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# Environmental considerations of plastic behaviors for automobile applications

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**Abstract**

It is well known fact that the thermo-mechanical behaviors of polymeric materials are strongly influenced by environmental factors, and, for automobiles, the mechanical properties of interior plastic structures are noticeably changed by being repeatedly exposed to environments such as sun light and rains. As the properties change, mechanical fits such as fasteners and clips in automobiles lose their tightness, creating unexpected noises. To consider Buzz, Squeak and Rattle (BSR) from initial stage of the interior design, it is very important to obtain, analyze and understand the structural behaviors of the materials under environmental changes as well as time. In this report, the mechanical property changes of the plastics for automobiles are measured to investigate the temperature and humidity effects. The samples are undergone different temperature and humidity conditions, and regularly taken out to measure the thermo-mechanical properties. The data are compared with the original samples, and analyzed for the properties change. Viscoelastic characteristics such as glass transition temperatures and storage/loss modulus were also investigated.


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*Keywords*: Plastics, Degradation, Aging, Automobiles, BSR

## 1. Introduction

The plastic materials are widely applied to the automobile interior structures, and those are exposed to many environmental factors during the operation. As well known, the behaviors of polymeric materials exhibit strong dependency on environmental conditions due to (semi) amorphous molecular structures.

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The continuous changes of the mechanical behaviors under time, temperature, humidity, ultra violets and other environmental effects frequently cause many engineering issues, and pose unique and very complex problems such as mechanical loss of tightness of clips and fasteners. In addition, the dimensional changes of the structures by heat and humidity generate unexpected noises termed as Buzz, Squeak and Rattle (BSR). The noises are perceivable, particularly under the feature of quietness of modern high technology vehicles such as hybrid and electronics automobiles. To prevent the mishaps at the initial design stage, it is essential to predict the mechanical property changes under the environmental effects. Physically, the behaviors are described as ageing and degradation [1,2]. Ageing is known to be reversible, and from continuous progress of the materials to thermodynamic equilibrium of the molecular structures. Degradation, on the other hand, stems from permanent chemical and physical changes of the molecular structures, and is irreversible. Many researchers have been reported about these two phenomena [3-8], however, there are not any definite descriptions about the relationship between those [9-11].

In this study, a preliminary experimental investigation on the mechanical property changes of thermal plastic materials under temperature and humidity influences are performed. ABS, ABS+Polycarbonate (PC) and Polypropylene mixed with a mount of fiber chops (PPF) were chosen for the tests. The materials are popular selections for the dash board, side panel and fasteners for the automobile applications. Three different environmental treatments of moisture absorption, thermal cycling and isothermal managements were applied. The samples were regularly taken out during the treatments to measure the mechanical property changes such as Young’s modulus and Poisson’s ratio at room temperature and coefficient of thermal expansions (CTE). Viscoelastic properties such as glass transition temperatures (*Tg*) and storage and loss modulus under temperature and frequency sweeps were also measured. The data were compared with the original ones before the aging to analyze the behavior changes.

## 2. Tests and Results

### *2.1. Weight changes by Moisture absorption and Isothermal tests*

Before the tests, the samples were placed in a dryer and undergone 60$^o$C for 7 hours to remove the moisture. The samples were then moved in the hygro-thermal chamber for the moisture absorption treatment under 85% relative humidity at 82.5$^o$C. The samples were taken out periodically, and the weights were measured by a precise electronic scale. The results are shown in Fig 1. As seen, the moisture absorptions of ABS+PC and PPF reached at the maximum in about one day, while ABS took about one and half days. The results also show ABS absorb the moisture much more than the other two materials, about 0.8% maximum by weight ratio.

Isothermal treatment effects were also examined. Without the humidity, the samples were exposed to the same temperature of 82.5$^o$C, and the weights were measured periodically. The results are included in Fig 1, indicating that the weight loss of ABS was noticeable and continued after four days. At this moment, it is not clear the loss was generated by the moisture residue removal or actual degradation of the samples. Further analysis is in progress for the clarification.

### *2.2. Young’s Modulus and Poisson’s Ratio*

Young’s modulus and Poisson’s ratios at room temperature were measured after the moisture absorption, the isothermal and the thermal cycle treatments. The treatment conditions for the moisture absorptions and the isothermal treatment were same as the weight change analyses. The thermal cycles were designed to jump the temperatures between -40$^o$C and 85$^o$C. The dwell time at each temperature was two hours, meaning that six cycles were completed in a day. The samples were taken out at 10, 15 and 20 days after the treatments, and the properties were measured based on ASTM D638. Five samples were used for each case. Fig 2-5 show the Young’s modulus changes of the materials by average values and standard deviations. The results represent that ABS and PPF demonstrate slight decrease of the average modulus, while ABS+PC almost same within the error range. On the other hand, after the isothermal treatment, the moduli of the materials were generally increased, although the trend of ABS is relatively weak. The results presumably indicate that ABS and PPF gradually degraded after full absorption of the moisture, while ABS+PC show little influence of the moisture by maintaining the modulus. For the case of the thermal cycling, the modulus of ABS was slightly decreased, and the other materials remain to be almost same. The changes of Poisson’s ratios are also included in the Figures. Unlike Young’s modulus, the ratios did not present discernable changes due to the thermal and humidity treatments in the ranges employed in the tests.

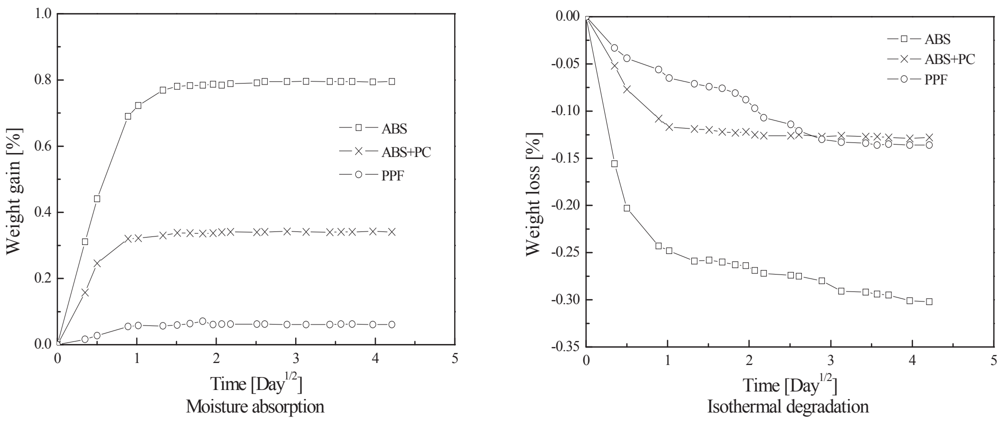


Fig. 1. Weight change results of moisture absorption and isothermal treatment tests.

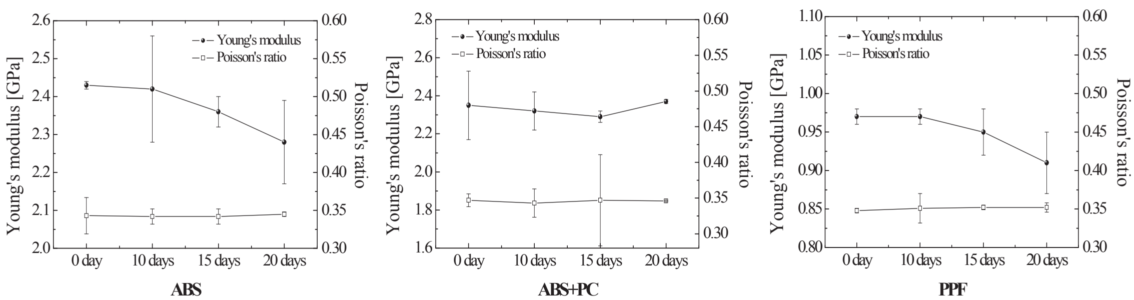


Fig. 2. Young’s modulus changes after moisture absorption.

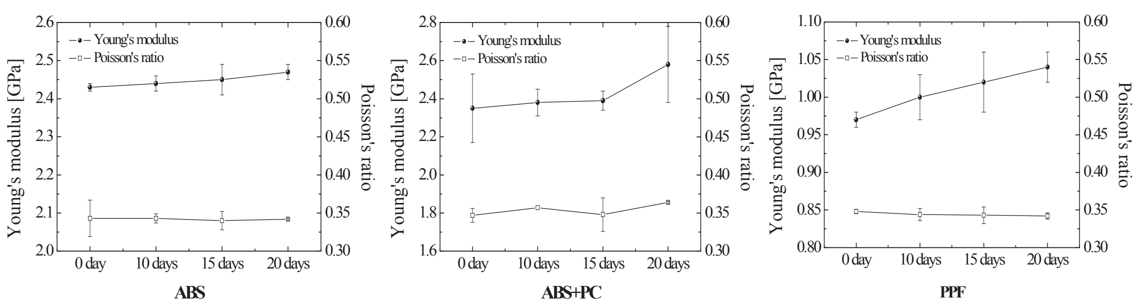


Fig. 3. Young’s modulus changes after isothermal treatment.

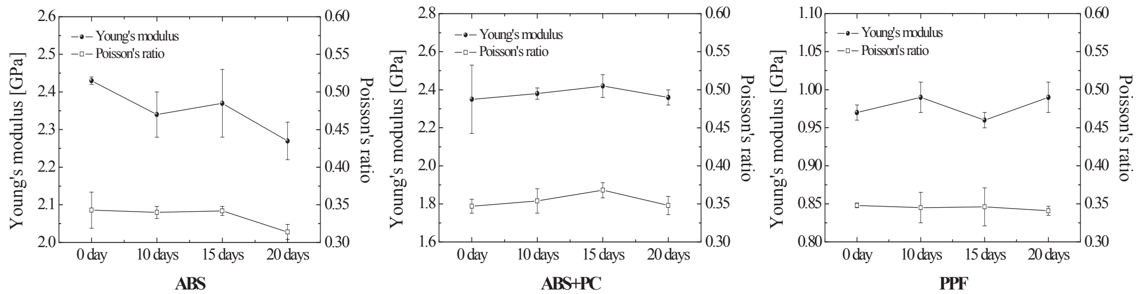

Fig. 4. Young’s modulus changes after thermal cycles.

## 2.3. Coefficient of Thermal Expansions

The coefficients of thermal expansion were measured by a thermal mechanical analyzer (TA Q400), and the results are represented in Figure 5. The temperature was increased from -50$^{o}$C to 100$^{o}$C at the rate of 5$^{o}$C/min. Due to relatively short test time, the changes of the moisture contents in the samples were assumed to be minor. As seen, the CTE of ABS+PC was decreased after the treatments. ABS showed the increase of the CTE when the sample experienced the thermal cycles, otherwise slightly decreased. PPF did not show any definite trend of the value except the moisture absorption case.

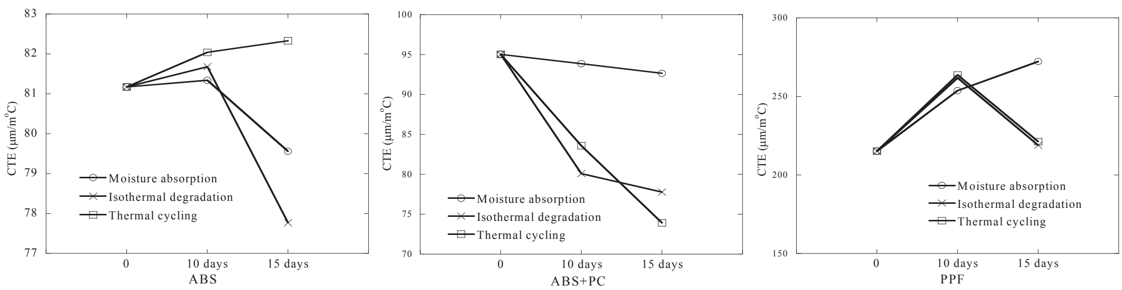

Fig. 5 Coefficients of thermal expansion measured under the environmental changes.

## 2.4. Glass Transition Temperature

Glass transition temperatures were measure by a dynamic mechanical analyzer (TA 2980) using single cantilever mode under 1Hz. The temperature was increased by 5$^{o}$C/min from room temperature to the point when the storage modulus practically reached to zero. The glass transition temperature was measured at the peak of *tan* $\delta$ as shown in Fig 6. The temperatures of ABS and ABS+PC were found to be 128$^{o}$C and about 141$^{o}$C, respectively, For PPF, no perceivable peak was found. After ten days of moisture absorption and isothermal treatment, the *Tg* of ABS was increased to 134$^{o}$C and 145$^{o}$C, respectively. However, almost identical temperature was found after the thermal cycling. For ABS+PC case, the Tg was slightly decreased to 136$^{o}$C after the moisture absorption, and increased to 147$^{o}$C after the isothermal treatment. Again, like ABS, no changes were found after the thermal cycle. The *Tg* of PPF persistently showed no peak after the environment al treatments.

## 2.5. Storage and loss modulus

In the vibration analyses of plastic materials for the noise analyses, it is necessary to obtain the storage modulus for elastic analyses and loss modulus for energy dissipation analyses. To obtain the modulus, temperature and frequency sweep tests were performed using the DMA. For the tests, the temperature was increased as stepwise from -20$^o$C to 130$^o$C, and the frequency was changed from 0.01Hz to 100Hz at each temperature. Fig. 7 represents the storage modulus results of the materials. As seen, the temperature was increased, the storage modulus was decreased. ABS and ABS+PC noticeably show rapid decreases at high temperature ranges, while PPF at low temperature range. The loss modulus changes are shown in Fig. 8. Generally, ABS and ABS +PC show slight decrease in the low temperature ranges, and increase in the high temperature range. On the other hand, PPF modulus gradually decreases as the temperature increases. Regarding the frequency effects, the storage modulus remains relatively constant under the frequency changes. On the other hand, the loss modulus is slightly increased for ABS and ABS+PC as the frequency increases, and relatively same for PPF. It was interesting to observe that there are peaks at about 50Hz in the temperature range of -5$^o$C to 100$^o$C for ABS and ABS +PC, and -5$^o$C to 40$^o$C for PPF, the reason of which is under investigation.

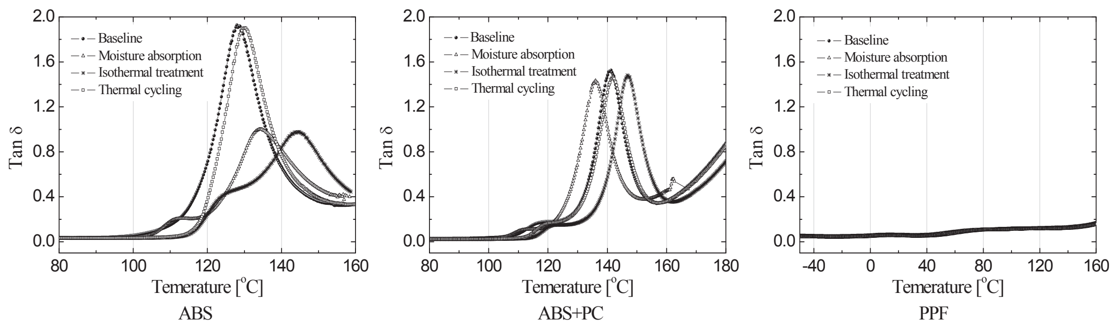


Fig. 6 Glass transition temperature measurements.

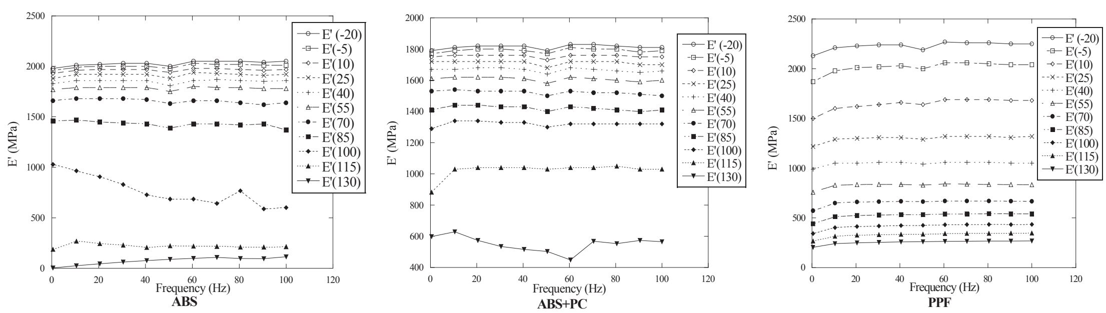


Fig. 7. Temperature/frequency sweep tests for storage modulus.

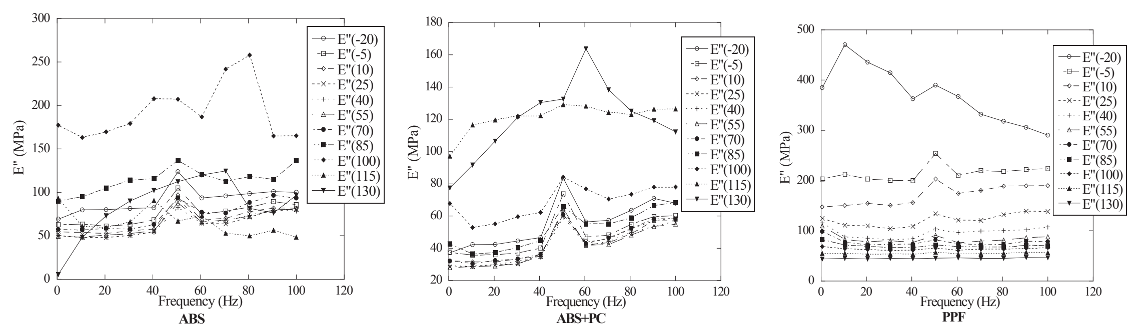


Fig. 8. Temperature/frequency sweep tests for loss modulus.

## 3. Conclusions

In this paper, experimental results of the mechanical property changes of the thermal plastics under environmental treatments are reported for preliminary analyses. The mechanical properties of Young's modulus, Poisson's ratio and coefficients of thermal expansion were measure under different environmental situations. Evidentially, the environmental factors had different level of influences on the materials. It was found that the moisture affected the modulus of ABS and PPF after the absorption. Although the full absorption was completed within a day or two, the noticeable effects appeared after 10~15 days. And the exposure to isothermal temperature rendered the modulus increases of the materials. Poisson's ratio, on the other hand, did not changed as much as the modulus in the test time and temperature ranges performed in this study. The coefficient of thermal expansion was measured, and ABS+PC showed the decrease by the moisture and temperature influences. The glass transition temperatures were also changed depending on the treatments. Through the temperature and frequency sweep tests, the decrease of the storage modulus was clearly demonstrated as the temperature was increased. For the loss modulus, the reverse was found, although the trend was not certain as the storage modulus. The tests are in progress, and further mechanism analyses are planned as more data is available.

## Acknowledgements

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