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A Study of Aging Effect for Train Carbody Using Accelerated Aging Tester

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Abstract

The long-term exposure of polymeric composite materials to extreme-use environments, such as pressure, temperature, moisture, and load cycles, results in changes in the original properties of the material. In this study, the effect of combined environmental factors such as ultraviolet ray, high temperature and high moisture on mechanical and thermal analysis properties of glass fabric and phenolic composites are evaluated through a 2.5 KW accelerated environmental aging tester. The environmental factors such as temperature, moisture and ultraviolet ray applied of specimens. A xenon-arc lamp is utilized for ultraviolet light and exposure time of up to 3000 hours are applied. Several types of specimens - tensile, bending, and shear specimens that are warp direction and fill direction are used to investigate the effects of environmental factors on mechanical properties of the composites. Mechanical degradations for tensile, bending and shear properties are evaluated through a Universal Testing Machine (UTM). Also, storage shear modulus, loss shear modulus and tan ä are measured as a function of exposure time through a Dynamic Mechanical Analyzer (DMA). From the experimental results, changes in material properties of glass fabric and phenolic composites are shown to be slightly degraded due to combined environmental effects.

Keywords : *Tilting train, Environmental factors, Thermo-mechanical couple, UTM, DMA.*

1. Introduction

High-speed rail is becoming a popular mode of travel in East Asia. Although national governments may be ready for trains speeding along at 300 km/h or more, the regional geography is not. Tracks must often snake through mountainous terrain and other obstacles, which can create problems at high speeds. Tilting trains can keep the speeds up without causing passengers uncomfortable. Polymeric composite materials have high specific properties and specific strength, and superior corrosiveness, so they have been widely used for aerospace, port facilities, and train carbody. Specially glass fabric/phenolic composites are advantageous to manufacture the structural materials which curve shape and heat-resisting property are demanded by properties of fabrics form and phenolic resin. However, they can bring about problems in operating real composites structure. Because mechanical properties, thermal properties, and physical properties are changed by environmental factors on during long time exposure. In this study, the durability by aging of glass fabric/phenolic composites, which can be applied in real train carbody, were tested with using accelerated environmental aging tester. Specimens applied in accelerated aging are separated with Warp direction and Fill direction, those were performed in evaluation of mechanical properties through UTM, evaluation of thermal dynamic properties through DMA.

2. Materials and Methods

Glass fibric/phenolic composites used in this experiment were molded through the autoclave with using prepreg (Glass fabric #650/ AP300, Hankuk Fiber Glass co., LTD) that glass fiber fabrics (Glass fabric #650) were added in phenolic resins (AP300) for high temperature hardening. Tensile specimens (175 mm × 25 mm × 3 mm), bending specimens (125 mm × 25 mm × 3 mm) and shear specimens (76 mm × 20 mm × 3 mm) were molded with applying the autoclave after to laminate 0.5 mm-thickness of glass fiber fabrics prepreg up to 6 layers.

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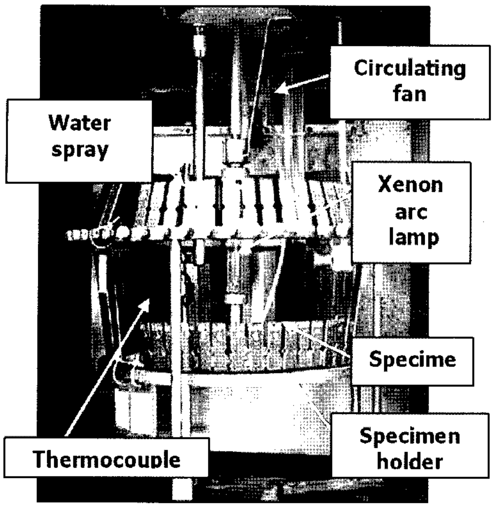

Fig. 1. Internal Chamber

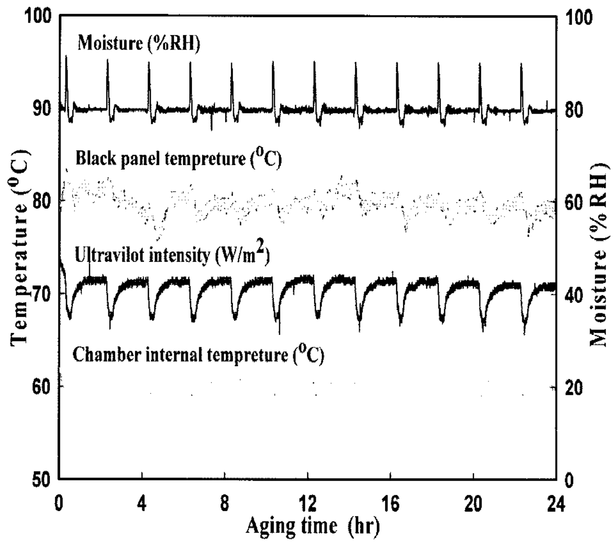

Fig. 2. Acquisition Data of Control Parameters

Accelerated aging tester shown in Fig. 1 has heating wire, water spray, and 2.5 KW xenon-arc lamp inside so that it can accelerate conditions of temperature, rain and snow, and ultraviolet light by sunlight. Test conditions are suggested by ASTM G155-00a [7] and ATLAS, one of accelerated aging environmental tester manufacturer to do accelerated aging test, water was sprayed for 18 minutes every 2 hours when lamp was on, and at this time it considered that 60°C of temperature, 80%RH of humidity. The data, which is collected to identify whether temperature, moisture, and ultraviolet are met to the setting-up condition, is shown in Fig. 2. It indicates that moisture is well-matched to the set-up 80%RH, relative humidity gets higher when to spray water for 18 minutes every 2hours, and internal temperature of chamber is well-matched to the set-up 60°C. it indicates that it is 80°C in specimens installed on specimen fixed equipment due to ultraviolet light and radiant heat, and where ultraviolet light is uniform according to exposure time.

Mechanical property testers, which is consist of load tester, signal amplifier, A/D converter (National Instruments, USA), and data collector, was used to evaluate mechanical properties such as tensile, bending, and shear properties of glass fabric/phenolic composites exposed in environmental for long time. Load tester is Zwick/Z100, and the strain to the load of action was measured with adhesive strain such as strain gage or non-adhesive strain sensor such as LVDT and extensometer. Mechanical properties of composites were evaluated by regulated procedure in ASTM. Each per second to analyze the experimental results are conducted statistical treatment to incline presumed value of average, remove outlier that increases the presumed value of accuracy, and get high reliable result value from the result data. Chauvenet standard [8] was applied to detect outlier, the way that remove vertex points if the probability value including each declination from data average is smaller than 1/2n, and re-decides statistical value from residual data was adapted.

Dynamic Material Analysis (DuPont DMA983) was applied to examine thermal analysis properties, such as storage shear modulus G', loss shear modulus G" and tanδ, which are against Warp direction and Fill direction of Glass fabric/Phenolic composites exposed in environmental factors (Eq. 1~Eq. 3).

$$G'(\omega) = \frac{\sigma_0}{\varepsilon_0}\cos\delta \tag{1}$$

$$G''(\omega) = \frac{\sigma_0}{\varepsilon_0}\sin\delta \tag{2}$$

$$\tan\delta = \frac{G''}{G'} \tag{3}$$

Specimen was installed on specimen fixed equipment in chamber charged with nitrogen gas with 32 mm of span, and scoped by 0.2 mm of amplitude, 1 Hz of cycle. At this time, temperature was increased from 30°C to 300°C by 2°C/min of rate of temperature increase.

3. Result of Evaluation of Environmental Aging Properties

Changes of tensile, bending, and shear properties by exposure time are show in Fig. 3. These result are from performing on 6 specimens each, modulus and strength in Warp direction are presented higher than those in Fill direction because of fiber density of specimens length direction. As exposure time is increasing, modulus and

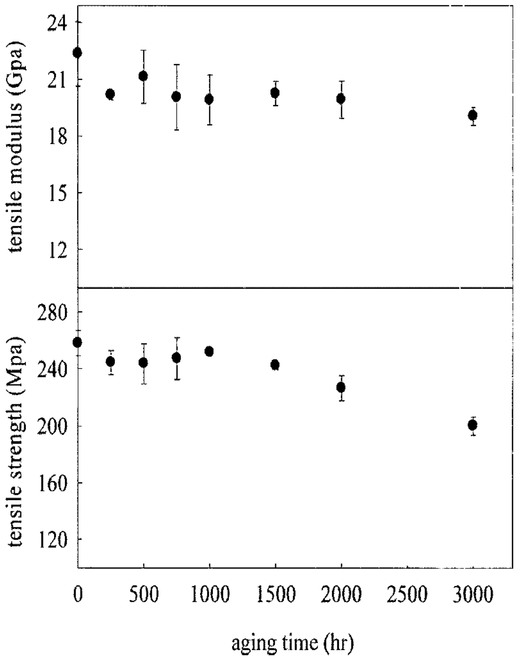

Fig. 3. Variation of Mechanical Properties w.r.t Aging Time of Warp Direction Acquisition Data of Control Parameters

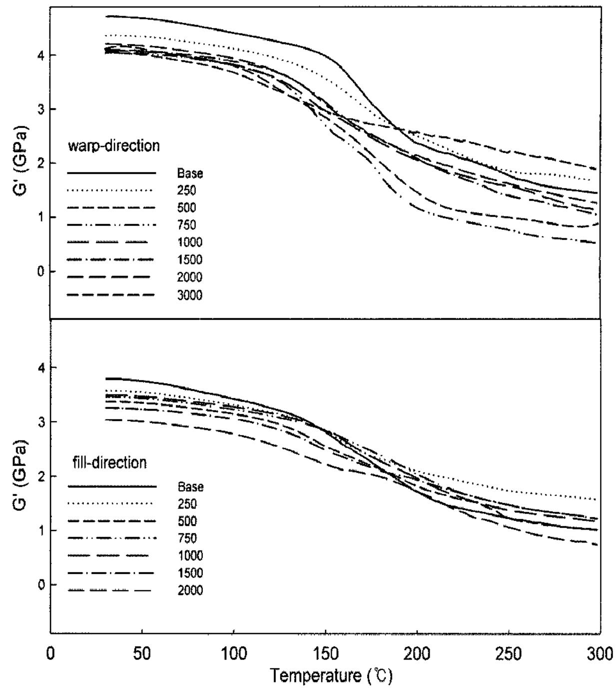

Fig. 4. DMA Result of Glass Fabric/phenolic Composite

strength are decreased little by little as compared to before to be exposed. Specially if specimens in Warp direction are exposed for 1000hours, tensile, bending, and shear modulus are decreased by 10.9%, 6.5%, and 2.2% each before the exposure, and tensile, bending, and shear strength are decreased by 2.5%, 7.0%, and 1.7% each. When it is exposed in environmental factors for 3000 hours, bending and shear modulus are increased by 0.5% and 0.1% each more than when it is exposed for 1000 hours, as the reason of these phenomenon, firstly it can be caused from post-curing of composites exposed in environmental factors when exposure time is increased, and secondly it is estimated that properties of each specimen are not even as each of specimens are mass produced. When it is exposed in environmental factors for 1000hours, bending properties in Warp direction are seriously decreased than those in Fill direction, because exfoliation on plastic layer occurred on surface of composites has greater properties decrease in Fill direction where relatively more plastics are as one major factor of aging.

Typical storage shear modulus G', loss shear modulus G'', tanä to DMA specimens before to be exposed are shown in Fig. 4. Here storage shear modulus that is glass state at normal temperature has primary flatness area, it is decreased slowly as temperature is higher, and it is rapidly decreased around at glass transition temperature that glass state is changed into rubber state. Loss shear modulus and tanä diagram before and after transition temperature are caused from interference effect of phenol by effect of bubble by adduct, such as moisture or carbonic acid gas occurred during composites during molding, and wide distribution of molecular weight, it is difficult to read loss shear modulus and tanä storage shear modulus with being different from storage shear modulus.

4. Conclusion

We could have following conclusion through the study to assessment of environmental factors by using accelerated aging tester to materials applicable on composites driver-cap of Tiltiing train.

Modulus by Warp direction and Fill direction of glass fabric/phenolic composites exposed in environmental factors is relatively insensible, but strength can be sensitive more than modulus, and these properties tend to be decreased as the exposure time is increased.

Storage shear modulus and glass transition temperature are decreased in both of Warp direction and Fill direction as the exposure time is increased. Glass transition temperature was increased a little in early exposure stage because of post-curing of composites, but if the exposure time is longer, chain cutting of composites occurs dominantly, and then it is gradually decreased.

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