構造用接着剤の硬化条件を考慮した動的・静的接着性能の最適化

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Optimizing Dynamic/Static Adhesion Performance for Commercial Structural Adhesive considering Curing Conditions

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1. Introduction

Structural adhesive bonding in automobile can replace the classical mechanical fastening such as a riveting, bolting, and clinching. Since the classical fastening techniques can cause heavy weight structure, poor stability (impact resistance, elasticity, stress concentration, and noise-vibration-harshness), corrosion in joining spot, the structural adhesive is actively adopted in automobile industry for overcome those problems. In case of Hyundai Motor Company, over 100 m of structural adhesives are used in one car since 2013, and 173 m are used in recent 2017. In automobile industry in Korea, annual usage amount of structural adhesive has been gradually increased. The major reasons for increasing the use of automobile adhesive materials is that; I. Innovation in the production process – expansion of usage through expansion of automation technology improvement of adhesive use process; II. Expansion of lightweight car issues – demand for new assembly process technology due to changes in vehicle materials; III. Increased interest in electric vehicles – increased use of adhesive materials as new structures and plastic materials [1].

Since automobile manufacture industry is the largest consumer in those industries, it is important to evaluate both static and dynamic performances on the structural adhesive considering the stability of automobiles in use. In this study, a commercial structural epoxy adhesive which is actually used in Korean automobile industries is selected for investigating optimization between static and dynamic performances. For the optimization, several different curing conditions are selected, e.g., curing time and curing temperature. SPFC340 (cold rolled steel for the automobile structure) was used as an adherend, and the single lap shear (SLS, ASTM D1002-10) test and the impact wedge peel (IWP, ISO11343-2019) test were conducted for evaluating static and dynamic mechanical properties. Curing conditions of the adhesive, i.e., curing temperature and time, were investigated as a base step of this study by using a temperature sweep and an isothermal mode of the differential scanning calorimetry (DSC) heat flow. Several conditions of temperature (160, 180, 200, 220°C) and time (10, 20, 30, 40, 50, 60 minutes) for curing the adhesive were chosen from the DSC results, and the test results of SLS and IWP were discussed and correlated for suggesting an optimized adhesion performance.

2. Materials and Methods

SPFC340 (1.6 mm thickness, cold rolled steel used for the automobile structure) was used as an adherend in SLS tests and IWP tests. Structural adhesive was Type-D provided by Unitech Co., Ltd, Republic of Korea. DSC in temperature sweep mode with 10°C/min was pre-tested for determining the curing temperature variations for optimization. The peak temperature was 181°C (recommended curing temperature was 180°C, 20 min by the provider), and 160, 180, 200, 220°C were selected by 20°C interval term in center of 180°C. Sizes of SPFC340 were formed following ASTM D1002-10 and ISO11343-2019. In SLS test, the length of overlap (i.e., adhesive applied length in SPFC340/SPFC340) was 12.5 mm. In IWP test, the length of overlap was 30 mm. Thickness of both test specimens was adjusted by the glass beads having diameter of 0.2 mm. Since the adhesive is paste state, binder clips were used to fix uncured SPFC340/SPFC340 specimen for curing. The curing times of 10, 20, 30, 40, 50, 60 minutes were determined by DSC isothermal mode which will be presented in presentation.

Test was obtained by universal testing machine (UTM, 5967 series, Instron Co., Ltd.) with the tensile speed of 5 mm/min following ASTM D1002-10. In IWP, the impact speed is recommended 2 m/s, so that the height of weight is adjusted to make the impact speed following the simple physics $mgh = 1/2mv^2$, where m is the weight of drop head, g is the gravity constant, h is height, v is velocity. The drop tower (Instron Co., Ltd.) was used. Moreover, following the ISO 11343 wedge shape of edge R1 was used to cleaving the specimen.

3. Results and Discussion

The single lap shear tests were conducted and the result was obtained. In 160°C the tensile strength increased slightly following the curing time increasing, and which can be explained with the DSC isothermal mode on 160°C. Increasing trends was kept by 180°C, however from 200°C the peak was detected in 10 to 60 minutes region. This suggests an existence of optimized curing condition on the static performance.

The impact wedge peel tests were conducted and the result was obtained. In 160°C the dynamic resistance to cleavage shows down peak in 40 min, which may show an existence of uncured-cured boundary in relatively low temperature. In 180°C and 200°C the peak was founded in both, and peak points were in 50 min at 180°C and 30 min in 200°C. This may show relatively high temperature make the better dynamic resistance to cleavage faster than low temperature. Finally, in 220°C, the dynamic resistance to cleavage decreased by the curing time increasing, which shows some degradation or increase of hardness (brittleness) of the adhesive.

In the presentation, more details on optimization aspect and morphological graphics will be discussed on above two results and the two will be correlated from introducing a new definition of optimization index. The optimized condition was found in each temperature or each curing time. The index can be balanced between static performance and dynamic performance by the engineering designer from introducing weighting factors. Moreover, DSC isothermal mode results on each temperature will be discussed with the two results.

References

[1] H.-J. Kim, Adhesive Market and Trend in Korea, *The 16th ARAC EXCO Meeting*, October 18, 2019, Grand Hyatt Incheon, Republic of Korea.