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Experimental study of low velocity impact behavior in epoxy matrix fiber composites reinforced with glass fibers

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Abstract— In this paper, low-velocity impact behavior of composites reinforced with glass fibers and epoxy matrix has been studied experimentally. In the constructed composite, glass fibers have been woven simply. Method used to make the composites was vacuum baking (Vacuum Assisted Resin Transfer Molding -VARTM) and epoxy curing has been carried out at temperature of 75 ° C under the pressure of 1.1 atmosphere. Then the constructed composites were cut and encoded using water jet in accordance with ASTM D7136 standard. The Low velocity impact test was conducted at energy values of 20, 30, 50, 60, and 80 and the penetration and perforation threshold energy was specified using the energy profile method. According to the results of contact force values with increasing impact energy enhanced energy absorption and deflection. In the next level by drawing contact force-deflection diagram, the manufactured composites behavior against the impact loads has been studied and the energy variation effects on the maximum contact force-deflection values has been probed. According to the results, as the contact force levels of impact energy increased, correspondingly the absorption and deflection energy increased.

Index Terms— Epoxy matrix, Fiber Composite, Glass Fiber, Low-Velocity Impact

1 Introduction

THE glass fibers use in the polymer composites structure in aerospace, marine and automotive industries is greatly expanded due to very high mechanical properties such as elasticity modulus and high resistance which is due to low density, high strength and elasticity modulus of these fibers [1]. In addition to their high mechanical properties, these composites because of good thermal properties of glass fibers such as high thermal conductivity, high thermal stability have acceptable thermal properties. Furthermore, these types of composites have good dimensional stability [2] and high mechanical fatigue resistance. Generally all composite materials are influenced by impact loads with different energy levels during the manufacturing and utilizing time. Perhaps these impact loads are due to very normal daily impacts or because of falling tools on objects made of composite materials. The impact loads with low energy levels might cause damages on external and internal structure of composites which are even undetectable by eyes. But the damages in the internal structure of these materials may decrease the mechanical characteristics of them and eventually cause irreparable damages during operation. Therefore, it's very crucial and important to study the reasons of formation of such damages and analyzing them in order for confronting the consequences and decreasing the damages. In recent years, due to extensive use of polymer- based composites reinforced with glass fibers and the sensitivity of these types of composites against high impact loads which in turn caused by glass fibers sensitivity against impact loads, extensive studies have been carried out on these composites behavior against the impact loads. In general, impact tests based on energy and projectile velocity classified in three different types. Low speed impact testing, high speed impact testing, and impact testing at a very high speed. There is no specific standard for projectile velocity to determine the type of test. For example, according to some researchers such Shivakumar [3] and Cantwell [4] the maximum speed for low speed test will be 10 meter per second.

In the following chapters of this study the maximum contact force values and energy absorbed by the composite was also evaluated. Datta and his colleagues [5] have carried out a research on the behavior of composite materials in a low-speed impact test in which they have examined the effects of Sample thickness on the amount of energy absorbed by the polymer composite samples reinforced with glass fibers and maximum contact force. Mitrovsky and his colleagues [6] have done a research that examined the effects of the projectile form on the composite behavior. Withangham and his colleagues [7] to explore the factors that affect the behavior of the composite impact have carried out a study on the effects of residual stresses in composite on these materials low-velocity impact behavior. According to the results, residual stresses in the composite structure reduces the contact force and absorbed energy in composite. In this article the effects of changing the impact energy amount on low velocity impact energy behavior in composites with epoxy matrix and reinforced with glass fibers were investigated and also composite behavior in different amounts of energy with respect to the key parameters of low velocity impact, such as maximum contact force, and the maximum deflection caused by shock loads were examined.

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2 Test Samples ion

Twill woven Glass fibers was purchased from Spinteks Textile Company in Turkey. In order to make composites, glass fiber tissues were placed on top of each other and using Hand-Lay-Up process were soaked with epoxy matrix. Then the process of making composites has been performed using the vacuum baking method (Vacuum Assisted Resin Transfer Molding) at a pressure of 1.1 atmospheres. This composite structure includes 45% matrix material and 55% glass fiber and the thickness of built samples is 6 mm. the schematic image of composites manufacturing operations has been illustrated in Figure 1.

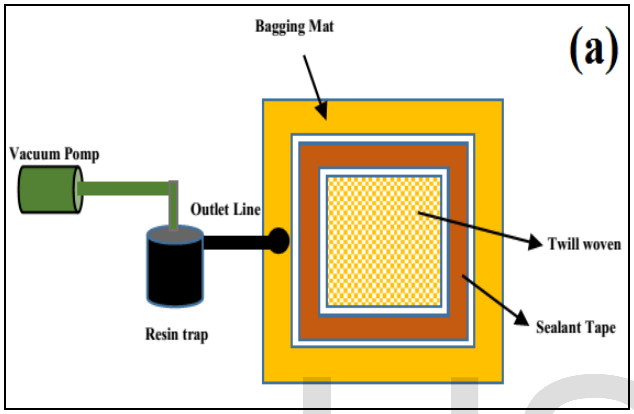

Fig. 1. Schematic illustration of Vacuum Assisted Resin Transfer Molding (VARTM)

Matrix material used in this study was thermosetting epoxy matrix and its curing operation was performed at a temperature of 75 ° C for 8 hours. Composite sheets were made with dimensions of 550*550 square mm. Composite plates were made with dimensions of 550 × 550 mm square and in order to provide impact test specimens cutting operations of samples was performed using water jet based on the ASTM D 7136 standard dimensions of 80 × 80 mm. The samples encoded after cutting operations and were prepared to conduct impact tests with different energy levels.

3 Impact Test with Low Velocity

Low speed impact test was performed according to ASTM D7136 standard using the pull-down weight machine. This device was connected to an automatic measurement software which can perform the test at different energy levels and record the data on test results such as contact force, absorbed energy, and projectile deflection and speed considering the time. The machine's load-bearing capability is about a 42.4 k/N and the fixture-pneumatic whole diameter which holds the sample is 76.2 mm. in this study profile energy method was employed to determine the composite failure threshold energy and samples were tested under different energy level impacts. And the Penetration and Perforation threshold determined using trial and error procedure.

4 Discussion

The size of the energy required to perform the impact test is one of the most important parameters that should be determined before starting the main test. This energy is determined using energy profile method. In this method the desired material samples are hit by projectile with different energy levels that start from low amounts. The purpose of this step is to detect perforation and penetration threshold energy. Penetration threshold energy is the amount of energy that projectile penetrate into the sample and therefore the total amount of projectile energy is absorbed by the sample. In this case, the amount of energy absorbed equals with impact energy, and energy point position will be on equal energy line. The minimum energy required for the projectile to perforate through the sample is referred to as threshold perforation energy. Energy profile diagram for the epoxy matrix composite reinforced with carbon fibers is illustrated in Figure 2.

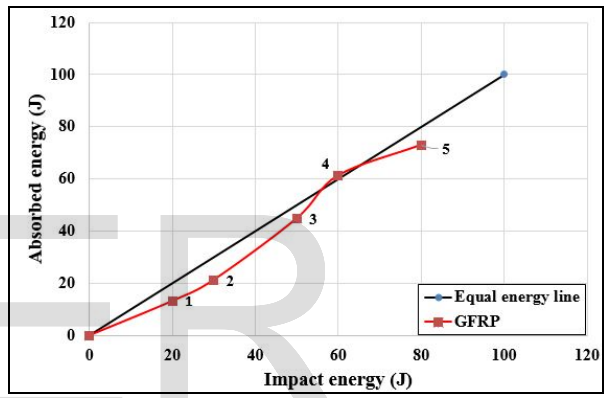

Fig. 2. Energy profile of epoxy matrix composite reinforced with glass fibers

In this study, five tests with different energy levels were carried out to obtain perforation and penetration threshold energy. The first 3 tests were performed at 20, 30, and 50 joule energy level. These tests indicated that the impact energy was not sufficient to pierce the sample and the projectile after hitting the sample and giving some energy to it rebounds from its surface. In this case, the energy point position is under the equal energy line. When the impact energy increases to 60 joules, as illustrated on figure 3, the energy point positon will be on equal energy line and the total amount of projectile energy will be absorbed by the sample. This amount of energy is referred to as penetration threshold energy. With increasing impact energy to 80 joules, after the collision projectile perforates and passes through the sample. In this case which indicated as the energy point 5, the absorbed energy by the sample is lower than the impact energy. Contact force-deflection Diagram of composite samples behavior under 20, 30, 50, 60 and 80 joules low velocity impact energy illustrated in Figure 3.

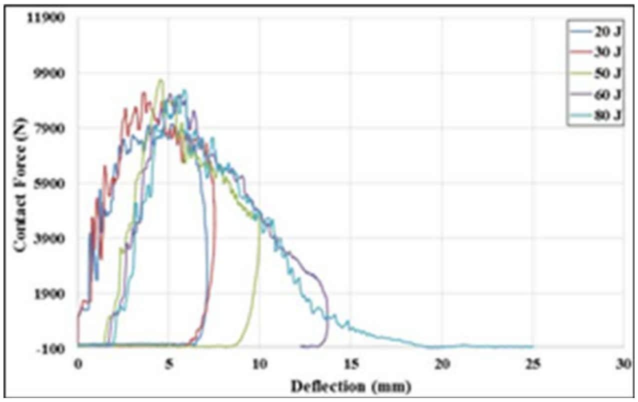

Fig. 3. Contact force-deflection diagram of composites reinforced with glass fibers at different energies

In general, contact force-deflection diagram includes two open and close modes. When the projectile impacts the sample's surface, three situations may occur during the process. In the first situation, as mentioned, the impact energy of the projectile was not enough to pierce the sample. In this condition, after hitting the sample and bringing some energy to it, the projectile changes its direction and moves on. During the process of Impact some minor damages may appear on the samples and this procedure is referred to as rebounding. As indicated in figure 4, the contact force-deflection curve is closed in this situation and the curve moves to the value of zero deflection after the energy level drops to zero point. As is clear in Figure 4, for all the impacts with energy levels below 60 joules rebounding mode occurred. With increasing impact energy to 80 joules, as seen in energy profile in Figure 3, the projectile penetrates into the sample and penetration mode occurs.

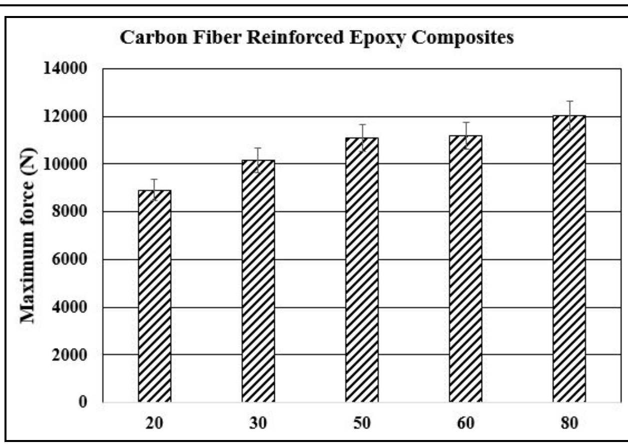

Fig. 4. The maximum amount of contact force with different impact energy

In this case also, the contact force-deflection curve is closed except the fact that when the energy drops to zero the deflection value will not be zero and this process occurs in the amount of 60 joules energy. With increasing impact energy the curve moves from close mode to open mode and in this case some amount of energy is lost due to the friction between projectile and sample. The deflection diagram for glass fiber reinforced composite samples with respect to is illustrated in Figure 4.

In general, as is evident from Figure 4 with increasing amount of impact energy the maximum contact force between the projectile and sample increased. With the impact energy of 20 joules the amount of contact force is about 8040 newton and as the impact energy increases to 30 joules of impact energy of 30 joules the contact force increases by 14.18 percent and reaches to 1010 Nm. With the continuing increase of impact energy to 50 and 60 joules, which is referred to as penetration threshold, the contact force between the projectile and sample increases by 5.093 percent that will be 11100 and 11321 Newton respectively. With increasing impact energy to 80 joules, which is perforation threshold, contact force increases by 2.37 percent and reaches 12038 Newton. Maximum deflection values for different energy levels are compared in table 1

TABLE 1

THE MAXIMUM AMOUNT OF CONTACT FORCE AND MAXIMUM DEFLECTIONS AT DIFFERENT ENERGY LEVELS

Impact energy (joules)	20	30	50	60	80
Maximum contact force (newton)	8040	10010	11100	11321	12038

5. CONCLUSION

In this article, low-speed impact behavior of the epoxy matrix composites reinforced with glass fibers was studied experimentally. The amount of energy required for the perforation to perform impact testing using energy profile method is 80 joules. According to the results, with increasing impact energy the maximum contact force increased. Also with increasing impact energy, the deflection amount and the amount of absorbed energy by the sample increase during the process of impact testing. Therefore, the sample damages will increase. Due to occurring of rebounding mode during the impact tests with lower amounts of impact energy than required for penetration threshold, the contact force curve according to the samples' deflections will be close. With increasing impact energy to perforation threshold this curve changes form close mode to open mode

REFERENCES

[1] S. H. Han, H. J. Oh, H. C. Lee, S. S. Kim, The effect of post-processing of carbon fibers on the mechanical properties of epoxy-based composites, Compo-

sites Part B-Engineering, Vol. 45, No. 1, pp. 172-177, Feb, 2013.

[2] M. M. Rahman, M. Hosur, K.-T. Hsiao, L. Wallace, S. Jeelani, Low velocity impact properties of carbon nanofibers integrated carbon fiber/epoxy hybrid composites manufactured by OOA–VBO process, Composite Structures, Vol. 120, pp. 32–40, 2015.

[3] P. Akangah, S. Lingaiah, K. Shivakumar, Effect of Nylon-66 nanofiber interleaving on impact damage resistance of epoxy/carbon fiber composite laminates, Composite Structures, Vol. 92, No. 6, pp. 1432-1439, May, 2010

[4] W. J. Cantwell, J. Morton, The impact resistance of composite materials a review, Composites Vol. 22, pp. 347-362, 1991.

[5] S. Datta, A. V. Krishna, R. M. V. G. K.Rao, Low velocity impact damage tolerance studies on glass/epoxy laminates – effects of material, process and test parameters, Journal of Reinforced Plastics and Composites, Vol. 23, No. Journal of Reinforced Plastics and Composites, pp. 327–345, 2004

[6] T. Mitrevski, I. H. Marshall, R. Thomson, The influence of impactor shape on the damage to composite laminates, Composite Structures, Vol. 76, pp. 116–122, 2006

[7] B. Whittingham, I. H. Marshall, T. Mitrevski, R. Jones, The response of composite structures with pre-stress subject to low velocity impact damage, Composite Structures, Vol. 66, pp. 685, 2004