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# Injection molded direct joining assisted by abrasive blasting and boehmite process

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**Abstract**
Injection molded direct joining (IMDJ), a process to directly join metal and polymer, consists of a surface treatment of a metal piece and injection molding of a polymer part. The surface treatments produce a nano-/micro-structured surface on the metal piece. The treated metal piece can be joined to a polymer part by injection molding with the treated metal piece initially placed in the mold. Abrasive blasting has been investigated for the surface treatment of the IMDJ. To enhance the joining strength of the IMDJ using abrasive blasting, this study proposed to use a boehmite process as an additional surface treatment. Applying the boehmite process to the blasted surfaces was expected to produce more complicated fine structures on the surfaces. The comparison of the treatments, which were the blasting with and without the additional boehmite process, showed that the joining samples produced with the additional boehmite process were stronger. This could be because the complicated textures enhanced micro-/nano-anchoring, chemical connections, and/or intermolecular force between metal and polymer surfaces.

Metal/polymer direct joining, Injection molding, Abrasive blasting, Boehmite process, Joining strength

## 1. Introduction

Metal/polymer direct joining has attracted attentions in recent industrial fields because of the recent increase of polymer material usage. Injection molded direct joining (IMDJ) is one of the joining methods with high productivity and consists of two processes, a surface treatment and an injection molding process, as shown in Fig. 1. (a) The surface treatment forms a fine structure, which ranges from nanometer to micrometer, on a metal workpiece. The treated workpiece is then placed in an injection mold. (b) The melt polymer flows into the fine structure during injection molding. (c) The molded polymer is joined with the metal workpiece after cooling and hardening. One of the joining mechanism is nano-/micro-anchoring at the fine-structured interface.

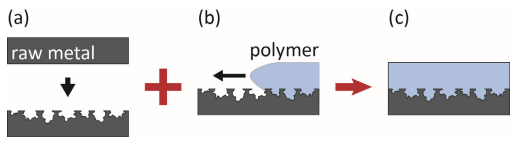


Figure 1. Overview of IMDJ process.

Abrasive blasting, which is one of the proposed methods for the surface treatment of IMDJ [1-3], has a large potential for the IMDJ applications because of high compatibility with existing factory lines. However, the joining strength of the IMDJ using abrasive blasting has yet to achive large enough for the practical use. To enhance the strength, this study proposed an additional surface treatment, a boehmite process [4], to the abrasive blasting and investigated the effects of the additional treatment. The boehmite process can be also easily introduced to existing lines due to a negligibly low cost.

## 2. Injection molded direct joining

### *2.1. Surface treatment*

This study utilized a micro blasting process and a boehmite process to form fine structures on metal workpieces, the material of which was A5052 aluminum alloy. A micro blasting machine propels white alumina particles (WA#150, SINTOKOGIO. Average size of particles: 84.5 µm. The grit size: 75 µm) from a scanning nozzle as shown in Fig. 2 by using compressed air, the pressure of which was 1.0 MPa. The propelled particles strike against a workpiece, and then the surface structure is formed. This study used the fixed condition of the micro blasting that was suitable for the IMDJ [3].

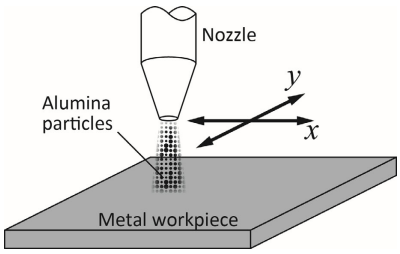


Figure 2. Schematic of micro blasting.

The micro-blasted workpieces were additionally treated by the boehmite process. In the boehmite process, the workpieces were immersed in temperature controlled water [4]. The temperature of water and the time length of the immersion were varied as shown in Table 1. To confirm the effects of the boehmite process, the treated workpieces were observed by a scanning electron microscope (SEM).

Table 1. Condition for boehmite process.

| type | Water temperature/°C | Immersion time length/s |
|---|---|---|
| a | 55, 65, 75, 85, 95 | 300 |
| b | 95 | 30, 60, 120, 300, 600 |

### *2.2. Injection molding*

The treated metal workpieces were joined with injection molded polymer, the material of which was polybutylene-terephtalate (PBT. 1101G-X54, Toray). In the molding process, one of the workpieces was initially placed into an injection mold, and then the polymer was injection molded to form a single-lap

joint. The shape and size of the joint followed ISO19095 as shown in Fig. 3. Table 2 shows molding conditions used in this experiment, the values of which were suitable for the IMDJ using the micro blasting according to the previous study [3].

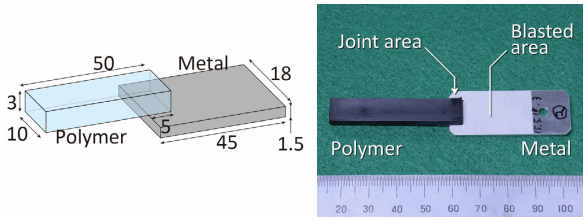


Figure 3. Schematic and photograph of signle-lap joint.

Table 2. Condition for injection molding. The parameters were optimized in the previous study [3].

| Mold temp. | Polymer temp. | Packing pressure | Holding pressure | Injection speed |
|---|---|---|---|---|
| 140 °C | 270 °C | 90 MPa | 60 MPa | 100 mm/s |

To evaluate the strength of the IMDJ samples, a tensile shear test was carried out by using a special tester developed in the previous work [5]. The test applied strain with constant speed of 1 mm/min until the sample fractured. The shear strength was calculated as the maximum load divided by the joining area.

## 3. Results and discussion

### *3.1. Surface condition*

Figure 4 shows SEM images of surfaces of the metal workpieces surface-treated under different conditions. Because of the space limitation, the particular images are shown. From the images, the effect of the boehmite process was confirmed in only the two conditions ((e) and (f)), where the fine protrusions can be observed. These fine protrusions were expected to enhance the anchoring effects and the resulting strength of joining. The other conditions of the boehmite process did not produce any unique structures on the surfaces, the images of which were similar to the image of the only micro blasting condition (without the boehmite process, Fig. 4 (a)).

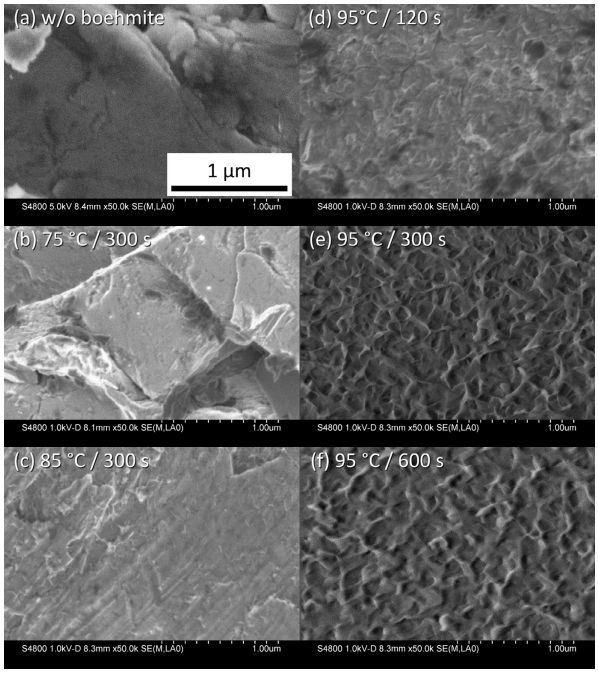


Figure 4. SEM images of surfaces of metal workpieces. The condition of the boehmite process: (a) non boehmite processed (only micro blasting), (b) 75 °C/300 s, (c) 85 °C/300 s, (d) 95 °C/120 s, (e) 95 °C/300 s, (f) 95 °C/600 s.

### *3.2. Joining strength*

Figure 5 shows the joining strength (averages and standard deviations) affected by the boehmite conditions. Note that the number of samples in each condition was four. Compared with the strength without the boehmite process, the samples with the boehmite processes provided higher strength. However, the difference among the boehmite process conditions could not be found; although the different structures existed, which could be seen in the SEM images. This indicated that the fine protrusions, which were expected to enhance the anchoring effects, did not quite affect the joining strength. Therefore, the other factors, such as chemical connection and intermolecular force, had larger effects on the joining under this particular conditions. The actual mechanism of the increase of the strength will be investigated in the future work.

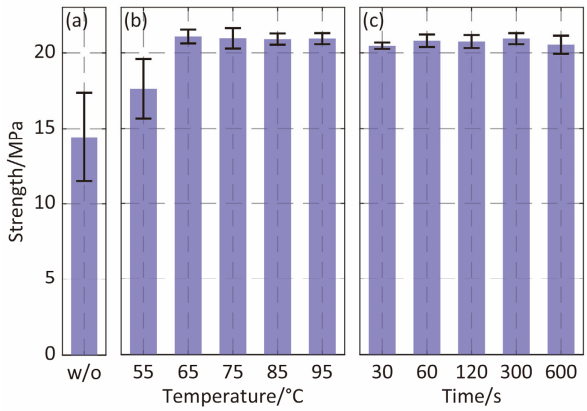


Figure 5. Results of tensile tests: (a) without the boehmite process, (b) the effect of the water temperature, (c) the effect of the immersion time length. The data of (b)-95 °C and (c)-300 s are the same.

## 4. Conclusion

This study investigated effects of the boehmite process as the additional surface treatment for the injection molded direct joining. The comparison of the treatments showed that the joining samples with the additional treatment had larger strength. It was also shown that the different boehmite conditions did not provide the difference of the strength; nevertheless the produced surface structures were different. This result indicated that the increase of the joining strength was not primaly caused by nano-/micro-anchoring, but also by other factors such as chemical connections and intermolecular force. In the future work, the actual mechanism of the increase of the strength will be confirmed.


## Acknowledgements

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