Study the Impact Transition Behavior of the High Performance Polymer Composite

Najim A. Saad, College of Materials Engineering, Department of Polymer and Petrochemical Industries, University of Babylon, Iraq.

Ahmed Fadhil Hamza, College of Materials Engineering, Department of Polymer and Petrochemical Industries, University of Babylon, Iraq.

Rand Fadhil Kadhim, College of Materials Engineering, Department of Polymer and Petrochemical Industries, University of Babylon, Iraq.

Abstract--- Reinforced thermoplastic composites used for primary aircraft structures are subjected to thermal effects throughout their lives. That is why the understanding of the temperature impact on the mechanical properties of glass fiber reinforced plastics is very important for the choice of the appropriate plastic for aircraft design. Polyphenylene sulphide (PPS) has been commonly used in high-performance composites as a matrix component. In this research, PPS and 40% glass fibers reinforced PPS composites are used. The impact transition behavior of PPS and its composite were studied by evaluating the impact test at temperature range ($T_{Room} \approx 23^\circ C$, -26˚C and -78.5˚C). The low temperatures (-26˚C and -78.5˚C) were obtained by using a specific Refrigerator and a dry ice, respectively. In addition, the morphologies of PPS and its composite surfaces fractured by charpy impact test were investigated by scanning electron microscopy (SEM). DSC Test is used to study the crystallinity of PPS and 40GF PPS composite. And the results show that the crystallization of pure PPS is higher than 40GF PPS. The results indicate a mechanical properties dependency of PPS and PPS composite reinforced with glass fibers on temperature. PPS shows a ductile behavior at room temperature and the behavior turns to be brittle as the temperature decreased to reach -26˚C. While 40GF PPS composite show a brittle behavior at room temperature and turns to be ductile as temperature decreased to reach -26˚C.

Keywords--- PPS, Glass Fiber, Low Temperature and Impact Strength.

I. Introduction

Since the present days, thermo plastic and its composites are commonly used in the aircraft applications and passenger aircraft components typically have to perform their duties in temperature ranges from -50 ˚C to +80 ˚C, Knowledge of the thermal properties of such materials is crucial. In that regard, the behavior of these thermoplastic polymers is known to be rather complex as it is time, temperature and strain rate dependent, and couples both viscoelastic and viscoplastic deforming modes[1]. The mechanical characteristics of these polymers were greatly affected by strain rate and temperature. For many commonly used structural materials, impact at high speeds and low temperatures result in brittle fracture without any yielding (or plastic deformation). So, the structural component for aerospace applications should present good energy absorption capability [2-4].

Some methods used to avoid brittle fractures include [5]:

1. Selection of structural materials that show a ductile behavior under all anticipated operating conditions, including some abnormal situations.
2. Avoidance of High stress (residual or applied)
3. Avoidance of impact loading or include a means to absorb the impact energy.

One of the best solutions to increase the absorption of the impact energy is the improvement of the impact toughness of materials, which is one of the basic material criteria used to assess plastic consumer quality[6].

Blending and reinforcing methods are frequently used to improve the toughness, wear and friction properties of polymers [7].

II. Experimental Work

2.1 Materials Used in the Study

Two types of polymeric materials sheets have been used in this work with dimensions of (4 ×300×300) mm supplied by Guangzhou Engineering plastics industries Co. Ltd/china.

DOI: 10.5373/JARDCS/V12SP1/20201118
ISSN 1943-023X
Received: 18 Nov 2019/Accepted: 18 Dec 2019

1. Pure polyphenylene sulfide (PPS).
2. PPS with 40% Glass fiber filled.

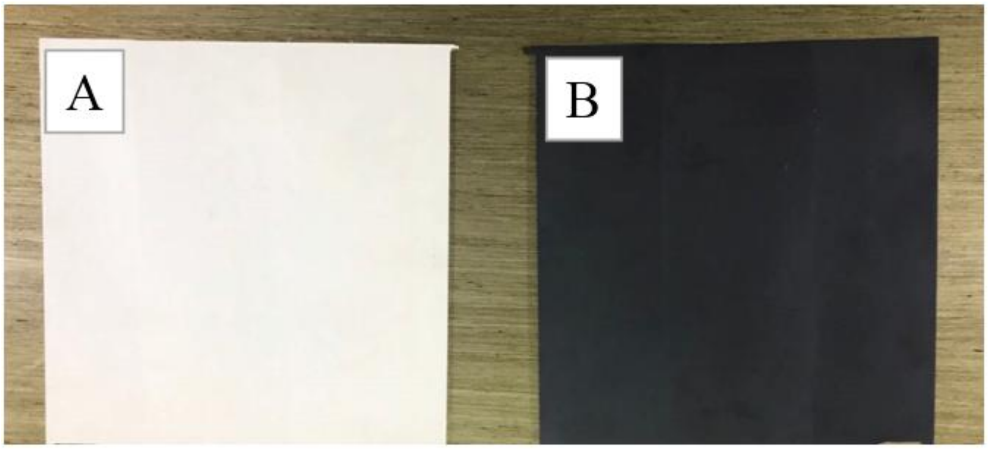

Fig. 1: Materials Used in This study 1: Pure PPS and 2: PPS+40% Glass Fibers

The specimens were machined according to ASTM D 256.The figure 2 show standard and experimental un-notched samples.

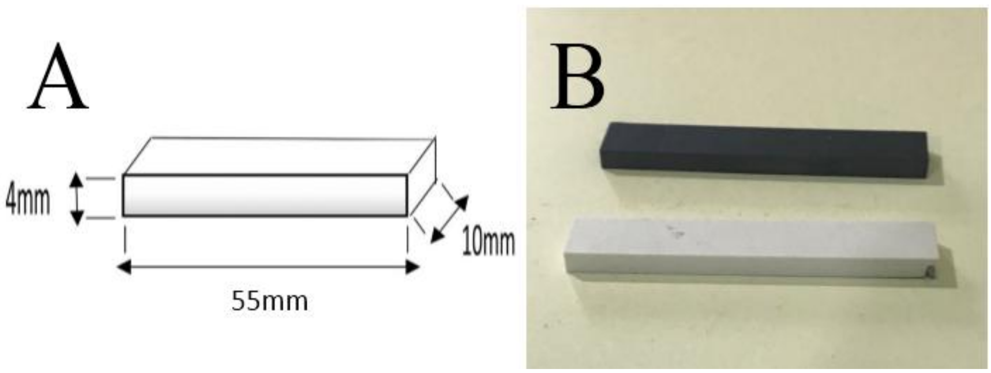

Fig. 2: (A) Schematic Impact Specimen (B) Experimental Impact Specimens

2.2 Test Procedures

Pendulum impact tester German, charpy type, gant (HAMBURG) company, Model WP 400 as shown in figure 3 (A) was used to conduct the impact test. In this test the specimen is fixed from both sides in a horizontal position as shown in figure 3 (B). The arm of a pendulum strikes the specimen. The energy absorbed by the specimen in the breaking process is defined as the breaking energy. The breaking energy can be measured by joule unit.

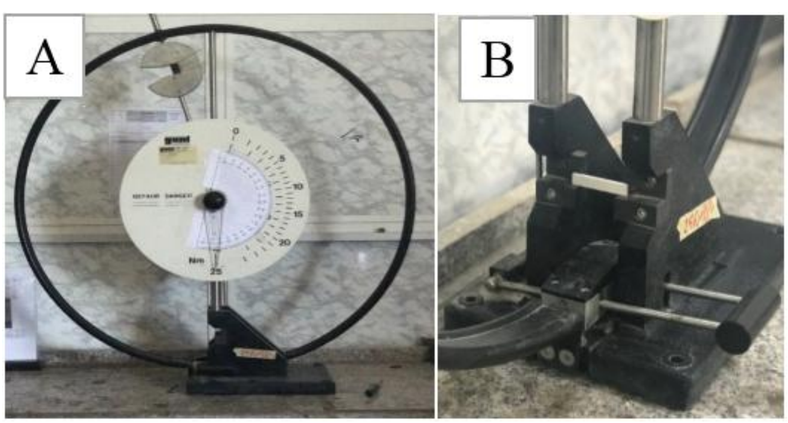

Fig. 3: (A) Impact Machine Used in the Test (B) Fixation of the Specimen

DOI: 10.5373/JARDCS/V12SP1/20201118
ISSN 1943-023X

Received: 18 Nov 2019/Accepted: 18 Dec 2019

The procedure to estimate the mechanical properties: the impact test was evaluated at three temperatures (Room Temperature ≈ 23˚C, -26˚C and -78.5˚C). The low temperatures (-26 and -78.5) were obtained by using a specific Refrigerator and a dry ice, respectively [8].

Fig. 4: (A) A Specific Refrigerator. (B) Block of Dry Ice. (C) The Sublimation of Dry Ice

The dry ice becomes carbon dioxide frozen. A block of dry ice has a surface temperature of -109.3 degrees Fahrenheit (-78.5 degrees C).Dry ice also has a very nice sublimation characteristic as it breaks down and turns directly into carbon dioxide gas instead of liquid. The super-cold temperature and sublimation make dry ice perfect for cooling[9]. An infrared thermometer was used to measure the three temperatures.

The specimens were cooled for 4 hours in both temperatures (-26˚C and -78.5˚C). In the case of the temperature (-26˚C), the specimens were leaved in the refrigerator. While in the case of the temperature (-78.5˚C), the specimens were leaved between two blocks of dry ice in an insulating box of cork.

The SEM test was used to examine the GFs/PPS composites surfaces fractured by impact. While DSC test is used to study the rate of crystallinity of PPS and 40GF PPS composite.

III. Results and Discussion

3.1 Impact Test

The results of impact test of (Pure PPS) at exposure Temperature varying between (23 ˚C to - 78 °C) are shown in figure 5. It is noted from the results that there is a Strong PPS-impact behavior dependence on the test temperature. While an obviously ductile behavior of PPS material was observed in room conditions.A change in the failure mode was detected when a temperature of -26˚C was achieved, resulting in a change in the polymer's ductile / brittle behavior. The behavior of the transition from ductile to brittle continues to be significant if the temperature drops to -26˚C.

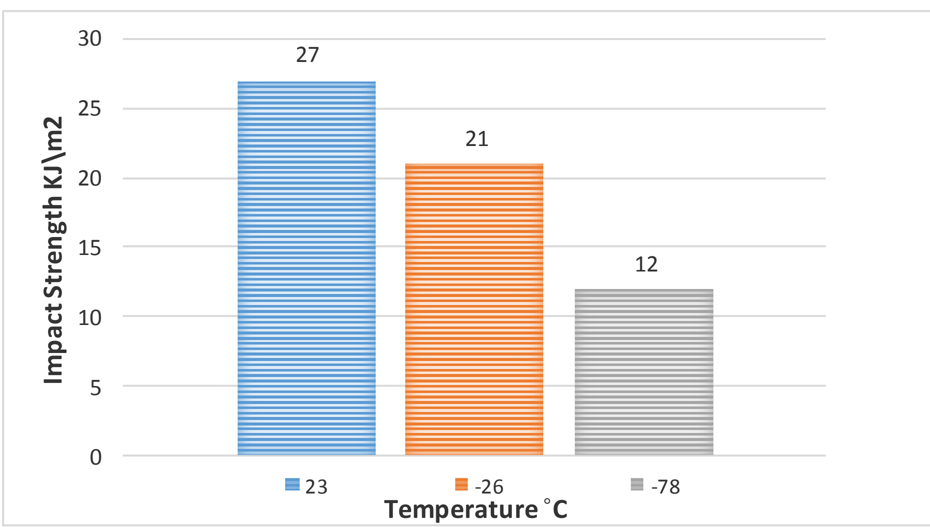

Figure 5: The Variation of Impact Strength with Temperature for Pure PPS

DOI: 10.5373/JARDCS/V12SP1/20201118
ISSN 1943-023X

Received: 18 Nov 2019/Accepted: 18 Dec 2019

While Figure 6 shows the impact test results of (PPS+40% GF) at exposure Temperature (23˚C to -78˚C).

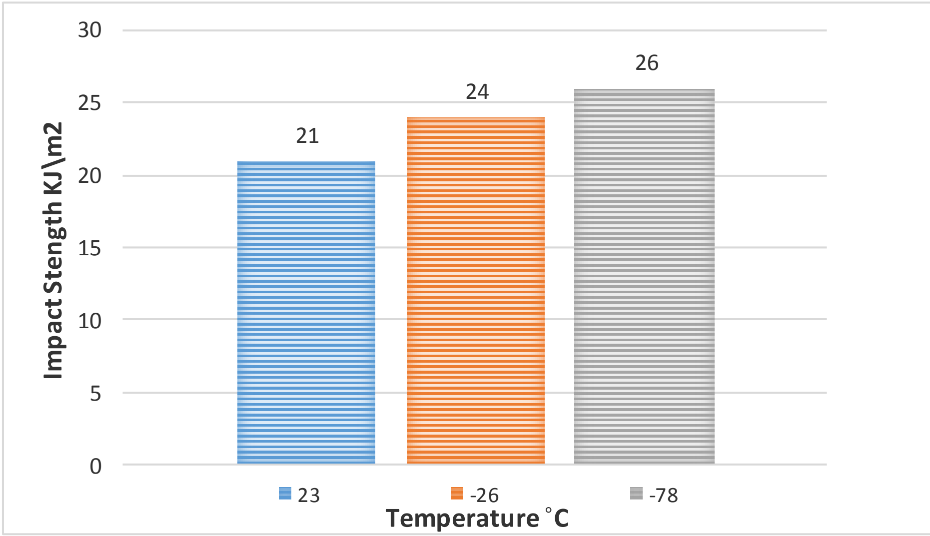

Figure 6: The Variation of Impact Strength with Temperature for GF40 PPS Composite

At room temperature, the results showed that the addition of 40% GF causes a decrease in the impact strength of PPS due to a decrease in the crystalline level of the matrix composite. The brittle nature of glass fibers causes a decrease in the impact strength of PPS.

While at -26 and -78˚C, it is noted that the addition of 40% GF can lead to simultaneous improvements in impact strength. The maximum impact strength is obtained at -78˚C for the reinforced PPS with 40%GF.The GFs / PPS matrix interface adhesion was stronger at low temperatures than at room temperatures due to the thermal shrinkage of the PPS matrix, this leads to a greater strength of the composite. For another, at low temperature, the polymer matrix molecules are firmly frozen resulting in a higher resistance than at room temperature.

3.2 SEM Test

Scanning electron microscopy allows high magnification than optical microscopy, which enables observing the surface, and fracture region of polyphenylene sulfide and its composite. The SEM test was used to examine the GFs/PPS composites surfaces fractured by impact, which are clarified in figure 7.

Figure 7 (A) showed that the behavior of pure PPS is ductile at room temperature. A change in the failure mode is detected when a temperature of -26 ° C was reached (B-C), resulting in a change in the polymer's ductile / brittle behaviour. The transition behavior from ductile to brittle tends to be significant when the temperature drops to -26°C.

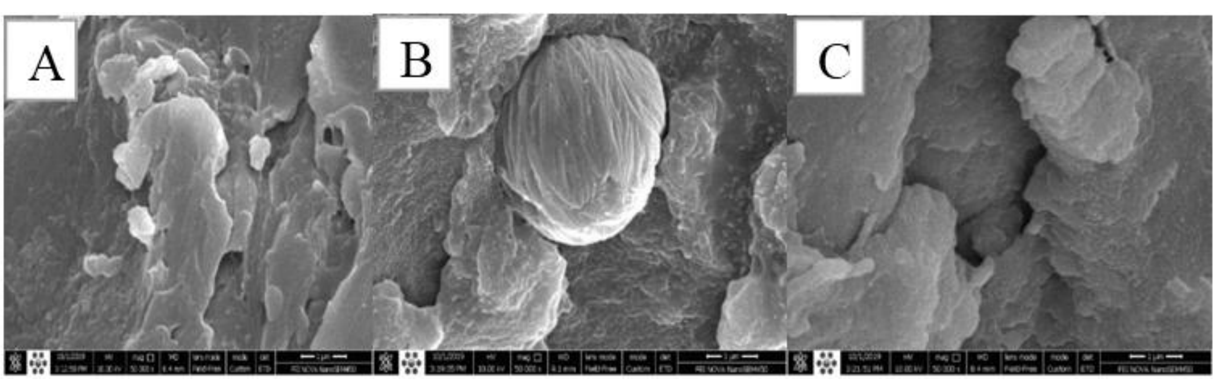

Fig. 7: SEM Micrographs of the Pure PPS Surfaces Fractured by Charpy Impact Test: (a) Impact Fracture at RT, (b) Impact Fracture at -26˚C, (c) Impact Fracture at -78.5˚C

While the fractured surfaces of polyphenylene sulfide with the addition of 40% glass fibers examined by SEM are clarified in Figure 8.

DOI: 10.5373/JARDCS/V12SP1/20201118
ISSN 1943-023X

Received: 18 Nov 2019/Accepted: 18 Dec 2019

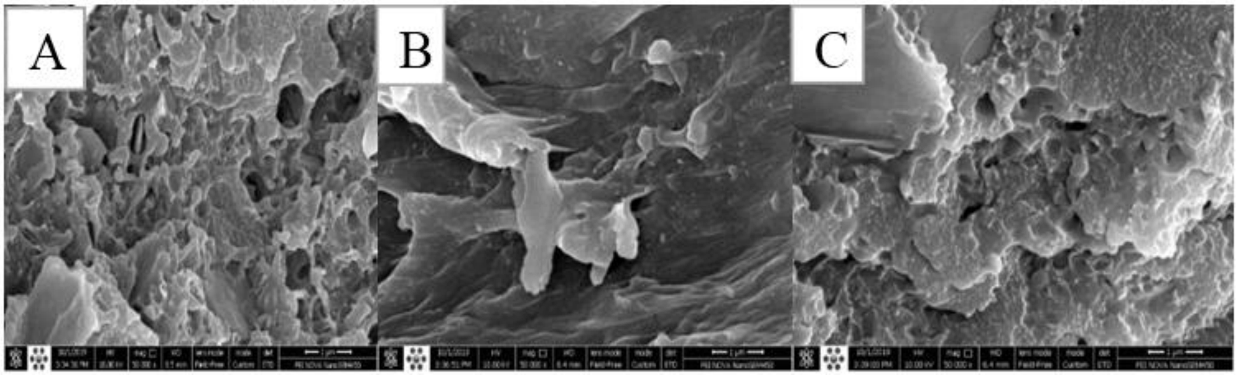

Fig. 8: SEM Micrographs of 40% Glass Fibers Reinforced PPS Surfaces Fractured by Charpy Impact Test: (a) Impact Fracture at RT, (b) Impact Fracture at -26˚C, (c) Impact Fracture at -78.5˚C

The glass fibers are distributed orderly in matrix, as seen in all the photos.

The short pull-out length of the glass fibers were the proof of the strong interfacial bond between the fiber and the matrix. Image (a,b and c) showed the morphology of fractured surfaces aftercharpy impact tests at RT, -26˚C, -78.5˚C respectively. It can be seen that glass fibers in these three images were pulled out in the impact test. Fractures surfaces at low temperatures as (b) and (c) Showed the effect of pulling more axiomatic. This is because the more brittle the PPS matrix became as the temperature decreased. From the photos we can see that 40% reinforced glass fibers shows a brittle behavior at room temperature and going towards the ductile behavior as the temperature decreased to reach -26˚C.

3.3 DSC Test

DSC is used to show the effect of 40% of glass fibers on the crystallinity of pure polyphenylene sulfide.

From the comparison between the figures 9 and 10 which are representing the DSC curves for low temperature range for PPS and 40GF PPS composite, the rate of crystallinity is very clear and its value for the PPS is higher than that for the 40GF PPS composite, this is because of the presence of the glass fibers and its brittle nature. And that means that the fracture toughness for PPS is higher than that for 40GF PPS.

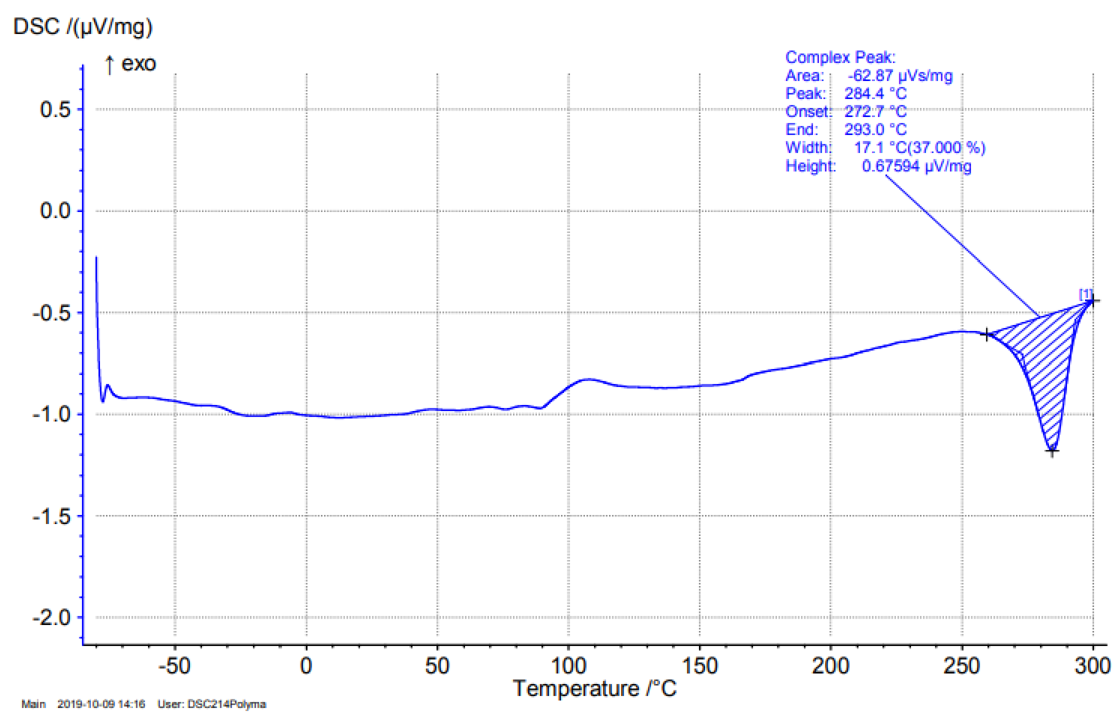

Figure 9: DSC for PPS

DOI: 10.5373/JARDCS/V12SP1/20201118
ISSN 1943-023X

Received: 18 Nov 2019/Accepted: 18 Dec 2019

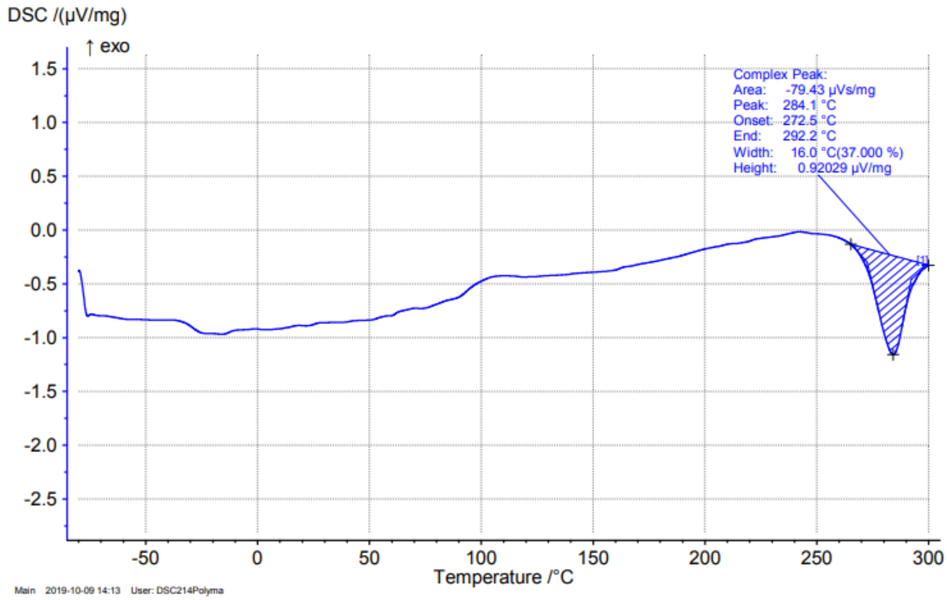

Figure 10: DSC for 40GF PPS

IV. Conclusion

According to the results were obtained and their discussion, the following conclusions were obtained:

1. The results revealed that there is a reliance of mechanical characteristics of pure PPS and PPS composite rei nforced with glass fibers on temperature.
2. SEM results show a transition in pure PPS and 40GF PPS composite behavior, where PPS shows a ductile behavior at room temperature and the behavior turns to be brittle as the temperature decreased to reach -26˚C. While 40GF PPS composite show a brittle behavior at room temperature and turns to be ductile as temperature decreased to reach -26˚C.
3. The impact strength of PPS decreased with temperature decrease while the impact strength of 40GF PPS composite were increased with temperature decrease.
4. DSC results show that the crystallinity of PPS is higher than that for 40GF PPS.

References

[1] Garcia-Gonzalez, D., Rodriguez-Millan, M., Rusinek, A., & Arias, A. (2015)." Low temperature effect on impact energy absorption capability of PEEK composites". *Composite Structures*, 134, 440-449.

[2] Ward, I. M., & Sweeney, J. (2012)."Mechanical properties of solid Polymers". *John Wiley & Sons.*

[3] Bassett, Vicki. (2000). "Causes and Effects of the Rapid Sinking of the Titanic". Vicki Bassett College of Engineering University of Wisconsin.

[4] Heimbs, S. (2012). "Energy Absorption in Aircraft Structures". *1st International Workshop on Hydraulic Equipment and Support Systems for Mining (IWHEM).*

[5] Luiz Otiivio Amaral AfFonso. (2006)."Machinery Failure Analysis Handbook". Gulf Publishing Company.

[6] Friedrich, Klaus Breuer , Ulf. (2015)." Multifunctionality of Polymer Composites : Challenges and New Solutions". Multifunctionality of Polymer Composites: Challenges and New Solutions.

[7] Cetin, B. Sahin, A.E. Karsli, N.G. Yilmaz, T. Sinmazcelik, T. Curgul, I. (2016). "Improvement of the toughness and crack propagation resistance properties of poly (phenylene sulfide)". *Acta Physica Polonica A.*

[8] Walo, M., Przybytniak, G., Nowicki, A., & Świeszkowski, W. (2011). "Radiation-induced effects in gamma-irradiated PLLA and PCL at ambient and dry ice temperatures". *Journal of Applied Polymer Science*, 122(1), 375-383.

[9] Konz, S., Hwang, C., Perkins, R., & Borell, S. (1974). "Personal cooling with dry ice". *American Industrial Hygiene Association Journal*, 35(3), 137-147.

DOI: 10.5373/JARDCS/V12SP1/20201118
ISSN 1943-023X

Received: 18 Nov 2019/Accepted: 18 Dec 2019