A Study on the Impact Absorbing Characteristics of Rubber and Metal Layered Structures

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Summary

Rubber material is useful to machine components for excellent shock absorbing characteristics. The impact absorbing characteristic of rubber is used a broad range of goods such as mobile phones, cameras, sporting goods and industrial parts such as vehicle bumpers. The impact characteristics of rubber were examined by experimental and finite element methods. The impact test was conducted with a free-drop type impact tester. The ABAQUS/Explicit was used for finite element analysis. The effects of the impact velocity and the hardness and thickness of the rubber specimen were investigated.

Introduction

Mechanical systems with rubber parts have been used widely in industry fields. The evaluation of the physical characteristics of rubber is important in rubber application. Many engineers have studied the mechanical properties of rubber with various research methods.

Lee studied the impact strength of rubber and plastic[1]. Chen studied the energy absorption of foam-filled rubber structures[2]. The dynamic material of polymer foam was investigated experimentally by Iannace[3]. The impact characteristics of pyramid type polymer foam was studied by Gilchrist using the finite element method[4].

In this study, the evaluation of absorbing characteristics of was investigated with free-drop impact test and finite element analysis. Impact specimens are made with rubber and aluminum. Its shape is cylindrical. To evaluate the effect of the material parameters of rubber part, the natural rubber specimens with various hardness were tested. The study for shape parameters was performed with various thicknesses of inserted rubber. Figure 1 shows the schematic diagram of impact specimen and impactor.

Experiment

The impact test of rubber was proposed as an impact resilience tester from the ASTM[5]. But the impact resilience tester did not measure the impact force and measured

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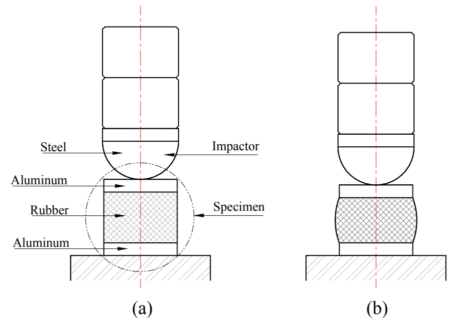

Fig. 1 Schematic of impact specimen and impactor

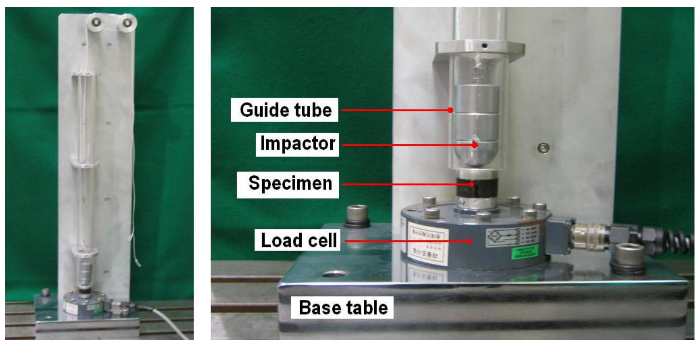

Fig. 2 The free drop impact tester

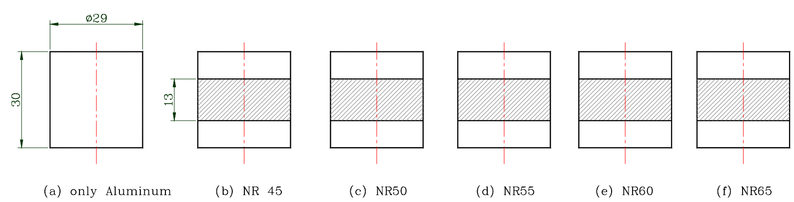

Fig. 3 The dimension and shape of specimens for various rubber hardness

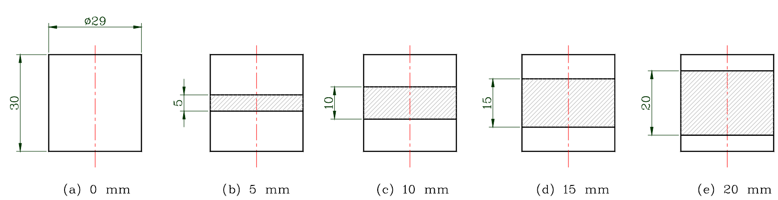

Fig. 4 The dimension and shape of specimens for various rubber thickness

only the rebound energy. Generally, in the low velocity impact test, the recommended testers used are the free-drop type tester, the sliding type tester and the pendulum type tester. In this study, we chose the free-drop type impact tester[6]. Figure 2 shows the photograph of the tester used in this study.

The impactor was made of steel, with the weight of 0.3 kg. It was dropped from the height of 0.51 m and generated an impact energy of 1.5 J. The specimen was made of rubber and aluminum. The impact force was measured by the load cell as it was impacted. The model of load cell is 7173-500 lbs(Lebow Co., Germany). The force signal of the load cell was amplified by the ML 55(HBM Co., Germany), from 0 V to 10 V. The amplifier,ML55, has the sampling rate of 4.8 KHz.

Five types of natural rubber (NR45, NR50, NR55, NR60, NR65) were bonded in order to construct the specimens. The shape of the specimens is the same as those shown in figure 3. The dimensions of the inserted rubber in each of the specimens have the height of 13 mm and the diameter of 29 mm. The absorbing impact force of the rubber was studied in order to compare the peak reaction force of the specimen which only contained aluminum against the specimen with the inserted rubber part. The thickness of the rubber was a consideration for the shape of the specimen. The thickness of the inserted rubber that were tested were 5mm, 10mm, 15mm, and 20mm. The shapes are shown in figure 4.

Finite Element Analysis

Finite element model

The finite element analysis used by ABAQUS/Explicit is compatibile with the non-linear analysis. The analysis of rubber must be considered hyperelastic material. The model is composed of the impactor and the specimen. The Lagrangian Processor was used to analyze the model with a 2 dimension Axi-symmetric. The element used in analysis is the CAX4R. In order to reduce the calculating time, the shape of the analysis model was contacted with the impactor and the specimen. The impact energy exerted depended on the impact velocity. The impact velocity was applied on the nodes of impactor in the axial direction. All node, which are placed at the bottom of the specimen model, is completely fixed. The number of elements is 895 and the number of nodes is 991. Figure 5 shows the element shape of the impactor and the specimen.

Material properties

Generally, the material properties of rubber were obtained from uniaxial tension test and equi-biaxial tension test. And these properties were used in FE analysis. Because finite element analysis results based on the static material property, These results showed some difference the compared with experimental results. In the impact condition, the time duration of rubber specimen occured very shortly. Thearfore, the linearity was considered in the material properties of rubber for the FE analysis. The table 1 shows the material properties of rubber. The results which was obtaind from the FE analysis with the linear material property was corresponded with the experimental results. Figure 6 shows the result of FEA and experiment

Table 1 Elastic modulus of rubber material

Rubber name	Elastic modulus (Mpa)
NR 45	2.4
NR 50	3.0
NR 55	5.0
NR 60	5.7
NR 65	6.5

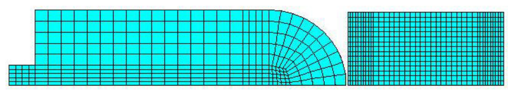

Fig. 5 Finite element model of the impactor and the specimen

Result and Discussion

Energy absorbing characteristics of various parameters of rubber hardness

Figure 6 shows the peak reaction force for the various impact energies and parameters of rubber hardness. In the conditions of various hardnesses of rubber, the absorbing ratio of the impact force was investigated experimentally with the free-drop type impact tester and numerically with ABAQUS. According to impact energy, the following results were obtained: The peak reaction force increase produced by the use of rubber hardness NR45 was from 40 kgf to 90 kgf. In the case of NR55, the peak reaction force increased from 50 kgf 110 kgf. NR65 produced a peak reaction force which was distributed from 65 kgf to 145 kgf. Finally, in the aluminum specimen, the peak reaction force increased from 190 kgf to 300 kgf. Figure 7 shows the absorbing ratio(Fa/Fs) which was calculated with the aluminum specimen and the rubber inserted specimen. In the impact energy from 0.3J to 1.5J, the absorbing ratio of impact force was distributed from 63 % to 80% with every hardness region of the rubber material. The increase of the impact energy was generated by decreasing the absorbing ratio.

Energy absorbing characteristics for various shapes

In this study, the impact characteristics for rubber thickness were investigated with various rubber thicknesses (5 mm, 10 mm, 15 mm, 20 mm). Figure 8 shows the peak reaction forces for the various rubber thicknesses. The peak reaction forces of the inserted rubber specimen increased as the impact energy increased for the same study for the changes in hardness. Figure 9 shows the absorbing ratio for the changes in rubber thickness. A rubber thickness of 5mm produced a large absorbing ratio which was distributed from 20% to 52%. In the 10mm, 15mm, 20mm, absorbing characteristics was occurred similarly.

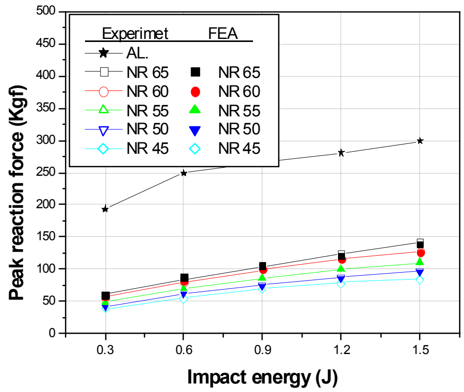

Fig. 6 The peak reaction forces for the various impact energies and parameters of rubber hardness

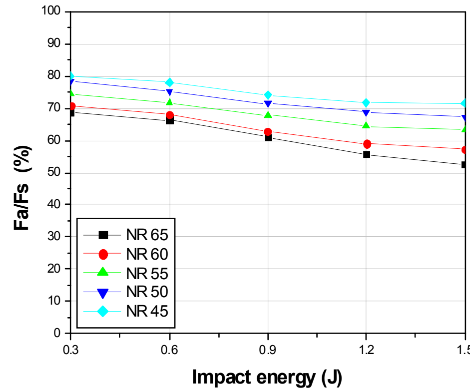

Fig. 7 The absorbing ratios for the various parameters of rubber hardness and impact energy

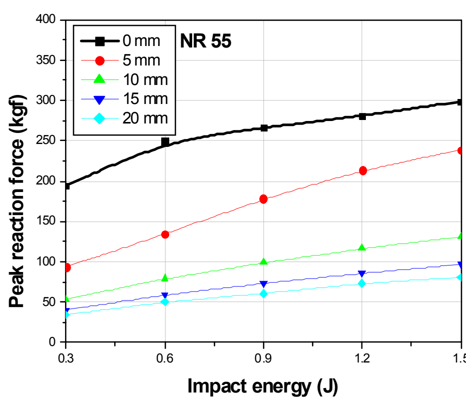

Fig. 8 The peak reaction forces for the various impact energies and thickness of rubber

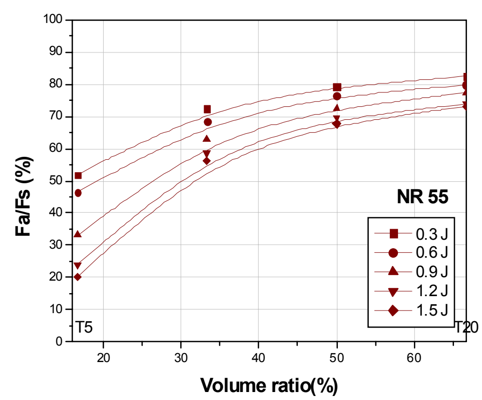

Fig. 9 The absorbing ratios for the various parameters of rubber thickness and impact energy

Conclusions

In this study, to evaluate absorbing characteristics of impact force was investigated with the free- drop impact test and finite element analysis. Impact specimens are made with rubber and aluminum parts. Its shape is cylindrical layered structures. The study for material parameters was performed with NR45, NR50, NR55, NR60, NR65. The study for shape parameters was performed with various thicknesses of inserted rubber.

1) The rubber inserted specimen has excellent impact absorbing characteristics.

2) The absorbing characteristics depend on the rubber's hardness and specimen shape.

3) In the rubber layered specimen, the absorbing ratio of the impact specimen decreases as the rubber hardness increase.

4) As the impact ratio increases the absorbing ratio decreases.

5) Increasing the thickness of the rubber inserted in the specimen is excellent for the impact absorbing characteristics.

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Acknowledgements

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