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Development of separation technology for dissimilar material bonding products of steel plate and CFRTP using the eddy current method

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Abstract: Owing to their lightweight and high specific strength, carbon fiber reinforced plastics (CFRTPs) are now receiving widespread applications in the transportation and energy industries. In this regard, developing technology for separating and extracting CFRTP from dissimilar material bonding products of metal and CFRTP has become a research hotspot. Therefore, in this study, we developed a separation technology for dissimilar material bonding products of steel sheet and CFRTP using the eddy current method. As a result, we succeeded in separating dissimilar materials using a fabricated induction heating system. In addition, atomic force microscope (AFM) analysis of CFRTP was conducted to confirm the change in physical properties before and after heating.

Keywords: CFRTP, eddy current method, dissimilar material bonding products, separation technology, induction heating system

I. BACKGROUND

Owing to their lightweight and high specific strength, carbon fiber reinforced plastics (CFRTPs) are now receiving widespread applications in the transportation equipment industry, such as aircraft fuselages, and in the energy industry, such as blades for wind turbine generators. However, cost-intensiveness has become a limitation. Some of the technical approaches to reducing the manufacturing cost of CFRTP include improving the manufacturing process, recovering and reusing carbon fiber from waste, and making multi-materials by bonding metals and CFRTP to different types of materials. CFRTP is attracting attention among resin materials owing to its excellent recyclability and the use of thermoplastics.

Currently, injection molding [1], laser heating [2], friction overlay bonding [3], thermal welding [4], and spot bonding technologies [5] have been proposed for dissimilar material bonding products of metal and CFRTP. The technical problem to address is how to develop a technology to separate and extract CFRTP from multi-materialized dissimilar material bonding products (Fig.1).

After its use, CFRTP is mainly disposed of in landfills as unburnable waste. Some recycling methods are in practical use. They involve pyrolyzing CFRTP to remove the base resin and to recover the carbon fiber. However, the methods are even more costly for recycling multi-materials.

Furthermore, how to prevent the deterioration of properties of CFRTP, such as tensile strength, after separation from dissimilar material bonding products of

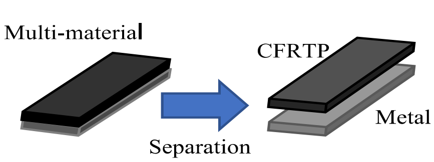

Fig. 1. Multi-material separation

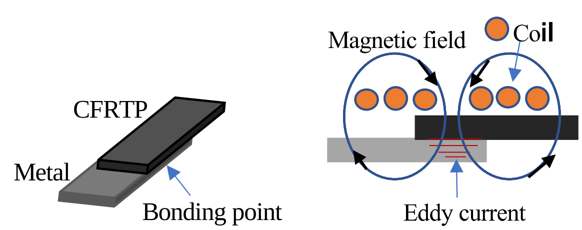

Fig. 2. Induction heating of bonding point using eddy current method

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steel plates and CFRTP is a technical issue.

In our previous study, we succeeded in pinpointing the melting of CFRTP resin using the eddy current method. It is still unknown what kind of eddy currents should be generated in the bonding area and what kind of heating should be applied to the bonding area to peel off the metal from CFRTP. It is also unknown how the heating conditions vary, depending on the composition of the resin, which is the base material of CFRTP. In addition, how the mechanical and electromagnetic properties of CFRTP are affected remains unknown. The evaluation method itself has not yet been established. Therefore, it is necessary to evaluate whether the separated CFRTP can be reused since the physical properties of CFRTP are expected to change due to heating.

II. PURPOSE

The purpose of this study is to develop a separation technology for dissimilar material bonding products of steel plate and CFRTP using the eddy current method for establish recycling methods for multi-materialized CFRTP to reduce its production costs.

III. INDUCTION HEATING SEPARATION EXPERIMENT OF DISSIMILAL BONDING PRODUCTS OF STEEL PLATE AND CFRTP

In this experiment, induction heating was performed using the eddy current method. Pinpointing was also performed on the bonding area using a coil shape that matched the shape of the dissimilar material bonding product of the steel sheet and CFRTP. SS400 steel plates were used for the steel plates. Fig. 2 shows a dissimilar material-bonded product made by bonding SS400 steel plate and CFRTP with a two-component mixed bond.

The size was fabricated to be 30 × 20 × 5 mm for the steel plate, 40 × 20 × 1 mm for the CFRTP, and 20 × 20 mm for the bonding point. The coil used was a general Litz wire, and a rectangular spiral-shaped coil frame of 150 × 10 × 10 mm was fabricated using a 3D printer. A thermocouple was attached to the steel plate of the dissimilar material bonding part, and the temperature change was recorded with a data logger. Experiments were conducted with real-time monitoring.

Fig. 3 shows the fabricated induction heating system. Fig. 4 shows the temperature variation of the steel plate surface with heating time. The output of the induction heating system was set at 80 kW. The heating time was 490 s, and the surface temperature of the steel plate was 250°C. The bonding products of dissimilar materials were successfully separated.

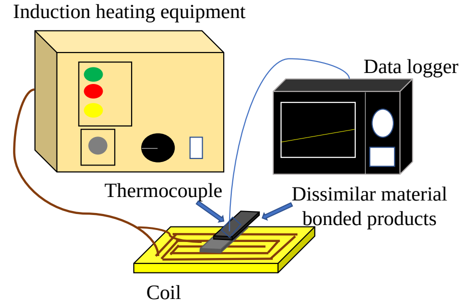


Fig. 3. Induction heating systems

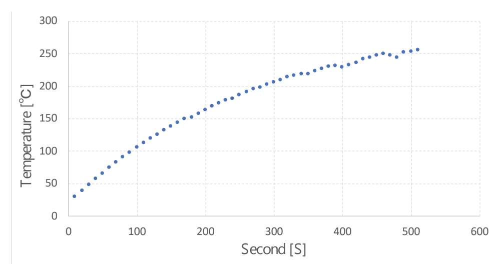
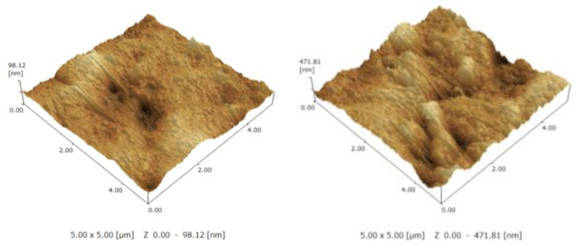


Fig. 4. Temperature change on steel plate surface

IV. CFRTP SURFACE OBSERVATION BY AFM

The CFRTP surface was observed using an atomic force microscope (AFM) before and after induction heating. In principle, a pointed tip is usually used to scan a material's surface for magnified observation of surface conditions. Each CFRTP used for observation was cut into 10 × 10 mm pieces. For CFRTP after induction heating, CFRTP at the bonding area was used. Fig. 5 shows the observed results of the CFRTP surface before and after heating by AFM. The change in the physical properties of CFRTP before and after induction heating was confirmed.



(a) before Induction heating (b) After Induction heating

Fig. 5. Surface image of CFRTP by AMF

V. DISCUSSION AND CONCLUSION

In the induction heating separation experiment of dissimilar materials of steel plate and CFRP, the coil shape will be further examined. Surface observation of CFRTP will also include the use of a digital microscope.

ACKNOWLEDGEMENTS

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