Small and Lightweight Anti-Vibration Rubber Products

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In the automobile market, regulations have become tighter on the emissions of environmental pollutants such as exhaust gases and carbon dioxide. While automakers are accelerating the development of hybrid cars and fuel-cell vehicles, weight reduction of automotive parts is highly sought for fuel savings. Sumitomo Riko Co., Ltd. develops technologies for reducing the size and weight of anti-vibration rubber products. Smaller anti-vibration rubber products are subject to larger input distortion and result in lower durability. To address this challenge, we have developed a high durability rubber using chemical bonding. The rubber is twice as durable as conventional rubber, and enables a size and weight reduction of products by about 30%, while maintain durability.

Keywords: anti-vibration rubber, small and lightweight, filler dispersion

1. Introduction

To contribute towards safer and more comfortable vehicles, Sumitomo Riko has been using a variety of technologies, including polymer compounds, to create products that achieve vehicles with low vibration and noise. We would like to introduce Magnetic Induction Foaming (MIF), a highly durable anti-vibration rubber, that is both small and lightweight, and also a noise absorbent material that radiates heat, which we have been successful in implementing.

(Small and lightweight anti-vibration rubber)

Support for the environment, safety and globalization has become important to the current automobile industry. For the environmental sector in particular, while the use of hybrid cars (HEV) and electric cars (EV) have become increasingly popular as environmental regulations in each country have become stricter, there have been technological developments to decrease the size of the engine and lighten the weight of the vehicle, even for conventional gasoline cars.

To control the vibration transmission of electric vehicles and hybrid vehicles, in addition to conventional ones, there is a demand for high performance in the durability and heat resistance of anti-vibration rubber for vehicles. Due to globalization of the market, vehicles are being used in a wider range of potentially harsh temperatures and environments, such as on unsurfaced roads and in regions with intense heat, further spurring the development of rubber that possesses high vibration control characteristic covering a wider range of the vibration frequency band. It is becoming even more important to achieve material development that considers such environmental and global production issues, while maintaining the same levels of quality around the world. To develop a material that meets these requirements, we have moved forward with new technological innovations, such as microstructure design and control technology, in addition to raw material development and processing technology, and have been working on the development of materials that further combines these technologies.

2. Anti-vibration Rubber for Vehicles

The types of anti-vibration rubber for vehicles, as shown in **Fig. 1**, are divided into four main groups: the engine system, suspension system, body system and the exhaust system. A large quantity of anti-vibration rubber is used, with the aim of reducing vibrations and noise that occur outside and within the vehicle, to achieve both a comfortable driving experience and provide stable handling. Approximately 40 to 50 pieces of anti-vibration rubber are used on a single vehicle. This provides support for each and every type of vibration and noise, to achieve a quiet and comfortable drive. The properties that are sought after for anti-vibration rubber for vehicles differ, depending on where it is used on the vehicle. However, in general, spring properties, heat-resistance, durability and reliability are required, and there is a demand for material that possesses a well-balanced combination of each of these properties.

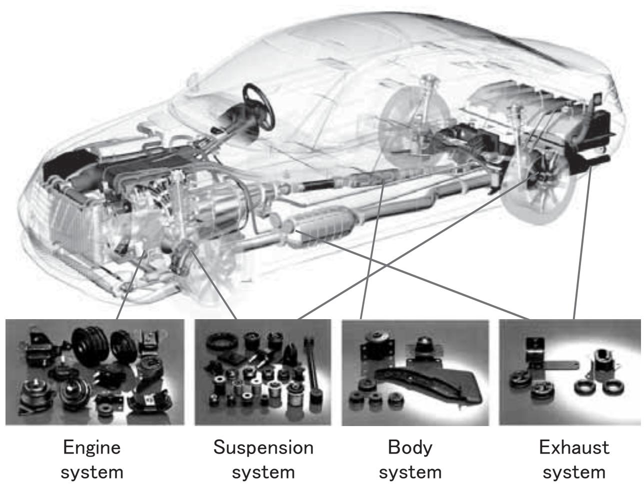

Fig. 1. Anti-vibration rubber products for vehicles

Due to the global emission regulations for such as exhaust gases and carbon dioxide, technological development trends in the recent automobile market, have shown measures put in place for power systems that includes the development of hybrid cars and electric cars, along with the reduction in size of gasoline engines. There has also been active effort in lightweight technology development, such as for the body of the vehicle and the suspension. Decreasing the weight of the vehicle improves fuel consumption, and it has been reported that the amount of emissions from carbon dioxide can be reduced[1]. Each automobile manufacturer is making efforts to make lightweight vehicles by actively adopting lightweight materials, such as high tensile strength steel, aluminum parts, and resin based materials.

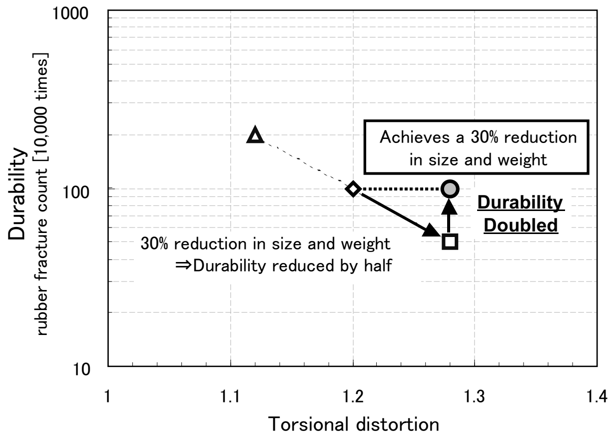

Fig. 2. Rubber input distortion and durability due to decrease in size

Lightweight technology development is also proceeding in the same way for anti-vibration rubber. For example, by decreasing the size of rubber bushes used on suspension parts, it is possible to decrease the size of peripheral parts, such as the arm, in addition to decreasing the weight of the rubber bush itself, and this means we can expect a greater weight reduction effect as a whole.

However, when decreasing the size of rubber bushes, the input distortion on the rubber increases and durability is lowered. Therefore, it is necessary for the rubber to have a high durability. At Sumitomo Riko, we make full use of structural analysis technology at the micro and nano level, cross-linked structure control, and reformation of polymer filler, which is used as a raw material for rubber, and have developed a high durability rubber that is twice as durable as conventional rubber. We have been successful in developing products that have the same durability and shape as previously, but with a 30% reduction in size and weight.

3. Development of High Durability Rubber

3-1 Reinforcing the filler interface

To improve the durability performance of rubber, or in other words, the repetitive fatigue resistance, in general, the techniques of (1) forming cross-linked chains that include long linked polysulfide chains, and (2) selecting small particle size filler with a large specific surface area are well known[2], [3]. However, since there are limitations on the heat-resistance performance and vibration characteristic of rubber, in order to develop many products, it is necessary to improve the durability performance with techniques other than those stated above. When we investigated the occurrence start point for rubber deterioration with repetitive fatigue, fine cracks occurred starting at the filler interface, which is filled with rubber, and these cracks grew with repetitive fatigue. In the end, we confirmed that this situation led to the rubber fracturing.

When looking at each binding form of the cross-linked polymer chain filler (**Fig. 3**), which is the structural material of the rubber, because the polymer filler reinforcement point is a physical absorber of static electricity, with regards to the chemical bonding of the cross-linked polymer chain, it has a weak binding force in comparison to any other position. Therefore, it is thought that this is a reason that cracks occur from the filler interface.

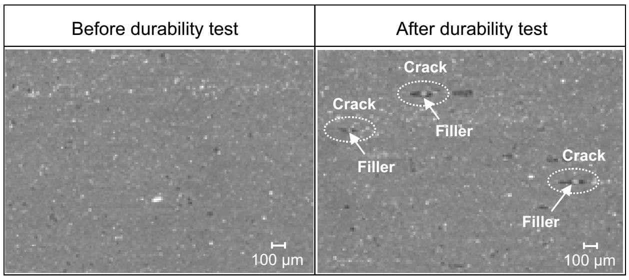

Fig. 3. Progress of cracks in the rubber

Due to this fact, we can infer that using a stronger substance at the filler interface could improve the durability. We have aimed to improve the durability by allowing a strong chemical bond to form between the filler and polymer. However, filler and polymer in general use are often insufficient in terms of the chemical reaction point, so it is necessary to grant a chemical reaction point by means of reformation and surface treatment. Substances, such as carbon black, silica and calcium carbonate, are used in fillers, and it is possible to grant a chemical reaction point using techniques such as surface processing, based on surfacing reforming using acid treatment with each substance, or by grafting, as well as the use of fatty acids, silicone oil, surfacants and silane coupling agents. Rubbers, such as natural rubber, styrene-butadiene rubber, butyl rubber, and ethylene propylene diene rubber, are used for polymers, and it is possible to grant a chemical reaction point through actions that include grafting or altering the polymer chain. Among these materials, natural rubber, which is generally used for anti-vibration rubber, and fillers, such as carbon black and silica, are used with a coupling agent, and allowed to chemically bond, as shown in **Fig. 4**, to make it

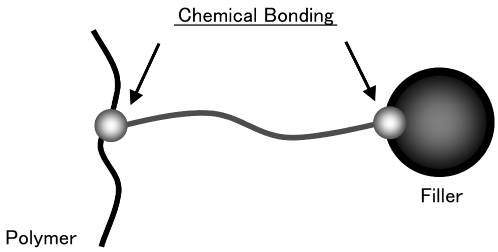

Fig. 4. Reinforcing the filler interface

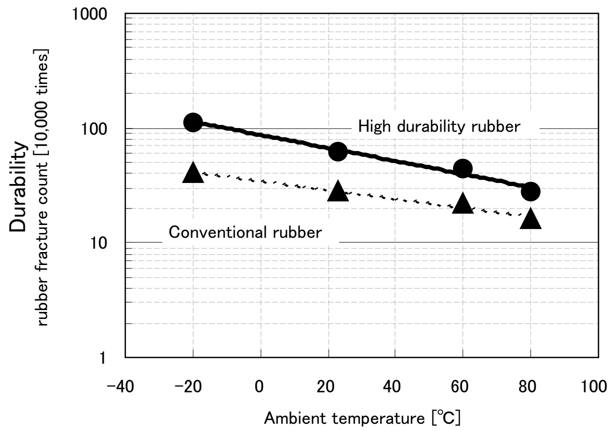

Fig. 6. Durability of high durability rubber at each ambient temperature

possible to control the occurrence of cracks and significantly improve the durability.

3-2 Durability properties of high durability rubber

Anti-vibration rubber for vehicles is used in various environments and the input distortion is different for each part. However, there are cases in which rubber is used under a high distortion input of approximately 200% as a localized rubber displacement. As shown in **Fig. 5**, the high durability rubber developed this time has over twice the durability of conventional rubber, even under these types of high distortion input conditions. Therefore, we are able to support almost all anti-vibration rubber products used on general vehicles.

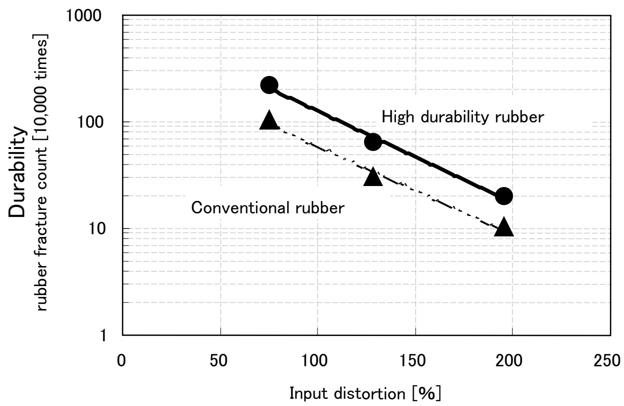

Fig. 5. Durability input distortion dependence

Also, depending on the region where the vehicle is used and where the anti-vibration rubber is attached, the rubber could be used in an environments ranging from low temperatures of below freezing to extremely high temperatures. Since rubber is an organic material, its characteristics change based on environmental temperatures. Therefore, we must develop target properties for all temperature regions where vehicles could be actually used.

In temperature zones assumed for vehicles, the high durability rubber possesses a superior durability over any other conventional rubber (**Fig. 6**).

Furthermore, there are also cases in which anti-vibration rubber used around the engine and the exhaust system is exposed to high temperatures and a hot environment over a long period of time. In particular, the recent trend of supporting regions of intense heat and temperature environments in which anti-vibration rubber is used inside vehicles has led to more strenuous requirements. For these types of parts that require a high resistance to heat, there is a demand for durability performance following thermal deterioration under fixed conditions, in addition to normal temperature durability at the initial stage. When rubber is exposed to a hot environment, there is an advance in complex deterioration phenomena, such as re-cross linking of rubber due to oxidative degradation, molecular scission of polymers and cross-linked points, and the residue from cross-linking agents and radicals that occur due to molecular scission, also lowers the durability of the rubber. Therefore, by selecting materials that are resistant to heat and incorporating combination techniques that control the deterioration of polymers and cross-linked chains, as shown in **Fig. 7**, we have succeeded in developing a heat-resistant high durability rubber that has superior durability,

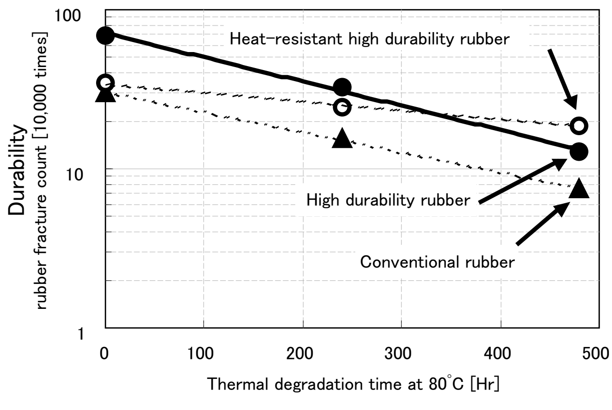

Fig. 7. Durability of high durability rubber after thermal degradation

particularly after thermal degradation. By using this rubber, it is now possible to develop products for parts of the vehicle that require high heat resistance, and improve the durability of many more parts.

3-3 Durability evaluation by product shape

Using the high durability rubber that we developed, we performed a durability test using the rubber bush shape, as shown in **Fig. 8**. The test was performed under the three conditions of conventional rubber + normal shape, high durability rubber + normal shape, high durability rubber + approximately 30% reduced size shape. The durability test results are shown in **Fig. 9**. We confirmed that using the high durability rubber with the same shape, produced an improvement of over double the durability for the product shape. Furthermore, by using the high durability rubber and a shape with a size reduced by approximately 30%, we obtained the same durability as a normal shape that uses conventional rubber. Thus, while maintaining durability performance, we confirmed that it was possible to decrease the size and weight of a part using our new rubber.

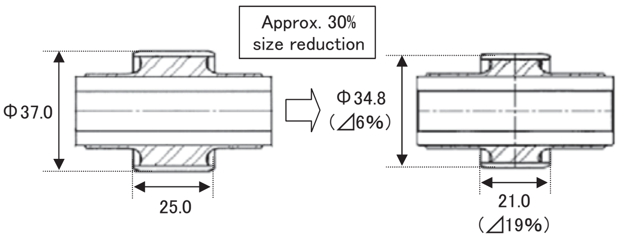

Fig. 8. Product shape used in the durability test

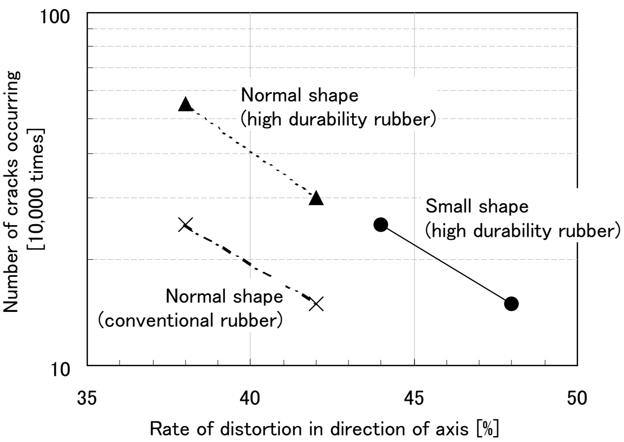

Fig. 9. Product durability test

4. Conclusion

By developing a material that has twice the durability performance as conventional materials from Sumitomo Riko, we were able to reduce the size and weight of the product while maintaining the durability performance. Furthermore, using this material will not only allow products to be smaller and lighter, but also allow products to be developed for regions where the input distortion on rubber parts is severe and it has not been possible to use such products. It will also allow the adoption of products for harsh regions where input conditions are extreme, such as unsurfaced roads. This will allow the range of new product designs to increase.

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