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Effect of Alkali Environment on the Tensile Strength of A Welding Line In an Injection Molding Part

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Abstract: *To observe the effect of alkaline concentration on weld line strength, after the molding process, the molded part was soaked in alkaline solution. Alkaline solutions with pH levels of 7.0, 8.0, 9.5, 11.5, 12.5, and 13.0 were applied for a period of 1 month, 2 months, 3 months, 4 months, and 5 months. The experimental results show that with the same soaking time, the strength force is reduced with higher alkaline concentration. In the case of pH 13.0, the strength decreased rapidly in the first month and changed from 34.75 to 30.39 MPa (about 9.1%).*

Keywords: *plastic process, injection molding, alkali environment, weld line strength*

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I. INTRODUCTION

Along with the strong scientific and technological progress in recent decades, the advent and development of composite materials occupies a dominant position in the manufacturing industry. With advantages such as high specific strength, high modulus, small specific weight, and diversified manufacturing technology, composite polymer materials are widely replacing traditional materials in order to manufacture the structural components of machines. They are used in several different fields, especially in the maritime industry (for marine hulls, fishing nets, etc.) and in the chemical industry (for the tanks of industrial chemicals). The environmental impact of work and time use affects the reliability of composite materials, especially when working in an environment with high concentrations of alkali. However, there are no research studies on the environmental impact of used to the reliability of the product.In the field of plastic and composite manufacturing, injection molding is one of the most common polymer processing techniques. As the product becomes smaller, thinner, and lighter, the mold design has higher requirements, and also new technologies have to be used. If the molding process is not proper, defects will occur. Today, there are problems associated with a welding line, especially with complex products [1]. When hot melt is injected into the mold cavity, a freeze layer is created at the contact of the melt and the cavity wall [2]. This freeze layer reduces the melt flow, which is a problem in the filling step of the injection molding process. This problem becomes more severe at the location of the welding line [3]. In the injection molding field, when partially frozen melt fronts meet, the weld line will appear as shown in Fig. 1. In several research studies, the strength of the weld line is weak when partially frozen melt fronts meet [4]. The orientation at the joint remains perpendicular to the direction of flow—a sign of the weakness. In general, it is not possible to eliminate the weld line, but it can be made sufficiently stronger or its position can be altered [5]. Koponen et al. showed that injection pressure and injection speed have a strong effect on the weld line strength of polyester material [6]. The variation of weld line strength was also mentioned with different geometry in the research of Wu [7]. These experimental results show that the weld line strength from a standard test is not applicable in micro injection molding.

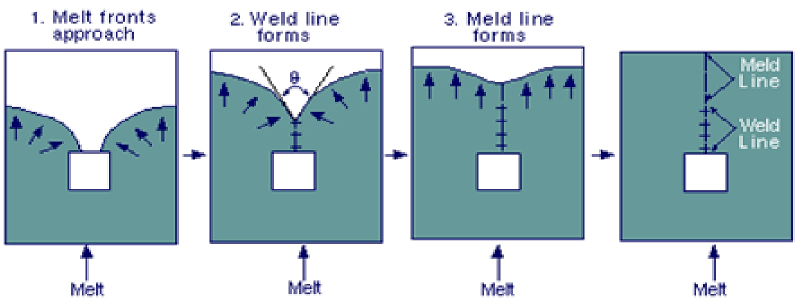


Figure 1. Welding line appearance [2]

II. EXPERIMENTAL METHODS

We developed a prototype in tensile strength composite material of short glass fiber-reinforced polyamide (PA66-30GF), which is based on the ISO 527 standard. We then proceeded to soak the sample in alkaline solutions with pH levels of 7.0, 8.0, 9.5, 11.5, 12.5, and 13.0 for a period of 1 month, 2 months, 3 months, 4 months, and 5 months. After soaking, the samples were tested on a tensile pull test machine (INSTRON series 3367). The molded part following ISO 527 – 1993 was a tensile specimen with two gates on the sides (Fig. 2). The molding conditions were as follows: melt temperature 230°C, filling time 0.5 s, packing time 5 s, and injection speed (100 mm/s). To observe the effect of alkaline concentration on the strength of the weld line, the research model was designed by the dimensions in Fig. 2 with a part thickness of 2 mm. According to the simulation results of the Moldflow software, in this model, the weld line will occur at the center of the tensile bar. Therefore, to observe the influence of mold temperature on weld line strength, the cavity plate was designed as in Fig. 4a and manufactured as in Fig. 4b. This design can support the appearance of the welding line by two gates in the filling step. After molding and soaking in the alkaline solution, the tensile bar was collected and the strength of the weld line was tested by the tension tester (INSTRON 3367). In each case, 10 samples were tested, and the average value was calculated for the comparison of strength.

Table 1: NaOH solution for controlling alkaline concentration

Assay (NaOH)	≥96.0%
Carbonate (Na_2CO_3)	≤1.5%
Chloride (Cl)	≤4%
Sulfate (SO_4)	≤0.005%
Nitrogen (N)	≤ 0.005%
Phosphate (PO_4)	≤0.001%
Silicate (SiO_3)	≤0.001%
Aluminum (Al)	0.05%

The stress is defined by Equation (1):

$$\sigma_k = \frac{P_{Max}}{a.b} \quad (1)$$

where σ_k is the breaking strength (MPa), P_{Max} is the force applied that caused the failure (N), and a.b is the least cross-sectional area of the testing sample (mm^2).

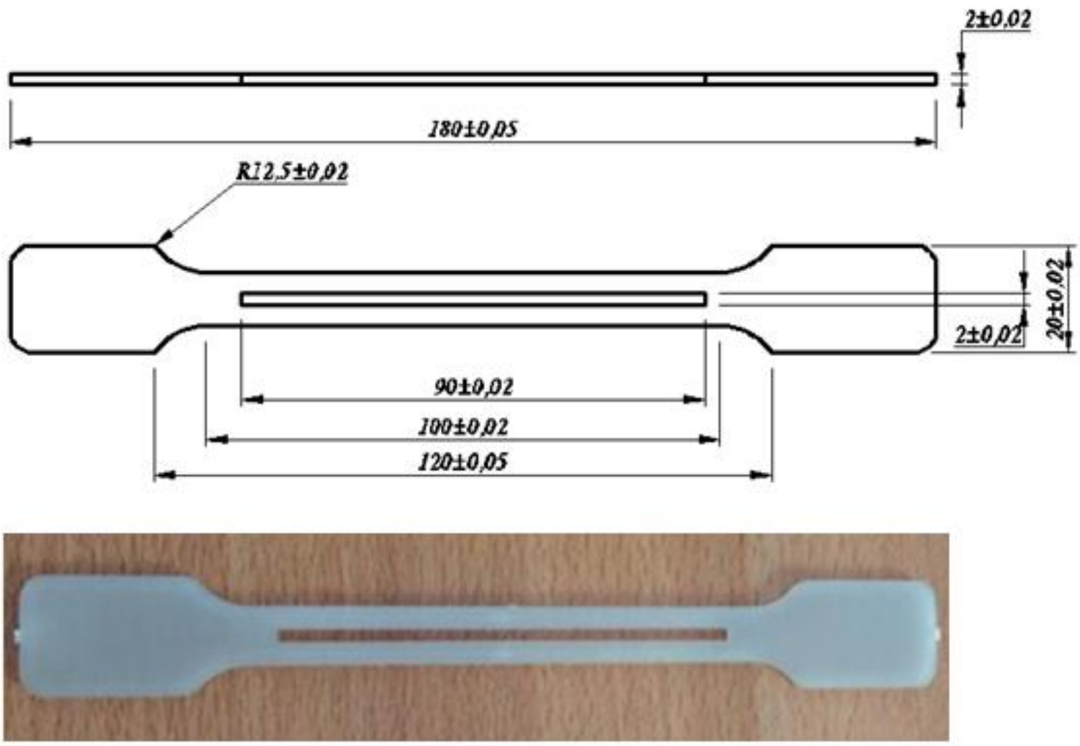
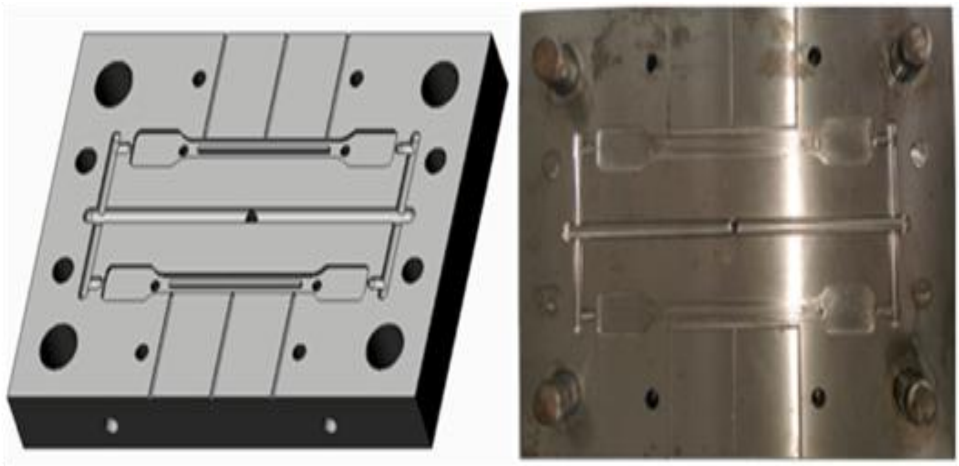


Figure 2. Tensile bar dimensions



(a) (b)

Figure 3. Mold plate

III. RESULTS AND DISCUSSION

To observe the influence of alkaline concentration on weld line strength, after the molding process, the molded part was soaked in the alkaline solution. In this paper, alkaline solutions with pH levels of 7.0, 8.0, 9.5, 11.5, 12.5, and 13.0 were applied for a period of 1 month, 2 months, 3 months, 4 months, and 5 months. To prepare the part, the testing samples were collected after 30 cycles running to satisfy the stable process of injection molding. The influence of alkaline concentration on the weld line was studied by observation and strength testing. Strength testing details are collected in Table 2 and compared in Fig. 4. The results show that with the same soaking time, the strength force will be reduced with the higher alkaline concentration. The strength force will reduce from 67.69 to 62.54 kgf in 1 month on increasing the alkaline concentration from pH 7.0 to pH 13.0. This decrease is more pronounced with longer soaking time. With 5 months of soaking, the strength force decreased from 61.71 to 51.18 kgf when the alkaline concentration increased from pH 7.0 to pH 13.0.To study the effect of soaking time on the strength force, the case of pH 13.0 was experimented with at a soaking time of 5 months. The weld line strength was tested and compared as in Fig. 5. The result shows that the strength decreased rapidly in the first month, from 34.75 to 30.39 MPa (about 9.1%). Then, the strength was almost maintained in the next 3 months. During this period, the strength changed in the range of 30.39–27.72 MPa. However, the strength dropped rapidly in the fifth month, from 27.72 to 24.32 MPa. This result can be explained by the influence of the soaking process. In the first month, the soaking process influences only the surface of the part; hence, the surface strength is lost after 1 month. Then, osmosis occurs on the core of the part, which is thicker than the surface layer. Hence, this step takes longer than one month. Finally, when the core of the part is almost soaked, the strength reduces drastically.

Table 2: Experimental results under different alkaline concentrations and soaking times

Soaking time (months) / Alkaline concentration (pH)	1	2	3	4	5
7.0	67.69	65.83	64.61	63.92	61.71
8.0	66.83	64.81	63.53	62.78	59.96
9.5	65.55	63.28	61.90	61.06	57.32
11.5	63.83	61.24	59.74	58.78	53.81
12.5	62.97	60.23	58.65	57.64	52.06
13.0	62.54	59.72	58.11	57.07	51.18

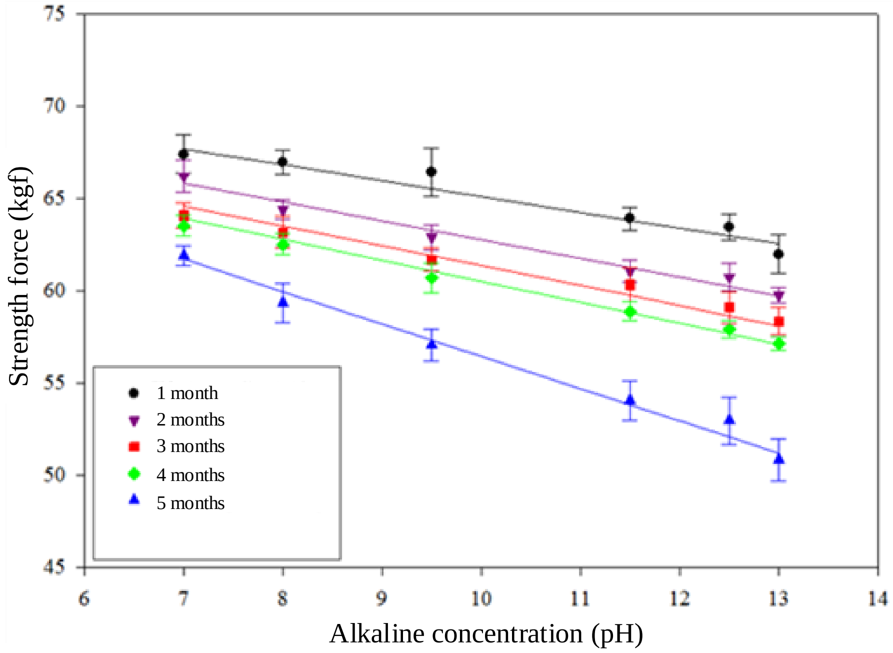


Figure 4. Weld line strength with different soaking times and alkaline concentrations

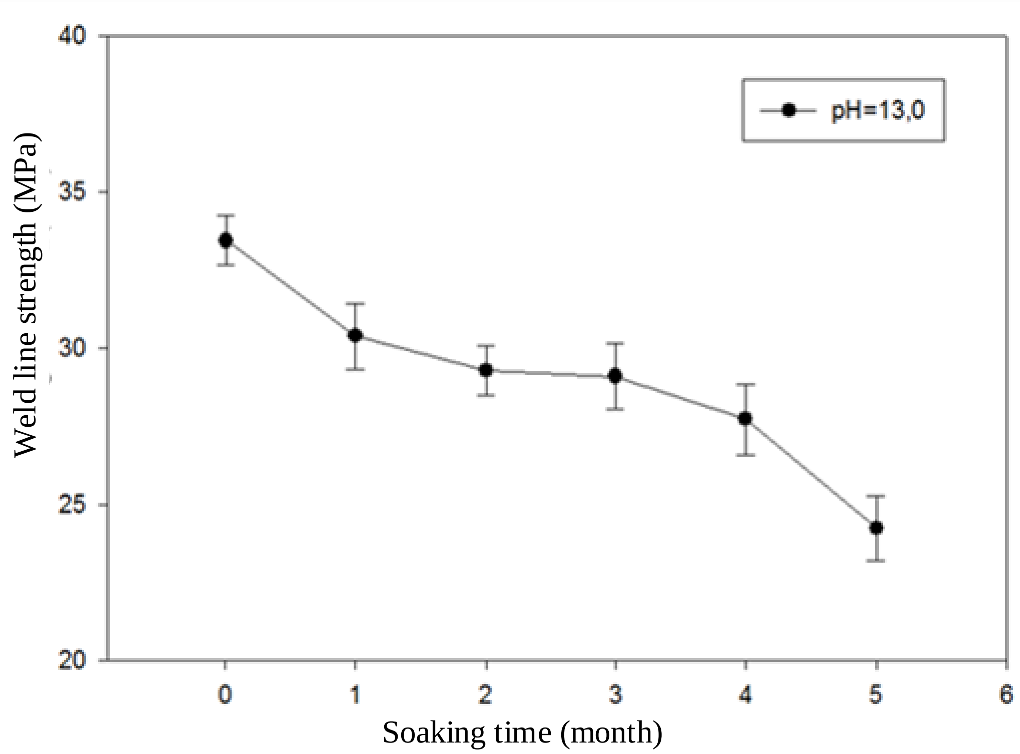


Figure 5. Weld line strength with different soaking times

IV. CONCLUSIONS

In this study, an injection molding system was used to mold the testing strength of a weld line. The molding part was soaked in different alkaline concentrations, and the time was varied from 1 month to 5 months. Then, the weld line strength was tested by a tension tester (INSTRON 3367). The results were collected and compared. According to the results obtained, the following conclusions were drawn:With the same soaking time, the strength force decreased with higher alkaline concentration. The strength force decreased from 67.69 to 62.54 kgf in 1 month on increasing the alkaline concentration from pH 7.0 to pH 13.0. This reduction is more pronounced with longer soaking time. In the case of 5 months of soaking, the strength force decreased from

61.71 to 51.18 kgf on increasing the alkaline concentration from pH 7.0 to pH 13.0.In the case of pH 13.0, the strength decreased rapidly in the first month, from 34.75 to 30.39 MPa (about 9.1%). Then, the strength was almost maintained in the next 3 months. During this period, the strength changed in the range of 30.39–27.72 MPa. However, the strength dropped rapidly in the fifth month, from 27.72 to 24.32 MPa.

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