentioned above were cut it from polymeric sheets of PVC, SAN and PP and placed in the slot which previously processed in the HDPE sheet. Thirdly; then it was fixed the provided sheet on the bed of a vertical milling machine to protect the sheet from moving out of place, so that this it will make the resulting sample of high efficiency after conducting friction stir processing (FSP) on the surface of the sheet. For the purpose of working the polymer blends it must be used tool called shoe tool, which where consists of three parts, the first part consists of two regions, the pin and shoulder as shown in (Fig. 2) Where this part is responsible for the mixing process and through this process adequate heat is generated for conducting FSP, the second and third part is bearing and aluminium base where help not to volatilize mixture molten and maintained it for stability in the FSP zone. The process of fixing the HDPE sheet on the milling machine was made from two pieces of a high carbon-steel fixture, however 20 mm thick plate of high Carbone steel was located under a HDPE sheet to play the role of the backing plate. The rotation and transversal speed selected were (492 rpm, 24 mm/min) respectively, in all process conditions, the plunge depth was 0.5 mm (the penetration depth of tool shoulder from workpiece surface); dwell time is 30 second (the time when the pin penetrate in the workpiece and moves a rotation speed without transversal speed).

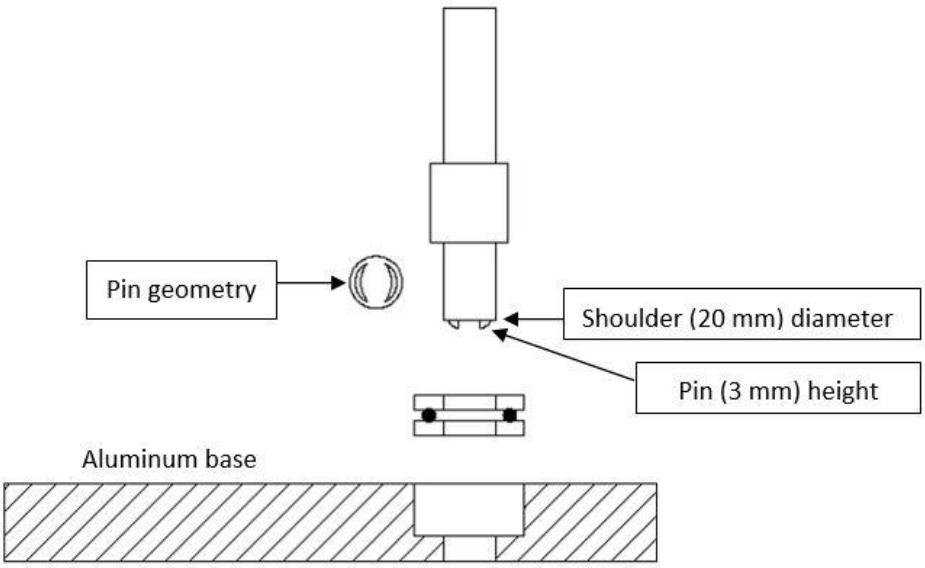

Fig. 2 Shoe tool parts

3. Mechanical Testing

For the purpose of verifying the efficiency of the blending process by FSP method, for each run, five samples were prepared for each mechanical test (bending and impact) and the rate reading were taken.

Flexural strength, flexural modulus and maximum shear stress were obtained through a three – point bending test, by using universal testing machine (model WDW 200 E) made in china, the test was carried out at a crosshead speed of 5mm/min, all tests were carried out at a room temperature (23 ± 5 C°) and atmospheric pressure, and samples were extracted from the plates of each group of polymer blends according ASTM D790 standard.

The impact test run out buy instrument model XJU-22, supplied from Time group Inc, impact test is performed at room temperature according to ASTM ISO 179.

4. Results and discussion

I. Flexural behavior

Figures (3), (4) and (5) were shown the effect of the addition of (PVC), (SAN) and (PP) to HDPE in solitary form by friction stir processing on the flexural properties (flexural strength, flexural modulus and maximum shear stress) of binary polymer blends respectively. It was observed that flexural properties reach to the highest values when adding (15%) of second materials ((PVC), (SAN) and (PP)) to HDPE in solitary form, and moreover, when increasing the ratio of adding second materials to higher than 15% these properties starts to decline, as well as it was noticed that the binary polymer blend (HDPE: PP) having high value as compared with their counterparts of other groups samples of binary polymer blends (HDPE: PVC) and (HDPE: SAN) that is related to the nature chains of constituents polymer blends and on the compatibility between the two phases of binary polymer blend which depend on the contributing properties of each of its components.

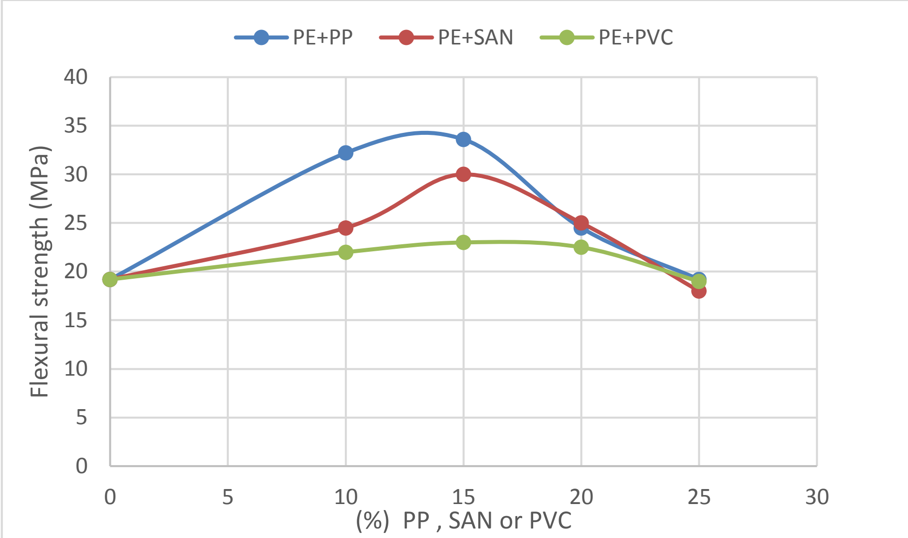

Fig. (3): Flexural strength for binary polymer blends (PE: PP), (PE: SAN) and (PE: PVC) as function of second materials [(PP), (SAN) or (PVC)] content in blend.

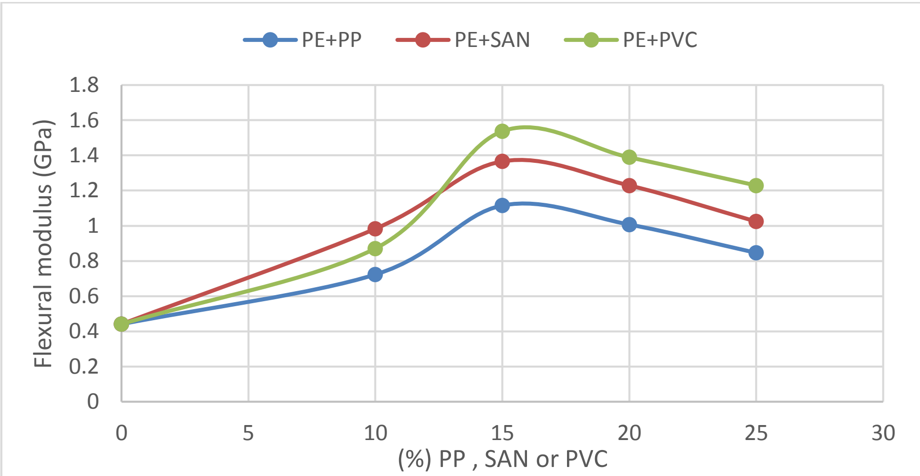

Fig. (4): Flexural modulus for binary polymer blends (PE: PP), (PE: SAN) and (PE: PVC) as a function of second materials [(PP), (SAN) or (PVC)] content in blend.

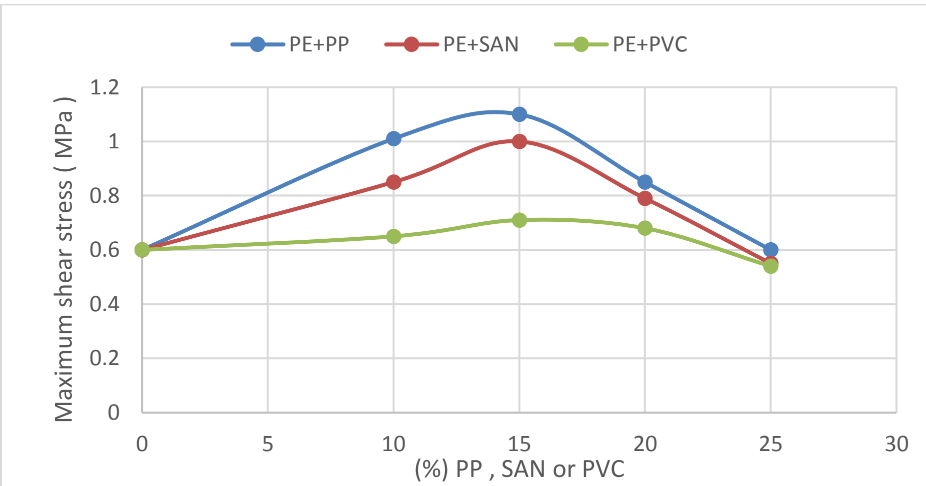

Fig. (5): Maximum shear stress for binary polymer blends (PE: PP), (PE: SAN) and (PE: PVC) as a function of second materials [(PP), (SAN) or (PVC)] content in blend.

II. Impact behavior

One of the important tests to determine the efficiency of many final products is the impact strength test, which is considered a destructive test. Figure (6) and Figure (7) show the variation in Izod impact strength and fracture toughness of binary polymer blend (HDPE: PP), (HDPE: PVC) and (HDPE: SAN). From Figure (6) it can be seen that there is a significant increase in impact strength and reach the highest value when adding the percentage of (15%) each of (PVC), (PP) to base material (HDPE), as well as the impact strength of the polymer blend (HDPE: PVC) is higher than the polymer blend (HDPE: PP) this is referring to the high compatibility and interfacial adhesion between the two phases of binary polymer blend (HDPE: PVC) which making it more shock absorption where the percentage increase of impact strength reach to (34%) and (13%) respectively, on the contrary, when it was added different percentage of (SAN) it was noticed a significant decrease in impact strength from the matrix . The low interfacial adhesion which leads to low-stress transport between the phases, this is the reason for reduction in impact strength, when the percentage of the (SAN) content is high, low impact strength is obtained. Figure (7) shows the highest value of fracture toughness when added (15% PP) to the matrix polymer. These results imply the ductile (HDPE) can be further toughened by the incorporation of minor (PVC), (PP) and less toughened by added (SAN). These results were consistent with the bending test results. as well as the fracture toughness of the polymer blend (HDPE: PP) is higher than the polymer blends (HDPE: PVC) and (HDPE: SAN) this is referring to the high flexibility of polymers blend (HDPE: PP) making it more shock absorption (Sihama *et.al.*, 2015).

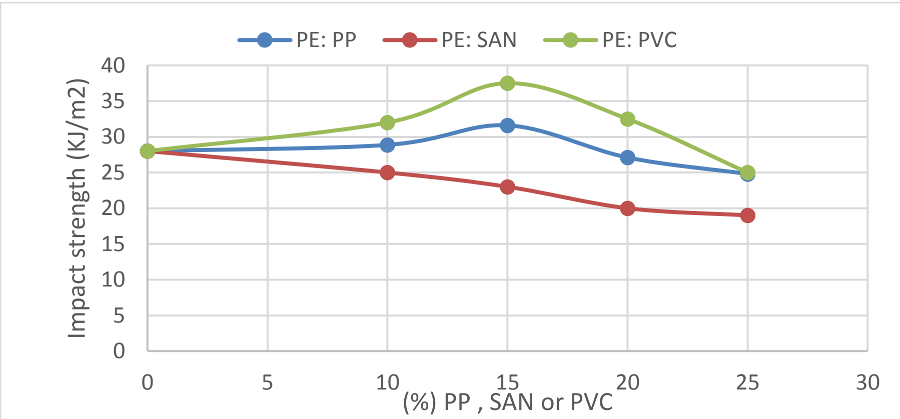

Fig. (6): Impact strength for binary polymer blends (PE+PP), (PE+SAN) and (PVC) as a function of (PP), (SAN) or (PVC) content in blend.

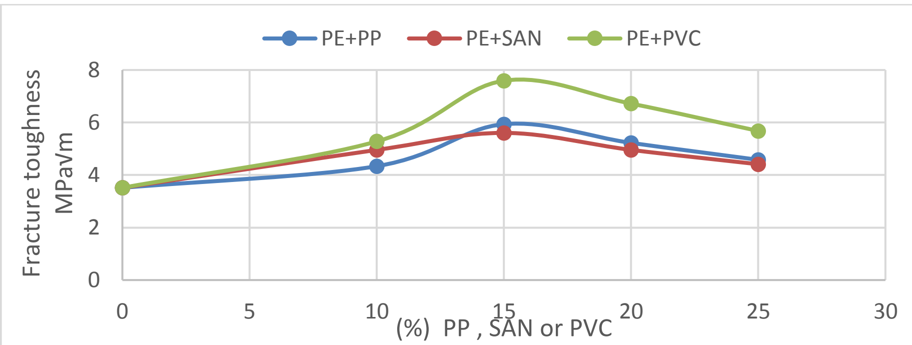

Fig. (7): Fracture toughness binary polymer blends (PE: PP), (PE: SAN) and (PE: PVC) as a function of second materials [(PP), (SAN) or (PVC)] content in blend.

Conclusions

In this work, the friction stir processing was successfully prepared local or surface polymer blends by selecting the suitable optimal conditions which was including: using proper tool called shoe tool with proper pin geometry was selected, with optimum spindle speed of (492 rpm), transversal speed (24 mm/min), plunging depth (0.5 mm) and dwell time 30 second. To obtain the effective surface of binary polymer blends on the (HDPE) matrix, through the values of mechanical tests (bending and impact), the highest increase in impact strength was obtained with the addition of (15% PVC) to (HDPE), where, the increase rate was reached to (34%) as compared to the matrix polymer (HDPE), whereas the highest increase in fracture toughness was obtained with the addition of (15% PP) to (HDPE), where, the increase rate was reached to (126%) as compared to the matrix polymer (HDPE). As well as the highest increase in flexural strength and flexural modulus was obtain when adding (15% pp) to HDPE, where the increase reached (85%) and 354% respectively. According to the results obtained, this demonstrate the success of the FSP method to preparation of different polymer blends and most of these polymers have high efficiency and without have any internal or external defects. therefore, based on this, it can be used the friction stir processing was successfully to repair cracks and defects that are formed in polymeric materials.

References:

Dobrovszky K., Ronkay F., 2015, "Toughness Improvement in Ternary HDPE/PS/PET Polymer Blends with Compatibilizer" Acta Technica Jaurinensis, Vol. 8, No. 1, pp. 36-46.

Hajnalka Hargitai, Tamás Ibriksz, János Stifter and Endre Andersen ", 2013, Development of PA6/HDPE nanocomposite blends ". Materials Science Forum Vol. 729, pp 216-221.

Hua-Yong Liao, Guo-Liang Tao, Chun-Lin Liu, Fang-Hong Gong, 2016, "A polypropylene/high density polyethylene blend compatibilized with an ethylene-propylene-diene monomer block copolymer: Fitting dynamic rheological data by emulsion models with a physical scheme ." Journal of applied polymer science, DOI: 10.1002/APP.43709.

Jia-Horng Lin, Yi-Jun Pan, Chi-Fan Liu, Chien-Lin Huang, Chien-Teng Hsieh, Chih-Kuang Chen , Zheng-Ian Lin and Ching-Wen Lou, 2015," Preparation and Compatibility Evaluation of Polypropylene/High Density Polyethylene Polyblends " Materials, 8,pp. 8850–8859.

Shahram Alyali, Amir Mostafapour, Ehsan Azarsa, March 2012, "Fabrication of PP/AL_2O_3 Surface Nanocomposite via Novel Friction Stir Processing Approach ". International Journal of Advances in Engineering & Technology.

Sihama Issa Salih, Jawad Kadhum Oleiwi, Rawaa Adnan Abdle Ameer, 2015, " Evaluation of addition ABS and EPDM effect on the mechanica properties of ternary polymer blends" International Journal of Materials Science and Applications; 4(1): 39-46

Sihama E. Salih, Kadhum M. Shabeeb and Rula F. Hasan, 2015, “Comparative study of some properties of two groups’ binary polymer blends prepared by a twin-screw extruder,” Eng. & Tech. Journal, Part (A), Vol. (33) N. 8, pp. 1971-1985.

Utracki L. A., 2003," Introduction to Polymer Blends "Polymer Blends Handbook, Kluwer Academic Publishers, 1-122.

Yadav D., Baur R., 2015, "Development of Cu particles and Cu core-shell particles reinforced Al composite". Mater. Sci. Tech. 31: 493-500.