

Optimum Guide Position Design of a Cockpit Module for Decreasing the Permanent Deformation

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ABSTRACT

The noise of interior plastic parts has been one of the major driving factors in the design of automotive interior assemblies. This phenomenon is one of the major contributors to the perceived quality in a vehicle. The noise is caused by interior plastic parts and other parts as a result of permanent deformation. Traditionally, noise issues have been identified and rectified through extensive hardware testing. However, to reduce the product development cycle and minimize the number of costly hardware builds, hardware testing must rely on engineering analysis and upfront simulation in the design cycle.

In this paper, an analytical study to reduce permanent deformation in a cockpit module is presented. The analytical investigation utilizes a novel and practical methodology, which is implemented through the software tools, ABAQUS and iSight, for the identification and minimization of permanent deformation. Here, the emphasis is on evaluating the software for issues relating to the prediction of permanent deformation.

The analytical results are compared with the experimental findings for two types of deformation location and the qualitative correlation is found to be very good. In this study, we also develop a methodology to design the guide and mount location of cockpit module for minimizing the permanent deformation. Nonlinear finite element analysis has been implemented and integrated with sensitivity-analysis techniques to minimize the permanent deformation at the

areas of interest. Finally, we find the optimal guide and mount locations that reduce the permanent deformation.

INTRODUCTION

Since 1990, the trend in the development of vehicles has been to focus on cost savings and improving functionality by minimizing weight and ensuring safety, i.e., protecting passengers and vehicles from collision impact [1]. However, since the minimization of weight and the assurance of safety are conflicting objectives, a method for solving this problem is to rationally design vehicles and minimize the weight by using light materials. A reasonable design method, as applied to the domain of cars, is to develop an optimal plan through computer-assisted structural analysis and modeling, as an initial step. The typical materials for lightness of weight are high-tension steel sheets, plastic, etc. [2]. Though the effect of reducing the weight through a high-tension steel sheet is 5~7%, the effect from plastic might rise to 20% [3, 4]. Hence, developed countries are seeking to use plastic for components of vehicles as an efficient alternative for enhancing maintainability, as fuel prices rise and pollution becomes a growing concern. The alternative can solve pollution problems by decreasing exhaust gases as well as saving fuel by reducing the weight of vehicles. In addition, the alternative can improve the degrees of freedom of design because various shapes can be made by the forming methods developed. The application of plastic parts, which have those characteristics, is also given more importance in domestic markets [5]. However, we must satisfy requirements (e.g., vibration by the road surface, heat-resistant cycle performance, impact resistance, chemical resistance, etc.) to

realize the efficiency advantages of plastic. The importance of heat resistance and impact resistance is underscored by the effect of the competition of automakers to secure overseas markets.

A car with a modular cockpit, such as that shown in Fig 1, consists almost entirely of plastic parts in this research. The annealing phenomenon of mounts, as a result of irregular vibration and heat-resistance, causes a degradation of the performance resistance and different sounds. The degradation of performance resistance and the generation of different sounds give rise to a serious problem in the functioning of components and the value of products. Since the underlying cause is a complex mechanism, it is very difficult to identify. Thus, to solve this problem, analytical methods need to be applied to improve the structural reliability; the verification of the feasibility of the analytical method through experimentation is also required [6].

However, analysis and optimization technologies with regard to deformation through complex loads (vibration and heat-resistance) are very poorly developed in the domestic context. In practice, considerable additional expense and time are frequently needed for structural matters during mass-production. Also, the fundamental problems are hard to solve.



Figure 1. Modular-Assembly Part of the Cockpit

Therefore, through an analytic process of a modular car which is acted upon by a complex load, this study ought to be able to predict the permanent deformation that arises from vibration and heat-resistance. Through the introduction of techniques for optimizing design parameters, the problems with the initial design are minimized prior to mass-production.

THE KEY-LIFE TEST

In this study, we use the key-life test of a cockpit module to compare and analyze the quantitative results of tests and analyses. A rough device diagram of the key-life test, which is used in this study, is depicted in Fig 2. It is very hard to perfectly describe vibration in accordance with the thermal cycle of the test condition. Owing to the problems of the time for analysis and creep for specific types of material in the steady state, we used constraints within a strict condition to analyze the problem. We used the value of the three-axis (X,

Y, and Z axes) acceleration of the center of Cockpit Module in the actual test as resonance data. We also stipulated the same condition for the analysis as that for the test. We applied the value of the acceleration, which was transformed to a load for the sake of analysis, because the resonance data were obtained through an accelerometer. The thermal condition was the same in both cases. Finally, we compared the findings from the analyses and the test results by applying elasticity and plasticity data under the strictest condition of 100 °C. Though the findings from the analyses and the results of the tests will be mentioned in the next section, we note here that the region of permanent deformation appeared in a similar manner in the plastic parts. Fig 3 shows the device of the key-life test [8].

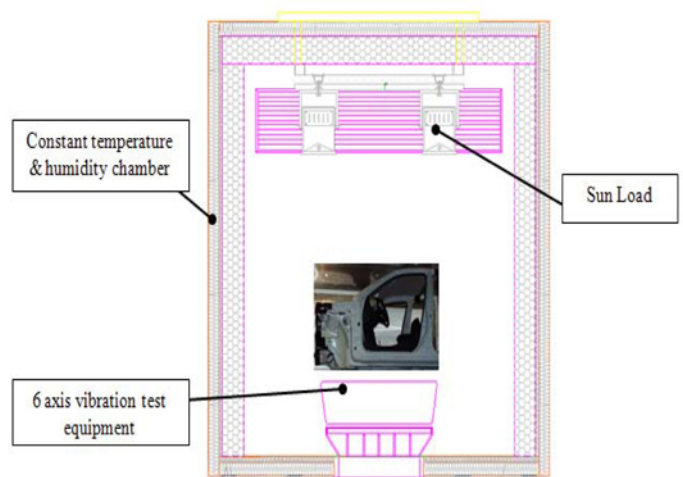


Figure 2. Device Diagram of the Key-Life Test.



Figure 3. Key-Life Test [8]

A FUNDAMENTAL EXPERIMENT

We executed a tension test to obtain data in the elasticity and plasticity regions of PPF 213-59 TY1=SO-5208, PC-ABS MS214-04=NS-5000, and ABS MS225-18 TY5=XR-474, which are the typical plastic materials used in this study. This test was executed by using the displacement controller of the

electric hydraulic Shimadzu Dynamic Testing System at a rate of 50mm/min under five thermal conditions (−40 °C, 23 °C, 50 °C, 90 °C, 100 °C). We used a 3-zone-type electric resistance furnace to maintain the high temperature, and we used a k-type thermocouple to control the temperature so that the temperature of samples could be kept within ± 1 °C of the test temperature. The tension sample was ASTM D638 Type 1, as shown in Fig 4. We determined the average value from the test data following five replications of the test [4].

Fig 5 gives the Stress-Strain Curve of PPF 213-59 TY1=SO-5208, which is mostly used in the cockpit module for the temperature constraint. Table 1 presents the data on mechanical properties of the material. Other plastic materials (PC-ABS MS214-04=NS-5000, and ABS MS225-18 TY5=XR-474) should not release for secret data of company.

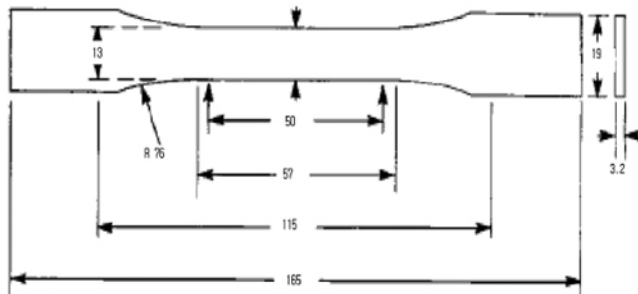


Figure 4. ASTM D638 Type 1 Specimen

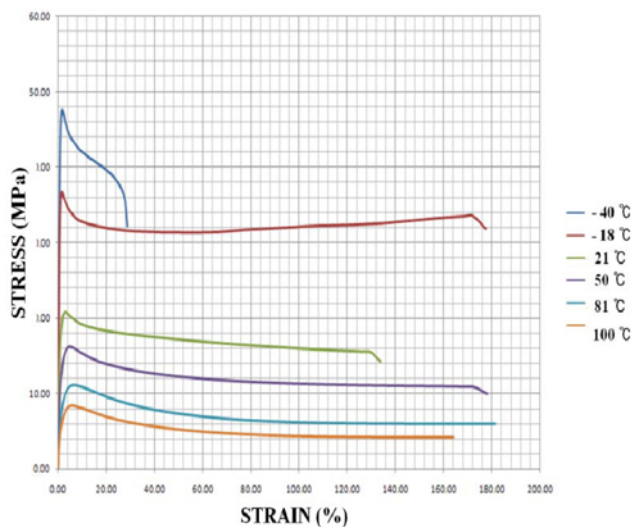


Figure 5. Result of the Tension Test at Each Temperature. (PPF 213-59 TY1=SO-5208)

Table 1. Mechanical Properties of the Specimen (PPF 213-59 TY1=SO-5208)

Temperature	Tensile strength (MPa)	Yield strength (MPa)	E (MPa)	Poisson's ratio
−40°C	52.4	43.8	7,060	0.34
23°C	32.5	20.3	3,574	0.44
50°C	26.9	15.5	2,174	0.47
90°C	19.2	11.4	1,413	0.52
100 °C	15.9	9.8	1,216	0.54

FINITE ELEMENT ANALYSIS

We performed an analysis of the cockpit module, as a preliminary study in the development of a process for reducing permanent deformation. Through a qualitative comparison, we confirmed the adequacy of our procedure of analysis.

FINITE ELEMENT MODEL

This section describes the constitution of the finite element model for the cockpit module. The finite element model of the cockpit module comprises pieces of 55 subcomponents, which are similar to those that prevail in a real model as depicted in Fig 6. As mentioned earlier, the materials used are four types of plastic material (PPF, PC-ABS, ABS, and TPO) and five types of steel material (SPHC, SPCC, STK500, SPFC590, and SECC).

We assumed the boundary conditions used in the analysis as the main mount jointing with the chassis.