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INFLUENCE OF INJECTION MOULD TEMPERATURE ON THE WELD QUALITY OF NANOCOMPOSITE POLYPROPYLENE

This paper deals with the influence of the mould temperature on the weld ability of nanocomposite polypropylene. By usage of ultrasonic welding (which is well proven for example in the automotive industry and electrical engineering), welded joint was created on the tested part, which was produced by injection technology by different mould temperatures. The main indicator of the weld quality is the obtained shear strength.

Keywords: ultrasonic welding, nanocomposite, shear strength, mould temperature

Introduction

Demands on the quality and the strength of the plastic parts are increasing these days. The plastic properties are mostly affected by type of the plastic, mould construction, choice of machines and technological parameters. The plastic properties could be modified by adding different ingredients. To improve the mechanical properties plastic parts the strength filler are used. In this way, the resulting materials are called composites. The intensive development of fillers is in progress in the last few years, in which the particle size are one direction a few nanometers. Thus prepared composites are called nanocomposites. These are new progressive and modern materials. By adding these fillers can be targeted to achieve the desired properties of plastic, to increase rigidity, reduce weight, etc.

Another aspect, which has a significant influence on the plastic parts quality, is the method of manufacture. The selection of appropriate technology is a very important aspect. The most common technology for the manufacture of plastic parts is injection molding technology. This technology can achieve a high dimensional and shape precision products, a high degree of automation and high productivity. High initial investment costs are a disadvantage of this technology. This method of plastic parts manufacture is therefore suitable for a large number of high volume productions. The several factors affect the material during the injection. These factors are collectively called the technological parameters. Individual parameters do not take effect separately, but they influence each other. The main technological parameters of injection moulding include injection pressure, holding pressure, mould temperature, melt temperature and injection speed [2]. Recently the mould temperature is the main parameter of this paper analyzed. The aim of this paper is to determine the influence of mould temperature on the weld quality.

The difficult design of plastic products can not be manufactured in one piece; therefore it is necessary to combine the individual parts mutually. Connection the plastic part can be in many means. This paper deals with the combining of nanocomposite part by means of ultrasonic welding. This method of connection of plastic parts is suitable for most industry branches. This method of connection of plastic parts is used in large series of production of the automotive industry because of high speed process. In addition, this method is used in electrical engineering. Optimal setting of welding parameters is possible to achieve high weld strength. The high weld strength is the main aspect that it has the greatest influence on connection quality of plastic parts [1]. The aim of this paper is to assess the influence of mould temperature on the weld quality. The weld has been created on the part from nanocomposite polypropylene. The weld has been created by ultrasonic welding.

The aim of this paper was to determine the influence of mould temperature on the weld quality. Modern and untried nanocomposite polypropylene was selected as a suitable material for this measurement. Strictly speaking polypropylene Mosten 230 was mixed with nanoblend. The resulting weight percentage of clay in this composite was 7.5%. This is a new advanced material that will find application in many branches of industry. The sample of this material was produced by injection moulding technology. Several samples were made always by using different mould temperature. The mould temperature has been changed from 20 to 80ºC. The samples were welded using the ultrasonic welding. This method of plastic parts welding is used in large series production of the automotive industry because of the high speed process. Thus welded samples were subjected to the exam shear. With suitable software the value was recorded which subsequently calculated in shear strength.

Experimental procedure

For this experiment nanoblend material was selected. Nanoblend was mixed with polypropylene Mosten 230. The resulting proportion of clay was 7,5% from the total weight. Therefore, the designation nanocomposite of polypropylene was used. From this material trial samples in the form of rod were produced. Gating parts were removed from the samples and then samples were welded. For each weld the part of the sample without a ledge and one part of a ledgeed sample was used. Figure 1 and 2 shows the dimensions sample with ledge.

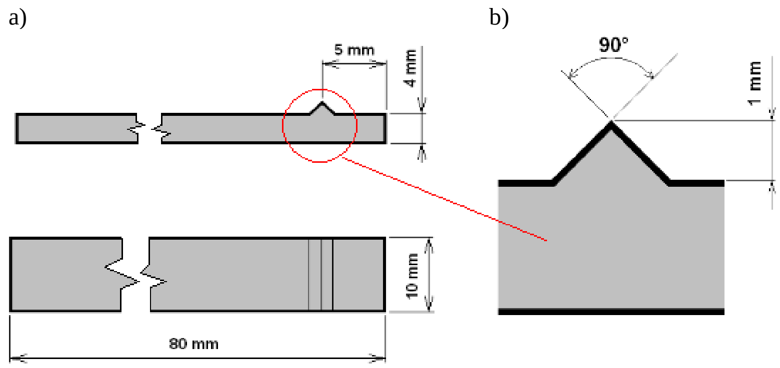
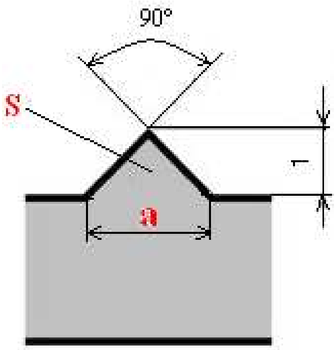


Fig. 1. The dimensions of sample with ledge (a) and detail of ledge (b)
Rys.1. Wymiary próbki z występem (a) oraz geometria występu (b)

The sample from composite polypropylene was produced by injection moulding technology. Injection moulding machine Engel ES 25/50 was used for the production of this sample. The sample had to be thoroughly mixed before the production. For this experiment, the dominant influence was mould temperature. Therefore, the other technological parameters were kept constant for all measurements. Only mould temperature has been changed. The mould temperature has been changed from 20 to 80ºC in the manufacture of the sample. The mould temperature was increased about 10ºC. The samples were made by injection moulding to stabilize all the technological parameters.

For the measurement several samples at different mould temperatures were made. Then these samples were welded by ultrasonic welding. The machine Dukane 220 (20 kHz) was used for welding samples. From the samples were separated inflow parts. Then samples can be welded. For the one weld were used part of the sample without a ledge and one part of sample with ledge. The technological conditions have been determined experimentally, because for this material and product shapes have not been determined yet. The samples were placed in a special preparation. Here both samples are locked. This is a very important objective for the next measurement. Strength system must be maintained: machine – tool – preparation – product.

To determine the weld strength the shear test was conducted. The shear test was conducted on machine Hounsfield H 10 K. In every mould temperature from 20 to 80ºC were analyzed 10 samples. If the sample was cracked outside the weld, it was not counted in the results. The test was carried out in specified conditions, which are given in the appropriate norm. Data have been reading through the relevant software during the test. Maximum force is the most important for the calculation in shear strength. This force was achieved on the machine at the deformation sample. The shear strength of the weld was calculated from this maximum force.



$$a = \frac{1}{\mathrm{tg}\ 45°} \tag{1}$$

$$\tau_S = \frac{F_{MAX}}{S} \tag{2}$$

Fig. 2. Detail of ledge, where: a = 2 mm – ledge width, S = 20 mm^2 – ledge surface area, F_{max} – maximum force, τ_s – shear strength

Rys. 2. Szczegóły występu: a = 2 mm – szerokość, S = 20 mm^2 – powierzchnia przekroju, F_{max} – siła maksymalna, τ_s – naprężenie ścinania

Results and discussion

The maximum force (the weld was destroyed using this maximum force) was recorded by the appropriate software. This maximum force was applied in the respective formulas and the shear strength was calculated from them. The measured values are listed in Table 1. From these values is apparent that the maximum force increases by rising the mould temperature. The greatest increase in force is visible with the mould temperature change from 40 to 50ºC. In this mould temperature change, the maximum force (needed to destroy the weld) increased in average by 57 N. The maximum force is increased by more than 5.5%. If the mould temperature is higher than 50ºC, the force difference is no longer so much significant.

Table 1. The results of shear test for various mould temperature

Tabela 1. Wyniki testu ścinania dla różnych temperatur wtrysku

Mould temperature [ºC]	20	30	40	50	60	70	80
Maximum force [N]	984	1009	1010	1067	1078	1086	1106
Shear strength [MPa]	49.2	50.4	50.5	53.4	53.9	54.3	55.3

Using the formula (2), individual shear strength was calculated for each mould temperature (Tab. 1). From these values is apparent that by rising the mould temperature the shear strength is increasing. The greatest increase in shear strength is visible with the mould temperature change from 40 to 50ºC. The shear strength increased in average by 3 MPa at these mould temperatures. Other differences are very small, not more than 1 MPa. The overall increase in the shear strength is more than 6 MPa (at the expense of the significant increase of mould temperature).

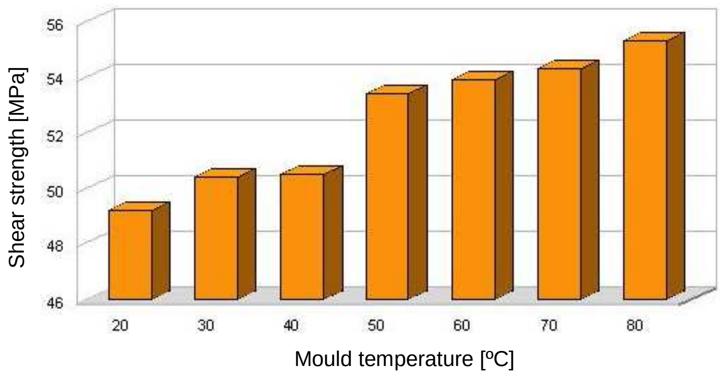


Fig. 3. Effect of mould temperature on shear strength of weld

Rys. 3. Wpływ temperatury wtrysku na wytrzymałość zgrzeiny na ścinanie

The results show clearly that the mould temperature has a significant influence on the weld quality. The weld quality has been assessed in terms of shear strength. Results of shear test indicated that by rising the mould temperature, the maximum force (required to disturbed of the weld) is increasing. The greatest increase in force is visible with the mould temperature change from 40 to 50ºC. In this mould temperature change, the maximum force (needed to disturbed the weld) increased in average by 57 N. Using the formula, individual shear strength was calculated from maximum force for each mould temperature. The shear strength is the main indicator of the weld quality. Again, it was found that the shear strength increases with higher mould temperature. The greatest increase in shear strength is visible with the mould temperature change from 40 to 50ºC (see Figure 3). The shear strength increased in average by 3 MPa at these mould temperatures. Other differences are very small, not more than 1 MPa. And thus further rising mould temperature has not practically influence on the weld strength.

Conclusion

The measurement results are clear. By rising the mould temperature the shear strength is increasing. This indicates that the proportion of crystalline phase increases and the mechanical properties are getting better. The increase in shear strength is not uniform. Especially in the higher mould temperatures (above 50ºC), the increase in shear strength is almost imperceptible.

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WPŁYW TEMPERATURY WTRYSKU NA JAKOŚĆ ZGRZEINY NANOKOMPOZYTÓW POLIPROPYLENOWYCH

Opracowanie dotyczy badań wpływu temperatury wtrysku na możliwość zgrzewania nanokompozytów polipropylenowych. Podczas zgrzewania z zastosowaniem ultradźwięku (zastosowanie którego sprawdza się na przykład w przemyśle samochodowym oraz energetyce) wykonano połączenia próbek z tworzywa wtryskiwanego w różnych temperaturach. Głównym wskaźnikiem jakości zgrzeiny była uzyskana jej wytrzymałość na ścinanie.

Słowa kluczowe: zgrzewanie z zastosowaniem ultradźwięku, nanokompozyt, wytrzymałość na ścinanie, temperatura wtrysku

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