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High-damping Alloy M2052

Examples of application in various field

CONFIDENTIAL

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Summary

・High performance not found in the previous generation of dumping alloys

This alloy is a Mn-based alloy consisting of Mn73, Cu20, Ni5 and Fe2 (atom %). Twinning activity (appearance, disappearance, moving) in alloys occurs, when receiving a vibration load. But this material is expected to produce high-damping performance by a unique activity that has not been seen in previous alloys.

In spite of the fact that is a metal, it has **the highest value of a loss coefficient similar to that of rubber** (**Figure 1**). Compered to rubber, the elastic module is an order of magnitude higher (**Table 2**), and it has **strength of mild steel** and does not have wobbling of soft materials like rubber. Although light-metal-alloy and lead have cheap strength, this alloy can also **serve as a structural materia**l and should be a useful alloy in this age of light, thin and short.

・Excellent molding processability allows products to be made in any shape.

The shape and size are arbitrary because of the extremely high formability. This is one of the features that has not been found in any other alloy until now. Moreover, it is also easy to weld, braze and solder, and can be joined to different metals (e.g. 18-8 stainless steel), and precision casting is also possible. Thin plate, foil and ultrafine wire are available (**Figure 14,15**). It has reported that damping was achieved by **attaching** foils as small as 0.1 mm can be cut with scissors into small pieces to device and equipment (**Figure 36,37**).

・High damping properties spanning from 0.01Hz to ultrasonic

It exhibits high damping performance over a wide frequency range from 0.01 Hz to 8 MHz in the ultrasonic range (**Figure 8,10**). In the ultrasonic range, the damping is said to be as good as rubber. Rubber absorbs high frequency efficiently, but cannot eliminate low frequency. This alloy not only has a high ability to remove high frequencies, but with a little ingenuity, it can also **remove low frequencies that rubber cannot**. The low frequency with large amplitude cause twinning activity to be suppressed and damping performance to be degraded because it tends to lead the alloy to plastic deformation, which leads to lattice defects and distortion. As a countermeasure, designing structure so that it can transform stresses applied to the parts into "bent, twist and shear" and it can receive the vibration within the elastic range, the damping performance will not be compromised. (**Figure 17-21**).

・High damping performance and high ductility at very low temperatures

Even in the extremely cold conditions of **helium temperature**, the damping performance is sufficient. Moreover, it is **highly ductile** and does not exhibit low-temperature brittleness (**Figure 9**). Both lead and polymers lose their damping properties and become more embrittled at lower temperatures, but this alloy is different.

・Easy to apply to precision instruments as it is not ferromagnetic

Since it is either paramagnetic or antiferromagnetic, it is advantageous for applications in a strong magnetic field environment.

・Easy to use

The higher the stress (i.e., the greater the amplitude), the higher the damping performance, if the use does not exceed the elastic deformation (**Figure 9,10**). This shows that it is easy to use. In ferromagnetic damping alloys, the effective amplitude of vibration absorption is limited to a narrow range and therefore requires strong constraints on implementation conditions. However, this alloy can bring out the damping effect even just by **laid or pinched on the parts.** In addition, a state with even higher damping performance can be seen under conditions where a certain amount of load is applied. Because it is so easy to use, **the evaluation of the damping effect can be immediately verified**. The reason why the spillover of this alloy was from the acoustic world is that they were able to immediately distinguish between good and bad effects using only good hearing, without the use of logic or expensive measuring equipment.

・Some practical examples

Initially, it was popularized in the acoustic field. First, the insulator of the speaker, and then it is well receiver as a fastener of washers, screws, etc (**Figure 23-37**). Some of the high-end models of major home appliance manufacturers use these fasteners in abundance. There is also an example of improvement in noise and performance by simply putting two washers in the installation point of a hard disk (**Figure 52,53**). Nowadays, it has spread to all industries and is used for various ideas in the field of machine tools and precision equipment. By sandwiching a thin sheet of this alloy in the tool, it is possible to achieve "eliminate chatter" (**Figure 41**) and "a super-finishing of the Hale cutting and polishing surface" (**Figure 38-40**). Several car manufacturers are also considering using this alloy. Nissan's Cima already use it as a ring for countermeasures against noise when injectors are seated (**Figure 54,55**). It is planned to be used in the various form of motorcycles, model airplanes, and helicopters for chemical spraying, etc.

An example was reported in which the resonance frequency of 25 Hz was significantly reduced by **laying an M2052 alloy mount** as the result of study that the effect of the material of the mount installed on a surface grinder in order to eliminate the resonance on the low-frequency side of the machine (**Figure 43, 44**). This is proof that we were able to remove the low frequency by reducing the spring constant. It is also excellent results were obtained when the alternative use of rubber was tested by bending a 1mm thick sheet of M2052 alloy into a U shape so that large displacements could be obtained (**Figure 64,65**).

In the national project TAMA300 (Gravity Wave Detection Project Preliminary Test), it is necessary to measure the laser beam under the conditions of ultra-high vacuum and extremely low temperature, and rubber, polymer and cast iron cannot be used because the material must have high damping performance at low temperatures and gas release from material is extremely hated. Therefore, this alloy has attracted attention and has been reported in detail (**Figure 56-62**).

As in the case of the application to CD mechanism, the simplification of the structure itself by using this alloy and the improvement of the damping performance (**Figure 26**) can only be seen in the **creation of a new product**. In addition to improved performance, it is possible to reduce processes and reduce the weight and size of products.

These two examples suggest that fresh applications and products are possible if the characteristics of this alloy are used well.

・Problems and issues

The production system for this alloy is not yet mass-produced, so the high cost is a concern. If mass-produced, it is expected to be as good as stainless steel.

Since the principal component, Mn, is an active element, surface coating is required in some cases. FA coatings and nickel plating are already in use. Other **plating products** such as black dye, copper, gold and silver are already on the market.

・Creation of products with new proposals

A noteworthy recent achievement is the recognition of **a breakthrough effect in preventing bolt and nut loosening.** Evaluation and comparison of the anti-loosening effects of S45C, Fe-Mn-Cr and M2052 alloy showed that the bolt and nut of the iron-based damping alloy was the best, while the anti-loosening effect of M2052 alloy was confirmed to be close to that of the iron-based damping alloy by using **only one washer with a thickness of 1 mm** instead of a bolt and nut (Fig.63, Table 4). This is groundbreaking data from a maintenance and safety perspective. We can be sure that this application will expand.

Rather than simply replacing conventional damping materials, this completely unique damping alloy can be **used creatively from a new perspective**.

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1 Current status and problems of damping alloys

1.1 Current status of damping alloys

With the advanced development of science and technology, the problem of vibration has emerged more rapidly than ever before. We have entered an era in which not only noise but also nanometer amplitude noise is a problem in the precision equipment sector. As a countermeasure against this problem, the rigid structure of the equipment that can be the source and the shielding of the source itself have a certain reduction effect by the design considerations, but these are limited in their own right, and the use of damping materials is essential. Traditionally, rubber, lead, resin, and cast iron have been widely used for vibration absorption, but now the much-needed material is a damping alloy that functions as a structural member.

Polymers such as rubber and gel absorb vibration well and generally have better damping performance than alloys. However, their strength is orders of magnitude lower than that of alloys, so they cannot be used alone as a structural member, and polymeric materials are only an adjunct in terms of damping measures [1]. If possible, a damping material that doubles as a structure is required. It's inevitable in this age of pursuing the light, thin, short and small. In response, further development of damping alloys is required. Several damping alloys have been reported to have been developed so far. Recent representative damping alloys are shown in Table 1. In terms of damping mechanisms, they are classified into four categories, and damping alloys with excellent characteristics have been developed for each of them, and recently products with composite technologies such as damping steel plates[1)] have been marketed. Sonostone, as it has been known for a long time, is still going strong on military ships, but other damping alloys are not as widespread as one might think[2)]. This is because many damping alloys have too many limitations in terms of application other than damping performance.

Due to the differences in vibration-absorbing mechanisms and material composition (bonded or integrated), it is difficult to compare and evaluate vibration-absorbing performance, so there is no unified method at this point. Figure 1 shows the contrast between the damping performance and the strength of a typical metal material limited to an integral type.

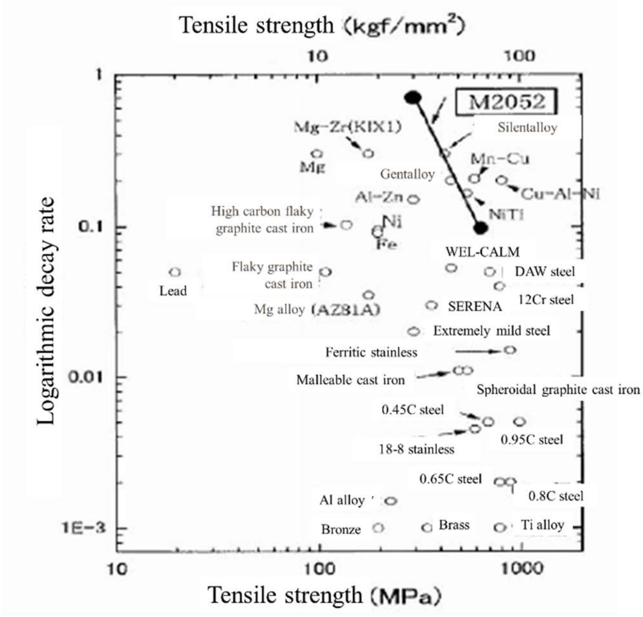

Figure 1 Damping performance and strength of major damping alloys

Familiar materials such as brass, carbon steel, stainless steel, aluminum alloys, and titanium alloys are clustered at the bottom of the figure and do not have much damping properties. Lead and cast iron, which are known to absorb vibrations, belong to damping materials, but their logarithmic damping rate is only 0.05, which is not very high. The alloy indicates the damping performance on the line connecting the two points in the black circle[3)], usually 0.3. The logarithmic decay rate of 0.72 is obtained if the conditions such as grain size adjustment, removal of contamination from raw material and furnace wall, and appropriate process control are met, and this value is 0.23, which is close to that of rubber. Even in the normal manufacturing process, the logarithmic decay rate of 0.2 to 0.4 (0.3 on average) is maintained, and even at these values, the performance is high in the figure. Recently, alloys with less damping performance and more economic efficiency have been attracting attention. The Serena and WEL-CALM are just some of them, so there's a lot of room for application options. But there are problems with them too.

[1)] This is not strictly a damping alloy, but a means of damping that consists of a metal plate and resin.

[2)]There are many examples of discontinuation of production.

[3)]It consists of Mn73, Cu20, Ni5, and Fe2 in atomic percentages, and is called M2052 with M of manganese followed by a value of 20, 5, and 2, which is the percentage of each remaining component element.

Table 1 Typical damping alloys

Category	Alloy-type	Practical alloy	Remarks.
Composite-type	Fe-C-Si	Flaky graphite cast iron	FC15,FC20,FC25 (General structural materials)
	Al-Zn	Cosmal-Z	Die casting alloy
Ferromagnetic-type	Ni	TD Nickel	Heat resistant alloy
	Fe-Cr	13% Chrome steel	
	Fe-Cr	Fe-8Al	Osaka Industrial Test Center
	Fe-Cr-Al	Silentalloy (Fe-12Cr-3Al)	TOSHIBA
	Fe-Cr-Al-Mn	Trankalloy (Fe-12Cr-1.36Al-0.59Mn)	NKK
	Fe-Al-Si	SERENA(Fe-2.4Al-0.54Si)	NKK
	Fe-Cr-Si-Al	WEL-CALM (Fe-3Cr-2Si-2Al)	NIPPON STEEL CORPORATION
	Fe-Cr-Mo	Gentalloy (Fe-12Cr-2Al-3Mo)	Research Institute for Electromagnetic Materials
	Co-Ni	NIVCO10 (Co-22Ni-2Ti-1Zr)	Westinghouse Corp.
Dislocation-type	Mg, Mg-Zr	K1X1 alloy (Mg-0.6Zr)	Dow Chemical Corp.
	Mg		
	Mg_2Ni		
	Mg-Cu-Mn	MCM (Mg-4Cu-2Mn)	Tokyo University of Science (Die casting alloy)
	Fe-Ni-Mn	DAW steel (Fe-15Mn-5Ni)	Hosei University, Mitsui Engineering & Shipbuilding
	Fe-Mn-Cr	Fe-22Mn-12Cr	Tokyo University of Science , Nagoya University
Twinning-type	Mn-Cu	Sonostone (Mn-37Cu-4.25Al-3Fe-1.5Ni)	Manganese Marine corp.
	Cu-Mn-Al	Incramute I (Cu-40Mn-2Al)	INCRA
	Cu-Mn-Al-Sn	Incramute II (Cu-40Mn-2Al-2Sn)	INCRA
	Cu-Al-Ni	(Cu-14Al-4Ni)	
	Cu-Zn-Al	Broteus (Cu-26Zn-5Al)	
	Ni-Ti	Nitinol	United States of America
	Mn-Cu-Ni-Fe	M2052 alloy (Mn-20Cu-5Ni-2Fe)	National Research Institute for Metals

1.2 Problems with conventional damping alloy

Cast iron has long been known as a structural member with damping properties, and it is still used today as the base and foundation of machine tools. However, cast iron contains a large amount of carbon, and the embrittlement problem caused by the notch effect cannot be ignored. Even though cutting is easy, molding is extremely difficult. Magnesium alloys are lightweight and are an attractive material. But in reality, the strength is low and molding is not possible. Aluminum bronze and Nitinol also have workability problems and are not commonly used as damping alloys. Mn-Cu alloys such as Sonostone and Inclamute have been known for a long time and are finding a way to be used for large parts, mainly as castings.

Ferromagnetic alloys represented by Silentalloy show high performance (maximum 0.3), but the fatal drawback common to this type cannot be dispelled. In other words, the range of effective amplitude (effective strain) in which damping performance appears is narrow, and if the amplitude is outside this range, the damping effect is significantly reduced, and the material can no longer be called a damping material. External vibration signals can only be accepted within a limited tolerance range, which causes disadvantages and complicates the design and hampers the application.

Iron-based damping alloys belonging to the dislocation type are originally high in strength.

Therefore, vibration absorption does not work unless high stresses are applied, severely limiting its application. In other words, the damping performance of wheels, gears, rails, etc., is not common because it is only under high load that the damping performance appears. And the damping performance is not so high.

Composite materials, such as damping steel sheets, have problems related to their structure, and weldability and formability cannot be expected. In addition, it is not suitable for structures that can support high loads, so it cannot be used to make complex shapes, large products, precision parts, or dense products, and is mainly used as a plate. It is suitable for lightly molded lids and containers, but has limited application in other fields. Besides, the peeling during operation is also troublesome. However, it is worth noting that it is inexpensive.

M2052 alloy can also be precision cast, making it ideal for products with complex structures. Moreover, since the amplitude dependence is linear and the damping performance is proportional to the amplitude, it can be used at high amplitudes as long as it is within the limit where plastic deformation does not occur. There is no difficulty in using it because its damping performance is flat, unlike alloys that show steep peaks in response to stress.

2 Novelty of the alloy M2052

At first, the M2052 has gained a reputation among acoustics enthusiasts, but it has recently made its way into precision instruments, machine tools, automotive, marine and space technology. The reason for this is related to the following characteristics.[4)]

1. The damping characteristics correspond to a wide range of stresses, frequencies and temperatures. In the elastic region, the higher the amplitude, the higher the damping performance. The frequency can absorb vibration over a range of < 0.01Hz to 5MHz. The operating temperature ranges from 4.2K to 200C.
2. The strength is about mild steel, and it functions as a structural member.
3. It has excellent moldability and can be supplied as foil, sheet, thin wire or wire in any shape and size. Normal sized planks and bars are no problem to provide.
4. Cutting, drilling and rolling are the same as stainless steel.
5. Casting is also possible, which is effective for mass production of precision products with complex shapes.
6. Welding (between different types of TIG, laser, electron beam, and 18-8 stainless steel), brazing is easy, and paintability is good.
7. Hard and soft plating such as copper, nickel, gold, and black staining is possible, and FA treatment is also available.
8. A stable supply of logarithmic damping rate of 0.3 is obtained, and under optimum conditions, 0.72 is obtained.
9. Damping properties are maintained even at helium liquefaction temperatures, and ductility is not lost.
10. The design of the shape that reduces the spring constant creates a function that absorbs low-frequency and high-amplitude vibrations in addition to shock relaxation.

Until now, there had been no alloy with such a multifaceted combination of features and comprehensive strength.

In this paper, we would like to introduce some practical examples[5)] that have been published so far and use them as a reference to create new objects and breakthroughs of problems.

[4)] The description of the M2052 alloy is already partly described in a separate journal.

[5)] There are many examples that cannot yet be disclosed due to the conclusion of a duty of care agreement.

3 Outline of the alloy M2052

3.1 Vibration absorption mechanism of alloy M2052

The vibration absorption mechanism is described in more detail in the rest of this article.Four damping mechanisms have been discussed in alloys, and M2052 alloy belongs to the twinned type. According to optical microscopy, twins are often observed as banded structures as shown in Figure 2. It is called so because of the contrasting crystal structures that are found at the interface between the mother phase and the band as if they were twins. (Figure 3 (6))

Figure 3 illustrates the mechanism of how the twinning absorbs external vibrations. As shown in (1), the crystal deforms elastically when an external force is applied to it, leading to (2). When the external force is further increased, it is not able to resist it and twinning occurs as shown in (3). Any further loading will result in the growth and widening of twins or the formation of new twins at other locations, as in (4) and (5). Except for external forces, the twinning will shrink or disappear. It is thought that the external force is received by such a twinning motion, where energy is consumed and the vibration is reduced.

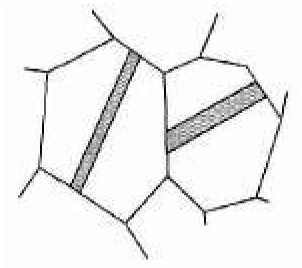

Figure 2 Simplified diagram of twinned tissue

Optical and electron microscopic observations show that twins of various sizes are formed or exist depending on the manufacturing process, ranging from very small twins of only a few tens of nanometers to several centimeters in length in unidirectional solidified specimens.

An example of an electron micrograph of this alloy is shown in Figure 4. Circumstances in which the twinning is parallel or orthogonal are seen. Compared to ordinary alloy twinning, the size is much smaller, the quality of the twinning is different, and it has the following characteristics

- Twinning is easily generated by external forces.
- The interface between the generated and existing twinning is easily displaced by the external force, and the twinning is reduced or lost by the removal of the

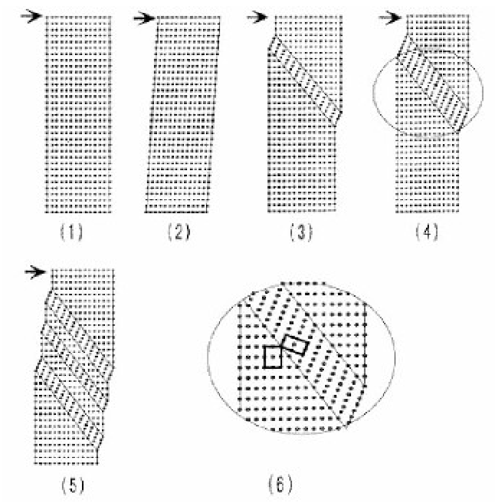

Figure 3 Twinning under an electron microscope

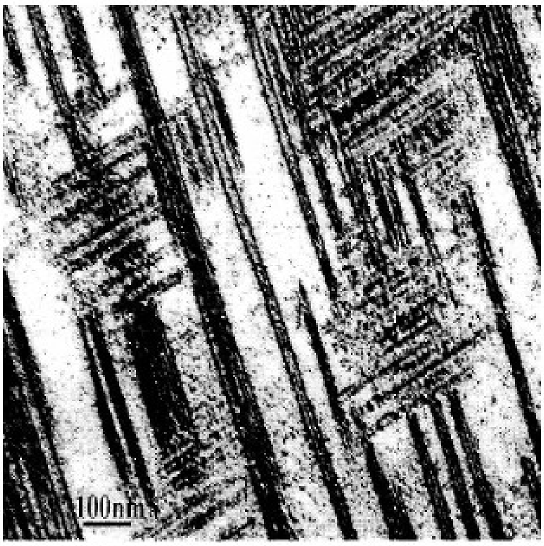

Figure 4 Twinning activity due to external force

external force, and the shape is restored to its initial state.

Many twins of different sizes, depending on the size of the external force, and the small twinning contributes to the damping of small amplitude high frequency oscillations and the large twinning contributes to the damping of large amplitude low frequency oscillations. Thus, the removal of small vibrations of amplitude is easy, but large amplitudes require a touch of ingenuity, as will be mentioned in the next issue.

4 Main properties of the alloy M2052

4.1 Mechanical properties and workability

This alloy can be easily formed and machined, and there are no problems with lathing, drilling, hot or cold working. We can supply not only thick and thin sheets, but also fine wires and foils in micron units. In fact, fine wire of 0.1 mm diameter and foil of 0.05 mm are available. The bellows are

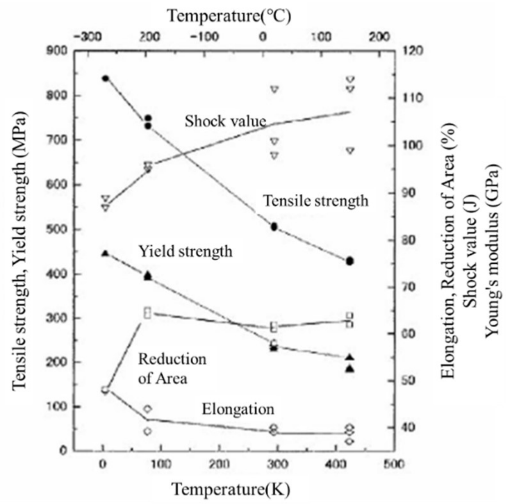

Figure 5 The main mechanical properties of M2052

made from such thin sheets by hydraulic or welding methods, and the effect has been measured.

The hardness depends on the process history, and after annealing, the hardness of Hv100 to 130
range. Since the work hardening ratio is small, it is possible to cold-roll a sheet 50 mm wide from 5mm to 0.5mm without intermediate annealing. In line drawing, the work hardening is small, and the concave phenomenon tends to occur, so intermediate annealing is essential to avoid it. The machinability in cutting and drilling is close to that of austenitic stainless steels and belongs to the category of softened alloys, but there are no difficulties in cutting as long as you understand the compatibility with the tool and the proper cooling conditions.

Figure 5 shows the performance of the mechanical tests from helium liquefaction temperature to 150°C. The tensile strength at room temperature is about that of mild steel. The strength increases at lower temperatures, and the ductility decreases, as in the case of general alloys.

What is noteworthy is the cryogenic properties. In other words, the alloy is sufficiently ductile even at the helium liquefaction temperature, and only dimples are observed on the fracture surface, explaining the high toughness of the alloy. Moreover, the damping performance is maintained even at such a temperature. These features are expected to be applied in the cryogenic field. Most of the ordinary materials, not to mention rubber, lead and resin, reduce or lose most of their vibration-absorbing capacity below -70°C, and even lead makes a metallic sound when tapped. In contrast, this alloy exhibits an exceptional behavior, and even when exposed to extremely low temperatures, the sound of striking is similar to that of a piece of wood.

Since the damping performance is dominated by the motion of the twinning, it is necessary to avoid factors that interfere with the motion as much as possible. Machining operations and rapid cooling operations from annealing temperature often cause distortion of the alloy, and the damping performance is extremely low as it is. However, if the product is annealed again at around 900°C after processing and then treated with slow-cooling from that temperature, the damping performance is almost restored, no matter how severe the processing is.

Since the grain size can be adjusted to some extent by the combination of processing and heat treatment, the correlation between damping performance and strength can be established. For the tensile strength of 600 MPa and 200 MPa, the logarithmic damping rates were 0.1 and 0.7, respectively, as shown in Figure 1. If a damping ratio of 0.1 is selected, it can be applied as a strong damping structural member, and even if the damping ratio is 0.3, it is sufficiently qualified as a structural member.

The residual strain and the presence of precipitates and dispersed particles will eventually reduce the grain size and shorten the kinetic distance of the twins, leading to a reduction in the vibration absorption performance. Therefore, in order to demand the highest possible vibration damping performance, attention to detail is essential and the manufacturing process is difficult. In fact, in many cases, strength is the main factor rather than performance. In the normal process, a logarithmic decay rate of 0.2 to 0.4 can be obtained, and even this value can be said to be revolutionary.

4.2 Temperature dependence

The temperature dependence of damping performance varies greatly between alloy types. Ferromagnetic types maintain their performance up to relatively high temperatures, while damping steel sheets are determined by the flow temperature of the resin. The twinning is dominated by the temperature at which the martensitic transformation takes place, so it cannot be handled as a high-temperature type, and 200°C is considered to be the limit.

Figure 6[6)] shows the temperature dependence of the three alloys in which the basic composition is not so different from that of M2052, but the amount of each alloy element is slightly changed to shift the transition temperature to the high temperature side. Alloy A is an alloy with a standard

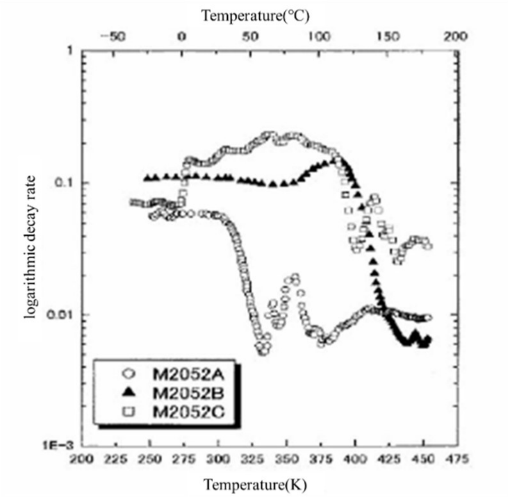

Figure 6 Change in transition temperature due to the shift in alloy composition

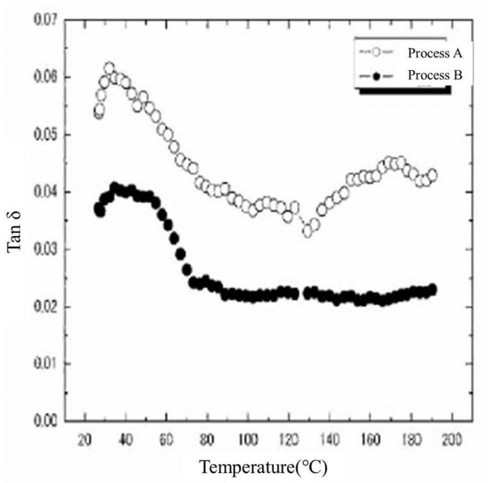

Figure 7 Performance change by process

composition. The so-called transition temperature, in which the damping performance suddenly deteriorates, is around 50 °C. In the case of alloy B, the transition temperature rises and there is no degradation up to about 120 °C. Alloy C retains its damping properties up to about 150°C. In addition, even when the composition is kept constant, a high temperature type up to nearly 180°C can be obtained depending on the combination of the process and heat treatment. Figure 7 shows an example of the effect on damping performance that appears when different processes are used for the same lot of test specimens. The performance of Process B was in accordance with the existing process, while Process A showed that the high temperature performance was improved by the combination of the processing rate and annealing. around 180 °C, and the Tan

6) This data shows a low damping performance due to experimental reasons, but the value increases if the standard treatment is followed.

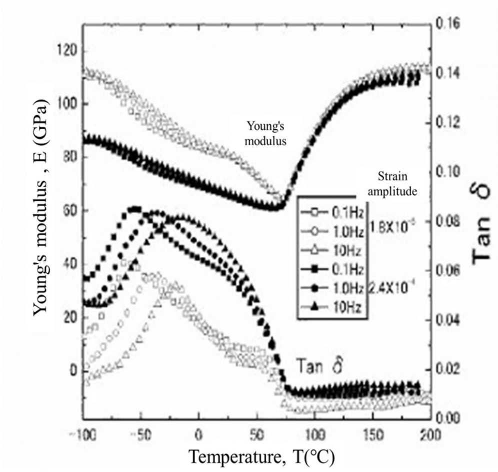

Figure 8 Vibration control at very low frequencies

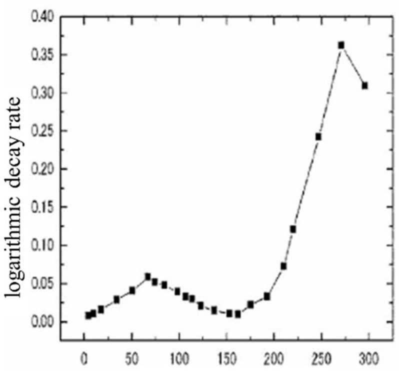

Figure 9 Damping in the vicinity of 4.2K

δ value of 0.045 was secured, exceeding the normal 0.02[7]. It is possible to achieve the desired high temperature performance by simply adjusting the process without shifting the basic composition of the M2052 alloy. By shifting the composition and combining the heat treatment and the process, we can be sure that the temperature up to 200°C can be achieved.

This alloy has a unique damping property at low temperatures. Figure 8 shows a standard composition M2052 alloy with a mountain near -50°C and a wide hem. The ease of use lies in the fact that the top of the mountain is not a steep peak. The measured frequencies range from 0.1 to 10 Hz, but the greater the distortion amplitude, the higher the damping performance. According to the measurement from 300K to 4.2K, as shown in Fig. 9, as the temperature gradually decreases from the peak at 230K, the damping property decreases, and at 150K, it significantly decreases, and then rises again, and at 70K, a small, though still small, peak appears again. The existence of such a damping property near the extreme temperature is important and can be expected, and research is underway to apply it to vibration control under the extreme environment.

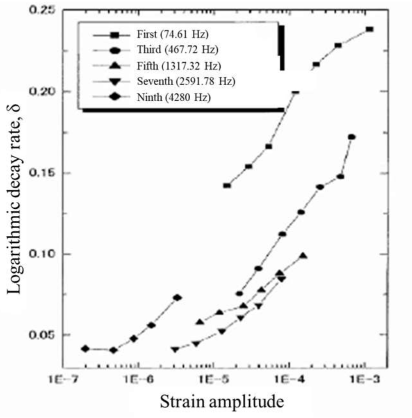

Figure 10 Example of amplitude and frequency dependence of M2052

4.3 Frequency and Amplitude Dependence

Attenuation of this alloy has been found to occur over a wide area from < 0.01 Hz at low frequencies to MHz at ultrasonic frequencies.

Figure 10 shows the results of measurements based on the frequency sweep method in the 75 Hz to 4.3 kHz range. The attenuation rate increases in proportion to the amplitude, whereas it is inversely proportional to the frequency. The ninth-order resonant frequency, 4.3 kHz, has the lowest attenuation, and this data may lead one to believe that the alloy is incompetent for high-frequency and low-amplitude vibrations. However, practical examples in the acoustic world prove that such vibrations can be eliminated without a doubt. In addition, a logarithmic attenuation rate of more than 0.7 was obtained in the ultrasonic frequency range of 3 to 5 MHz[8], which was comparable to that of rubber. Therefore, the data shown in Fig. 10, where the damping performance decreases as the amplitude decreases, is not necessarily correct. There may be a problem lurking in the measurement method. The details of the damping performance at each frequency are not yet clear due to the complexity and variety of factors involved in the damping performance of this alloy.

[7] Even at this value, the function of the damping alloy is still maintained.

[8] In this case, the frequency is much higher and the amplitude is very small.

4.4 Other properties

The main property values are shown in Table 2.

Table 2 Major Physical and Mechanical Properties of the Alloy M2052

Category	Condition	Data
Allowable stress	Tensile stress Compression	540 MPa
Longitudinal elasticity	Three-point bending Compression Tensile Ultrasonic	67.7GPa 35.1GPa 47.8GPa 104GPa
Transverse elasticity [a]	Ultrasonic Tensile	17.8GPa 46GPa
Poisson's ratio	Tensile	0.338
Elastic limit	Tensile	300MPa
Yield stress (0.2%)	Tensile	205MPa
Fatigue stress (bending)	Stress Strain, μ	160MPa 5×10^5
Hardness	Hv	100~130
Linear expansion coefficient [b]	300K	22.4×10^{-6}/deg
Specific heat [c]	300K	512.7J/Kg・K
Thermal conductivity [d]	300K	10W/m・K
Magnetism		Para magnetism /anti ferromagnetism
Density [e]		7.25gr/cm^3
Speed of sound in the solid	Longitudinal wave Transverse wave	7000m/s 4310m/s

[a]: Calculated from Poisson's ratio
[b]: Equivalent to Al, Mg, Pb and Sn
[c]: Equivalent to Fe, Ni and Ti, [d]: Equivalent to Bi, Sb and Ti
[e]: Equivalent to Cr, Fe, In, Sn and Zn

Magnetism is paramagnetic around room temperature or above, and antiferromagnetic below the temperature at which the twinning appears. Therefore, it is likely to be of high value for precision instruments that do not like magnetism.

The Young's modulus is sensitive to composition. This is because the composition causes the transformation point to fluctuate. Because the transformation point has a wide range, even if the composition is constant, it is not always determined by the temperature at which it is used. This can be easily understood from Figure 8. The minimum value of the Young's modulus is 70°C, but the value changes at other temperatures. There is a tendency to increase with low temperature and converge to a constant value. The figure shows 70 GPa at room temperature, but it ranges from 30 to 70 GPa depending on the composition, process and heat treatment. Broadly speaking, they are close to or exceed aluminum, silver, etc.

Its thermal conductivity and specific heat are close to that of titanium, which is one of the hardest metals for heat transfer. The thermal expansion can be considered to be the same as that of aluminum. The specific gravity is close to Fe, with a value of 7.25. (Continued)

5 The problem of vibration transfer rate and high damping ratio

The magnitude of the transmission of vibrations from the source to adjacent sites is expressed by the following equation, as is well known in vibration theory.

$$T_R = \frac{\sqrt{1 + \left(2\varsigma(\omega/\omega_n)\right)^2}}{\sqrt{(1-(\omega/\omega_n)^2)^2 + \left(2\varsigma(\omega/\omega_n)\right)^2}} \quad (1)$$

T_R is the transmission coefficient, ς is the damping ratio, ω is the forced angular frequency, ω_n is the specific frequency. A mechanism or material with a damping function at the boundary of the transmission path, such as a coil spring, dashpot, or rubber, is intervened to adjust ς. Fig. 11 shows the relationship between T_R and ω/ω_n when some of values of ς are given.

What we're about to find out from this is

1. the vibrational insulation effect appears in $\sqrt{2} > \omega/\omega_n$. Therefore, the smaller the specific frequency ω_n is, the greater the effect.
2. In the region $\sqrt{2} > \omega/\omega_n$, the vibration insulation tends to deteriorate as the damping ratio increases. From the damping side, the effect is diminished when $\sqrt{2} > \omega/\omega_n$ along with a larger damping ratio. Therefore, as a compromise, it is usually designed to be about $0.1 < \varsigma < 0.15$.

After all, in the range of $\sqrt{2} > \omega/\omega_n$, it is sufficient to remove the damper by reducing the spring constant of the vibration insulator as much as possible, but the machine becomes unstable as the spring constant becomes smaller. This paradox is due to the fact that the coil spring itself has little damping capacity. If the coil has damping ability, the situation would be completely different.

M2052 coils can have a much lower spring constant than ordinary steel coils, but they can also be used not in the form of coils but in the form of high spring constants, such as in the form of mounts, so the above-mentioned paradox can be overcome if vibration isolation is achieved with such mounts. In other words, it is possible to create a vibration isolator that is stronger and more damp than the coil type, and that

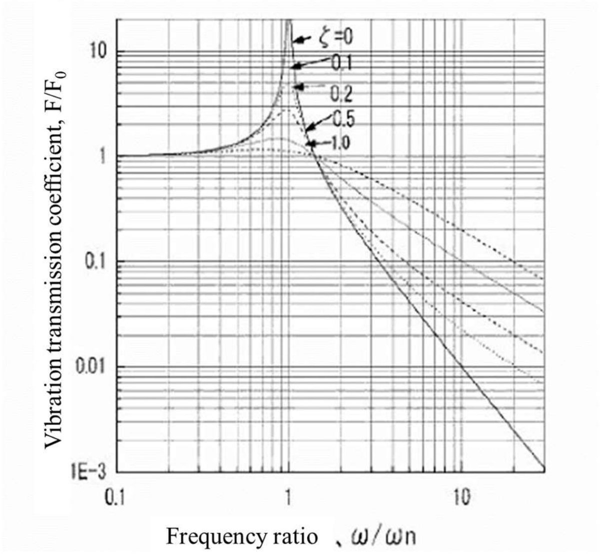

Figure 11 **Transmission rate via spring and dashpot**

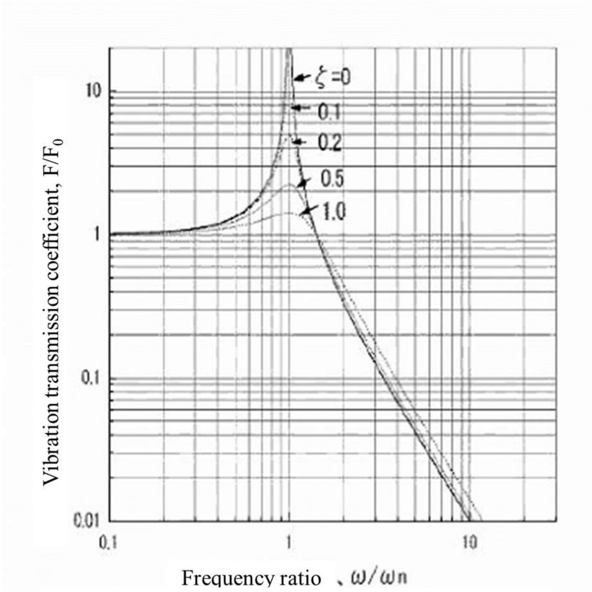

Figure 12 Transmission rate through rubber

has both stable support and high vibration insulation..

In the case of rubber, unlike the case of metal springs and dash pots, the following equation is considered reasonable using the loss factor η.

$$T_r = \sqrt{\frac{1+\eta^2}{(1-(\omega/\omega_n)^2)^2+\eta^2}} \qquad (2)$$

According to this, the transmission disadvantage that occurs at high K sites does not arise as the damping ratio increases. When anti-vibration rubber is used, as shown in Figure 12, even in the range of $\sqrt{2} > \omega/\omega_n$, there is no worsening of the vibration isolation effect that appears with a larger loss coefficient. Because of this, anti-vibration rubber is also used frequently.

M2052 alloy has the same advantages as rubber, being a metal that can use the advantages of rubber. In other words, the attribute can be functioned effectively without worrying about the size of the high attenuation capacity. The following points are the peculiarities of M2052 alloy that are superior to rubber.

1. Ordinary metal coil springs themselves have little damping property, but this alloy has a large damping value.
2. Rubber has very low strength and is susceptible to "wobbling" and "dancing".
3. The space required for installation of air springs is huge.

The M2052 alloy has overcome these problems. As shown in Table 1 below, there is a remarkable advantage when this alloy is used as a coil spring.

6 How to use the alloy M2052

This alloy can be used in the following ways. Although there are definite differences, at first glance they have many uses in common with rubber. M2052 alloy can be supplied in a wide variety of shapes, including plates and bars, pipes, wire rods, fine wires, foils, and powders, and it has good machinability, plastic formability, and castability, as well as mastery of microfabrication by etching, so it has a wide range of applications.

- Insert into the vibration path.
- Adhere to the vibration source
- Apply powder to the vibration source
- Surrounding the source of the vibration
- Connect the vibration sources.

If we make a conceptual diagram, we can see Figure 13. (A) pinch or insert, (B) support, (C) tie, (D) paste, (E) gather, (F) enclose. As will be discussed below, these are proven to be effective in real-world cases.

6.1 Can be used in any shape from a variety of materials

Because of the ease of forming, it is possible to obtain a material of a variety of shapes and products as one pleases. Examples of actual materials are shown in Figures 14, 15 and 16. The screws in the upper left of Figure 14 are those plated with various types of gold, copper, nickel, and black dye. Electrical components require continuity, and we are able to handle gold and copper plating. The long round bar on the left end is a special bolt with a 1mm diameter internal thread that has been applied to the parts of precision

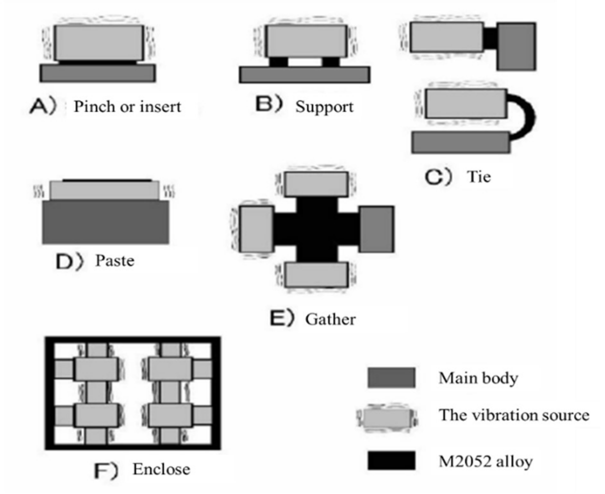

Figure 13 Typical usage examples:

instruments. The fact that plating is possible suggests that the corrosion and wear resistance of this alloy can be greatly improved, not only for screws. Although not shown, 0.1 mm foil is also produced. It can be cut into free shapes with household scissors and used as a paste or roll.

There are also speaker insulators, pedestals, and washers. There are also coil springs for tension and compression and bent plate type springs. A wire with a diameter of 0.1 mm is also shown. Figure 15 shows the pipes, which were made by cutting on the left and welding on the right. Figure 16 shows a recent hot topic in the field of acoustic products. a) is the shell of a cartridge for an analog record, b) is the spacer that goes underneath that cartridge, c) and d) are a pair, the power box tap. It has become common sense that there is a limit to the improvement of sound quality without taking measures to eliminate noise from the power supply, and this product is sold as a part of this. e) and f) are disk stabilizers. These are noise absorbing goods that can be placed on a disc. g) is a stabilizer for turntables. h) is a knob for a volume switch, which is said to be effective in isolating vibration through a shaft. i) is a stabilizer for a breaker. j) is a thick insulator. k) is a foot for a device, case or rack. Thus, in the field of acoustics, the use of this technology has been evolving rapidly.

Since the parts can be welded together, complex products can be created. It also has a track record of bellows and atypical foaming.

Figure 14 Products such as screws, washers, springs, pedestals and thin wires

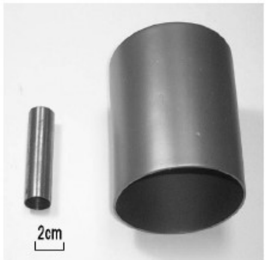

Figure 15 Pipe Products

6.2 New function by devising a shape that lowers the spring constant -Low frequency removal that is not possible with rubber

The damping performance found in this alloy is a rare damping alloy that can cover the range of absorbable frequencies from 0.01Hz or less to 10MHz. As experienced with rubber, while polymeric materials can easily remove high frequencies, their ability to remove low frequencies is small. Therefore, in the field of precision instruments, expensive anti-vibration tables and equipment are used in abundance, but the problem is that the function of anti-vibration cannot be brought out effectively because low frequencies cannot be removed. We are also struggling with this low frequency in high-voltage electron microscopy. There is also the problem of ultra-low frequency pollution emanating from transformers in substations. The M2052 alloy could be a clue to solve this traditional problem, since no material has ever absorbed low frequencies by itself.

The problem with low-frequency removal lies in how to

Figure 16 Examples of New Products in the Acoustic World

overcome the large amplitude. This can be achieved by adjusting the spring constant by devising the shape of the part to correspond to the magnitude of the amplitude. For the removal of high frequencies with small amplitudes, simply inserting this into the vibration path will be effective. Most of the applications in the acoustic world have been in this category. However, for large amplitude vibrations, even at low frequencies, the twinning should be made to move easily inside the alloy. For this purpose, it is necessary to convert the vibrational external force into bending, twisting and shear stress.

Figure 17 is a typical example of using it while remaining rigid. Low amplitude vibrations can be achieved with the simple shapes shown in the figure. a) insulators and washers, b) gasket packing rings, c) spacers for large precision perforators with a diameter of 100 mm and a thickness of 5 mm. d) is an example of a flange for a rotating body, right is an example of a flange made of steel with a plate made of M2052 pressed against one side, e) to h) are sleeves for bearings and examples of the use of a holder/inner/outer. These applications are for small amplitudes and are not difficult as long as the load is not concentrated on a point or line contact and the M2052 is not plastically deformed locally.

Figure 18 shows an example of a mount on the base of a device or equipment. The device absorbs unwanted vibrations by using a mount with damping properties for large shaking vibrations of the device itself. The shapes from a) to c) are capable of converting vibrations into compressive and bending loads. It absorbs the low frequency transmitted from the main body, or interferes with the low frequency vibration of the mount to reduce the low frequency. d) is a mount that is deliberately prepared to apply pre-strain of tension by the load of the main body in order to facilitate the generation of twinning. In any case, the spring constant is low in such a shape, and the frequency and amplitude of the vibrations that can be absorbed are categorically determined by the shape. Qualitatively, the lower the spring constant, the more low frequency and high amplitude can be eliminated. The low frequency around 25 Hz was significantly reduced, as in the practical example of the mount described below.

Figure 19 is an application of the coil shape. A metal coil can be used to reduce the spring constant easily and obtain high reliability. Ordinary springs are made of a high-strength alloy, and the alloy itself has little vibration-absorbing capacity, so high frequencies come and go freely through its coils, sometimes causing a surging phenomenon, and low frequencies can't be reduced much either. However, coils made of M2052 alloy are not springs, they bring a whole new function.

Table 3 contrasts the specificity of the damping coil with the structure showing the typical spring function. One of the characteristic features is that the damping performance is not lost even at near absolute temperature if the product is made of M2052 alloy, as shown in the previous article. Depending on the structure, it is possible to create the lowest natural frequency for a spring-elastic material. Comparing coils, i.e., coil springs and M2052 coils, there is a clear difference in performance. Since metal coil springs usually have small high-frequency insulation properties, the difference between stainless steel and M2052 coil springs is evident in the comparison as described below. When the two coils were vibrated at the same amplitude and the time taken to come to rest was compared, the stainless steel coil still had a significant amount of vibration after 40 seconds, but the M2052 alloy coil stopped in two seconds, one-twentieth of that time. As shown in Figure 19, it is possible to change not only the spring constant but also the natural frequency by varying the cross-sectional shape and area of the coil. Also, coils can be assembled as shown in c). d) and e) are examples of changing the spring constant according to a different shape from the coil. Because of its excellent

Table 3 Typical elastic bodies and their comparison

Category	Coil spring	Laminated plate spring	Air spring	Damping spring	M2052 coil
①Natural frequency that can be used as a normal vibration system(Hz)	1~10	1~10	0.7~3.5	4~15	<1~10
②Damping performance	×	○	Depend on usage	○	○
③High-frequency vibration insulation	D	D	A	B	A
④Settling resistance	A	A	B	B	A
⑤Preferred temperature(℃)	-40~150	-40~150	-20~80	-20~120	-270~150
⑥Oil resistance, aging resistance	A	A	B	B	A
⑦Uniformity of damping performance	A	B	B	B	A
⑧Simplicity of structure	A	B	C	A	A
⑨Requisite space	B	B	B	A	B
⑩Other properties					

(*1) A: excellent, B: good, C:passing, D: inferior, (*2) The ultrasonic absorption capacity of M2052 alloy is comparable to that of rubber.

Figure 17 Application of high frequency and low amplitude

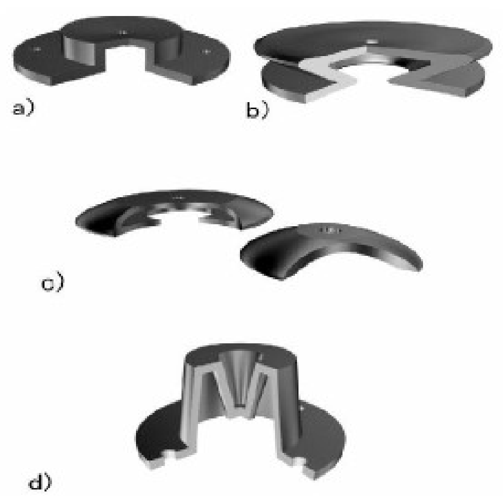

Figure 18 Application of semi-high frequency and low amplitude

molding processability, you can create works of art as you wish, depending on your ideas.

Figure 20 is an example of an application that can be achieved with a simpler structure than the previous figures. a) a board bent into a U-shaped shape, b) an elaborate shape like a chair, c) a wire or a pipe made into a circle for an o-ling-like application, and d) and e) are the use of pipes. In addition to the absorption of the passing high frequency, such a deflective use creates the possibility of eliminating the low frequency due to the interference with the spring constant depending on its structure. The results of the U-board will be described later.

Figure 21 shows a) a bellows, b) a damper wire, and c) to f) are parts that control vibration by attaching terminals with small spring constants to electronic circuits that emit high frequencies and low amplitudes. This is a resonator made by M2052.

7 Examples of applications

7.1 Audio

7.1.1 insulator

The first application in the field of acoustics was the insulator of the speaker. It was easy to verify the effect by simply placing it underneath the speaker and using an ultra-sensitive device called an ear. Figure 22 is an example of a loudspeaker used. It' s just a matter of sandwiching it between the speaker box and the base, and it worked very well. Care must be taken if the speaker is lightweight or if the installation floor is soft. The higher the weight on the

Figure19 Application of low-frequency and high-amplitude coil type

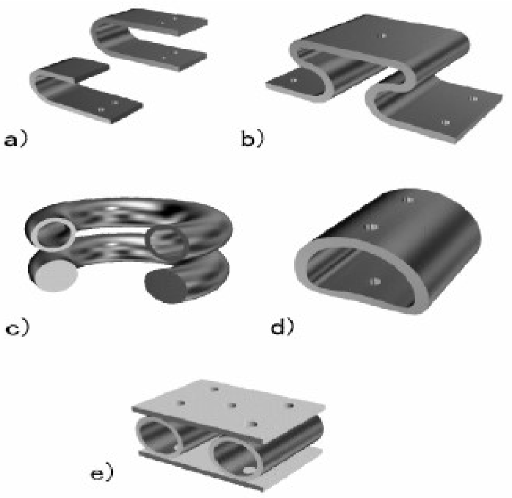

Figure 20 Application of low frequency and high amplitude

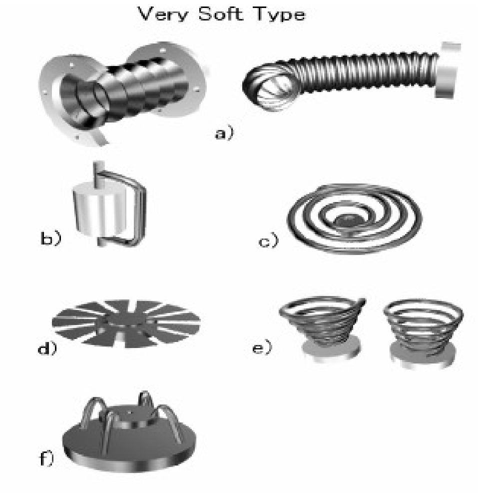

Figure 21 Application of high frequency and low amplitude to low frequency and high amplitude conversion

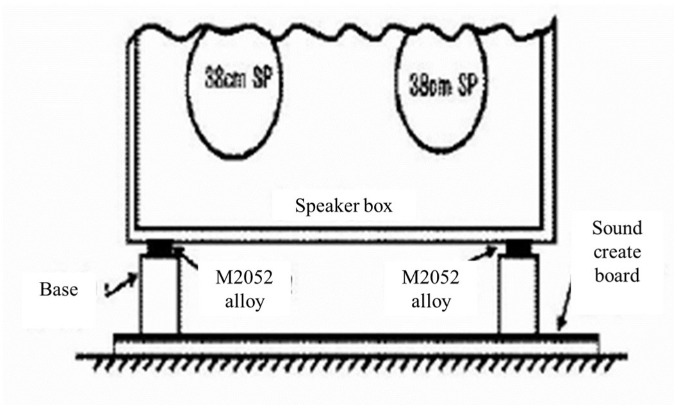

Figure 22 Insulators for Speakers

insulator, the more effective the damping effect will be, and when the floor is soft, there will be no opportunity for the twinning inside the alloy to work, so it will not have a sufficient damping effect. Since then, this type of insulator has become one of the best-selling insulators in terms of shape and thickness.

7.1.2 Vibration-absorbing screws and washers

There were no examples of damping alloys being applied to so-called fasteners for screws and washers, but the M2052 alloy did it.

The screws, bolts, nuts and washers have a reputation as absorbers and screws. It has already been adopted by some of the major audio manufacturers, contributing to the improvement of sound quality. There are experimental data on the effects of damping screws. This is shown in Figure 23. An iron plate 300 long, 40 wide, and 3 mm thick is tapped and a microphone is used to compare the two-second measurement records. On the left is a solid steel plate, and on the right is a test specimen with 4mm taps cut at five points on the plate and 4mm damping screws attached to the taps. Each waveform is a sound struck under the same conditions. Clearly, the effect of the screw can be confirmed to be decisive.

A large number of screws are used inside electrical products and equipment. When all the conventional screws were replaced with damping screws and washers, the sound quality was transformed into a much better model. An example of screw fastening is shown in Figure 24. This is an example of a pre-main amp, with the M3×6 and M4×15 screw washers in 11 places each. Just by using a damping device in such a situation, an extraordinary improvement in sound quality can be obtained. Figure 25 shows the CD player, which has four white stops, and the rubber was removed, and M6 washers were inserted into the top and bottom of the mechanism, and then the top was fixed. It is said that even if it is a simple task, the reformation is remarkable.

The replacement of the screws that attach the chassis and the IC circuit board has also had an effect, sparking debate about the fact of such an effect on digital signals. The mechanism

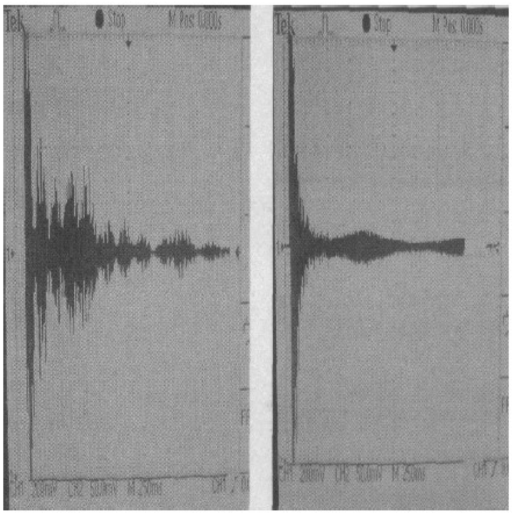

Figure 23 The effect of damping screws when striking an iron plate

has not yet been clarified. The detailed results of the screw-on experiments are reported as good. There is no way to determine which screw is the best to replace, except by trial and error, but the number of fans is increasing rapidly.

7.1.3 CD player

The mechanical base of the CD player was tested to improve the sound quality, and a groundbreaking result was obtained. An embodiment of this is shown in Figure 26. The improvement was not in the use of screws, but in the use of washers and supports. The conventional type on the left used rubber and springs, but the new type on the right eliminated them, and the sound quality is said to have improved remarkably despite the simplification of the structure. What is noteworthy here is that the extermination of the rubber has taken place. The rubber has a large stroke, which in some cases can induce second order disturbance vibrations. Based on the damping effect of the washer, it is also useful for gasket and packing.

In the case of an open CD, when an M2052 alloy disc (10mm thick, 50mm diameter) was mounted on a stand made of Corian (a resin with damping properties) and the CD's pickup mechanism was installed on it, the noise disappeared and the playback sound was dramatically improved. Figure 27 is a real example of this. The top is an overview and the bottom is the black M2052 disc with the pickups installed. It is believed that the sound quality was improved because the damping discs absorbed miscellaneous signals from the parts connected to the pickups.

Even though the same CD player is used, the CD installed in the car is subjected to harsh conditions, and the demand for high quality acoustics is a challenge because the CD

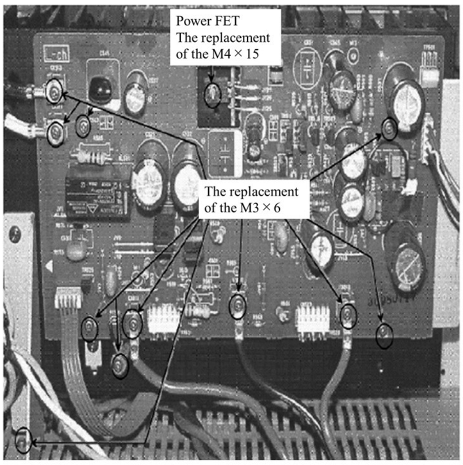

Figure 24 Screw fasteners on the base of the pre-main amplifier

transmits vibrations from the roadway. Pioneer overcomes this problem by developing the Kalotu Area RS-D7X, a system that creates the ultimate in sound quality in the cabin of a car. There are several factors that contribute to this, but the biggest one is the creative use of the M2052, a CD player that uses a clamper to compensate for the setting and rotation of the discs. Figure 28 shows the construction of the clamper and the ring made of M2052.

It was found that the CD set in the clamper had a resonance at around 700Hz (at 12cm) due to its own rotation, and the sound quality was degraded. However, by attaching a single 0.1 mm thick donut-shaped M2052 sheet to the side of the upper clamper in contact with the disc, the disc's vibrations were perfectly absorbed. Figure 29 shows the measurement data for the new and old clampers. The solid line is the data for the new model. The peak vibration around 700 Hz that appeared in the old model was reduced by more than a dozen dB. Figure 30 shows the change in the error signal of the focus servo of the CD spindle due to the deliberate disturbance of the vibration from the road surface. The large amplitude waveform at the bottom of the figure is the disturbance signal, and the waveform at the top left and right is the stopping effect of the servo. The results of using the damping sheet on the right show that the disturbance of the CD due to external disturbance was significantly reduced compared to the left side without the sheet, proving that the disturbance to the sound quality was less affected. The fact that a mere 0.1 mm of foil could have such a significant effect on vibration control is difficult to understand by experts who are familiar with vibration problems.

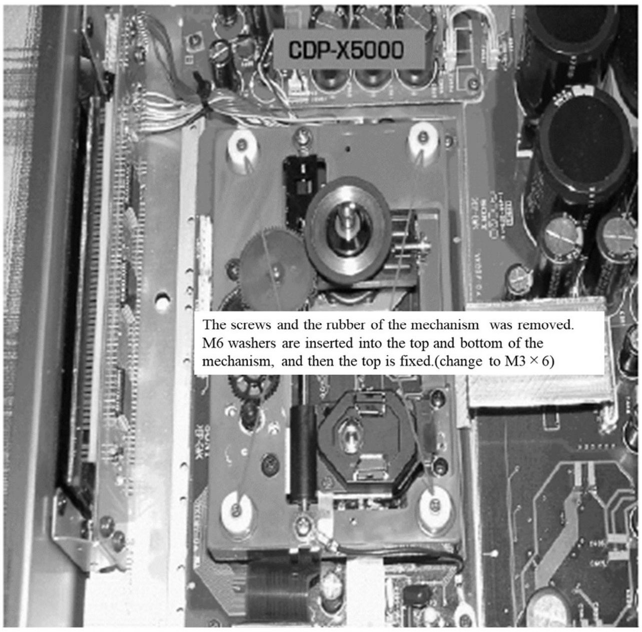

Figure 25 Mechanical set screw on CD player

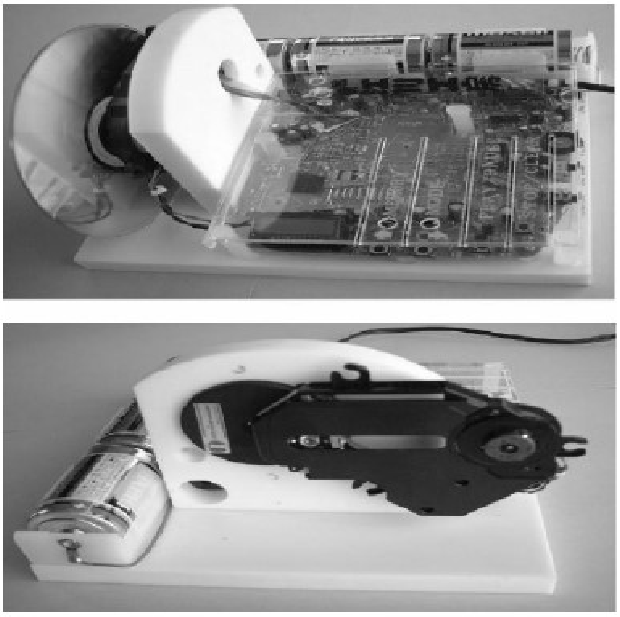

Figure 27 Open CD

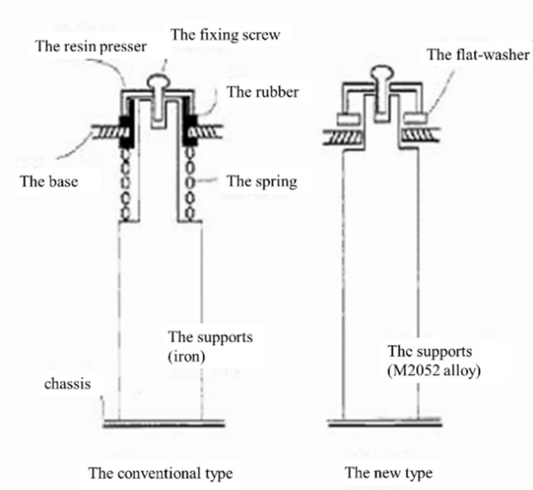

Figure 26 Improving the CD mechanism

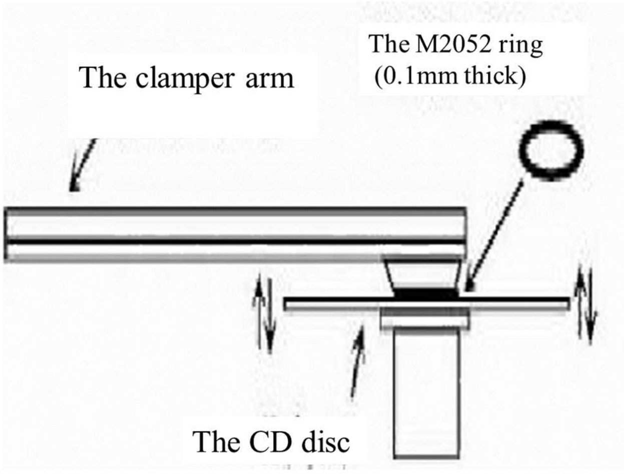

Figure 28 Paste the M2052 link to the CD clamper

7.1.4 Analog-record

Good results have also been reported in tests on straight arms and cartridges for analog records, as well as in the installation of wiring cords. Remnants of washer punches (known as punching belts) can also be used effectively. A noteworthy example is the amazing effect that the belt has had on the arm of the record. Figure 31 shows its experimental apparatus. It' s twisted to make the belt stronger, but it' s a simple structure with a cartridge on the left end and a stand to connect the belt to the right end. They rave, "Scratch noise is as small as it disappears, there is no known resonance in the tone arm, and the howling phenomenon is almost gone, and there is no need for exaggerated anti-vibration parts."

The tone arms made by SME are well known for their good sound quality among record enthusiasts. They used M2052 alloy to further improve the sound quality, and the improvement was so great that they had to rethink the sound of the record. The SME arm is shown in Figure 32, which features a plastic edge to support the arm in a balanced manner to maintain high sound quality. The improved parts are the knife edge at the bottom right of the photo and the spacer (a board to attach the arm to the turntable) at the bottom left of the photo, which is an attempt to use M2052 alloy. The result is a record that "sounds as fresh as if it's just been pressed after decades of listening to it on a variety of players.” Several LP records were played, the first part of "Take Five" was recorded on CD-R and its waveform was examined. The entire waveform is shown in Figure 33. One thing you immediately notice is the difference in sound pressure in the high frequency range. The original arm is located at the top of the range and there is not much

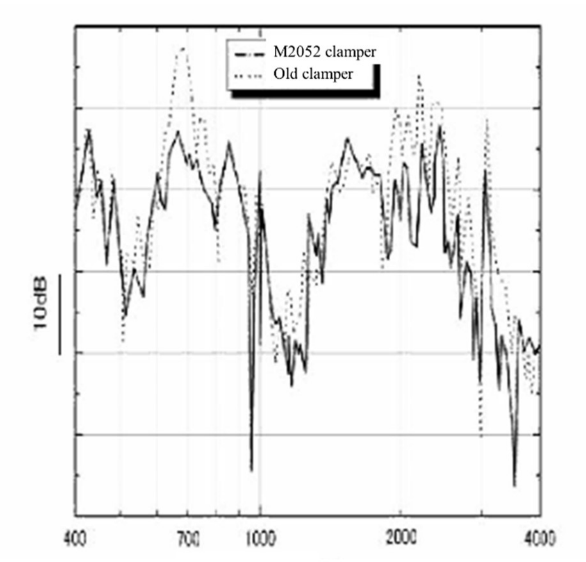

Figure 29 M2052 alloy for clamper damping

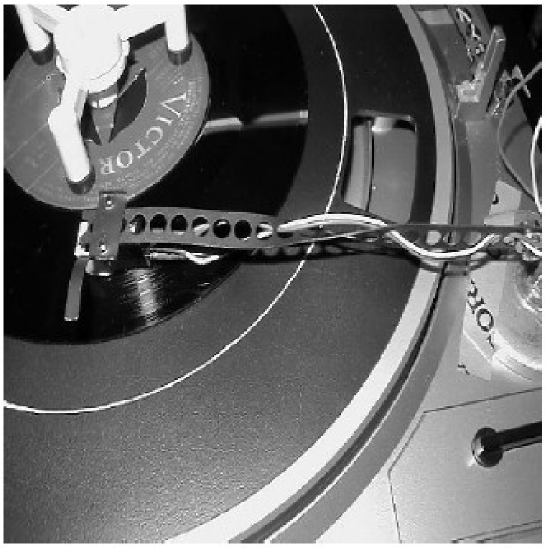

Figure 31 Silent effect with analog record arm

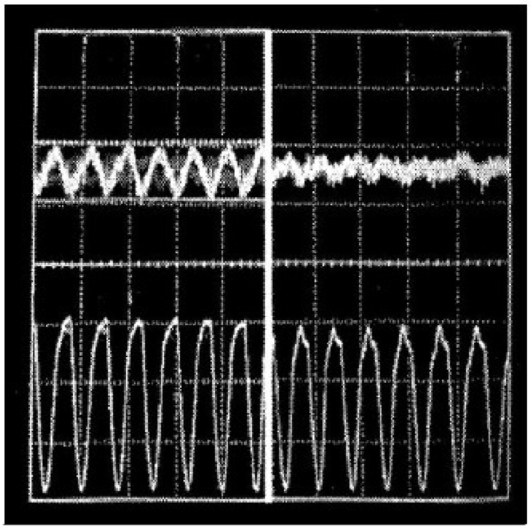

Figure 30 Even with the disturbance, the effect is still there

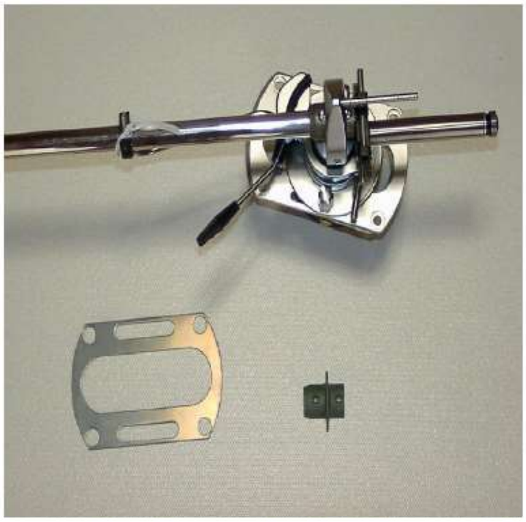

Figure 32 SME tone arm and improvement parts

difference of sound pressure between the upper and lower arms. If you compare the lower frequencies below 1kHz, the difference is clear. Figure 34 shows it, and if you look closely at around 200Hz, you can see that the M2052 has more up and down sound pressure, while the original has less variation. In other words, it can be interpreted that the improvement in sound quality is due to the fact that the M2052 alloy shows more vivid and subtle changes, even though the volume is lower than that of the original. Probably, it is still unexplored at the moment, but I can predict a dramatic improvement in sound quality by replacing the tubular arm made of Al with an M2052 alloy.
In addition, as an example of the application of the foil, the presentation showed the tremendous effect of cutting 0.1mm thick foil into small pieces and attaching them to various parts of the cartridge and to stabilizers such as records. Figure 35 shows the cartridge with the washer and foil set in place. In both cases, the effect was great.

The sheet is thin and can be easily cut up with scissors, so the shape and size can be adjusted by the user. A number of unique results have been reported by processing and attaching them in the right places[9]. Figure 36 shows a photograph of the record and CD stabilizers viewed from the back. Even a simple process of attaching three damping sheets to the side of the disc that makes contact with it is said to be effective in improving sound quality.

Simply screwing this alloy disc to the speaker's core case produced the effect, and when the 0.1mm damping sheet is attached to the clapping plate located in the center of the MD, it has been found to be unexpectedly effective. Figure 37

[9] It appears in "A&V Village" magazine every time.

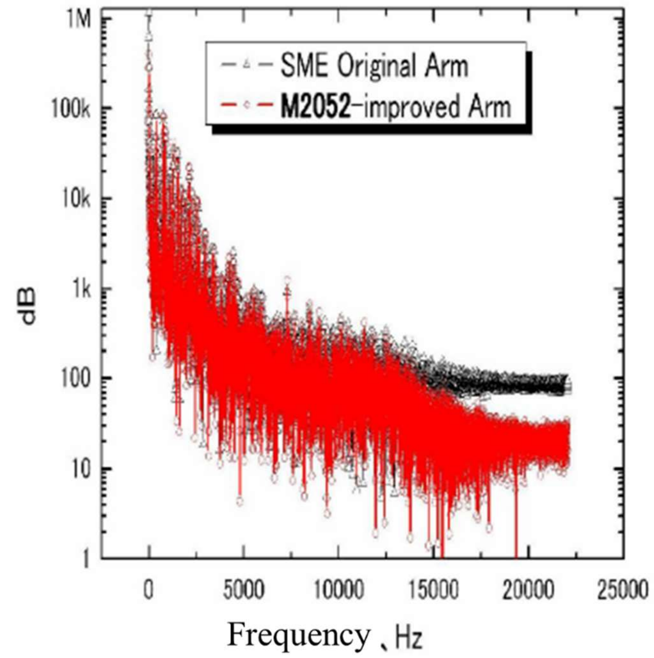

Figure 33 Improvement in the sound pressure change in the entire frequency range

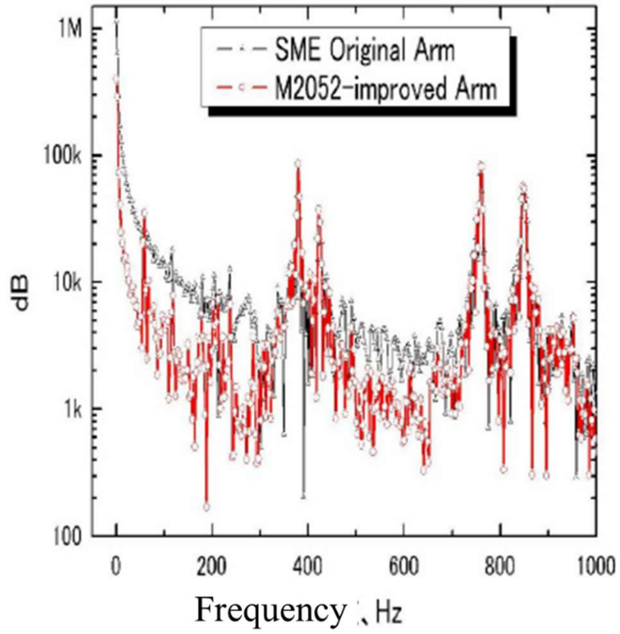

Figure 34 The sound pressure improvement effect seen below 1kHz

shows the MD. The one on the left is a conventional product and the one on the right is a finished product with a thin disc attached with epoxy adhesive. Such a simple measure[10)] was said to have produced an amazing sound quality.

The effect of the paste is accused of being a "glue" effect and not that of the M2052 alloy, but even the "glue" It is true that the sound quality will be changed no matter what kind of material is pasted on, but the problem is not the change but the modification. The M2052 alloy produces a modification.

Recently, it has become possible to produce fine powders, and new applications are emerging. The powder is dissolved in resin and applied to small, light-weight parts to remove vibration.

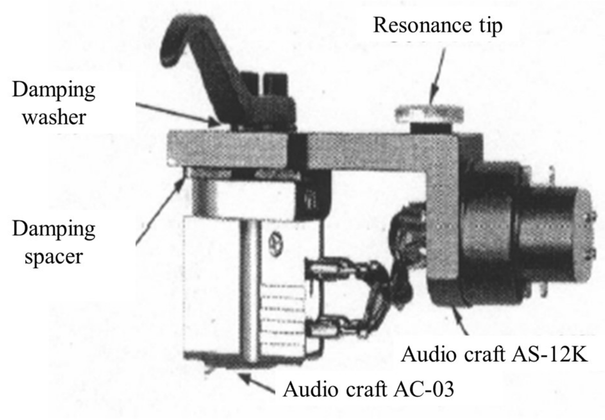

Figure 35 Application of damping alloys to record cartridges

7.2 Machining

7.2.1 Cutting tool holder

The requirements for machining accuracy are becoming stricter and stricter every year, and it is important to improve the quality of the finished surface and the accuracy of bevel cutting. It is serious. Various measures have been taken, and expensive holders made of cemented carbide are said to be effective. On the other hand, M2052 is also very effective, and is already being used as a spacer for tools and a holder for boring tools. It is commercially available. Most alloys used in tools, including cemented carbides, are designed to reduce vibration from the standpoint of weight and rigidity, but it should be kept in mind that vibrations propagating through the tool are rarely absorbed and may interfere with vibrations coming from other sources, which may contribute

[10)] Easy to test with double-sided tape.

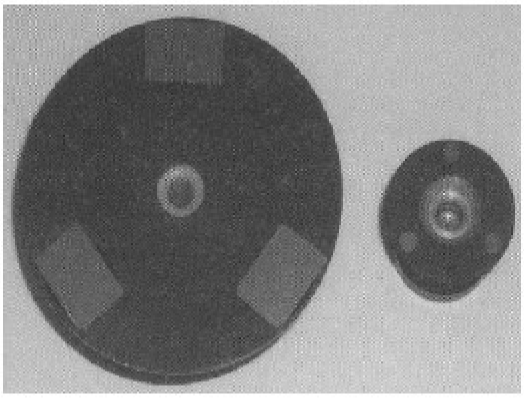

Figure 36 Application to Stabilizers for Records and CDs

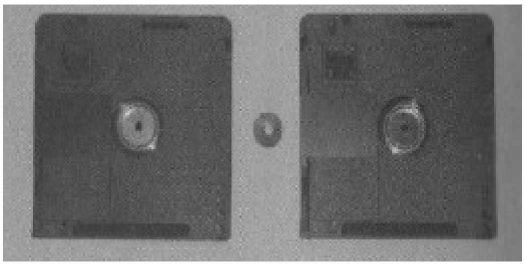

Figure 37 Application of MD to Clamping Plates

to unintended harm.

The processing method of cutting wood with a planer is called hale processing, and the holder used to support the tool. The material of SCM435 is commonly used. Since it was made of highly rigid material, it was prone to vibrations, which caused dissatisfaction on the surface finish. However, M2052 was adopted as the holder, and the results were excellent. Figure 38 shows the holder used in this study. Commercial products with a notch (left), without a notch (center), and M2052 one without a notch (right). Three different holders were tested and the results of this alloy were tremendous.

Figure 38 Hale tool holders and damping alloys

Figure 39 shows the results of testing a commercially available SCM435 hale tool holder and M2052 hale tool holder and the resulting surface roughness. When the depth of incision is shallow, there is little difference between the two, but the larger the depth of incision, the more obvious the effect is, and the M2052 surface roughness was evaluated. Made in M2052 has the upper hand. The vibration amplitude was significantly reduced and the surface roughness was reduced to 0.1 micron in the case of aluminum processing. A mirror finish was achieved. Figure 40 shows an example of mirror finish obtained by hailing the curved surface of an automobile sunroof (Al product) using six axes of control. The two columns on the left are the results of the M2052 holders. The two columns on the left are the results of the M2052 holder. The reflection image is clearly clearer than the ball and end mill finishes of the two examples on the right. High quality finishes are now possible without the need for wrapping finishes.

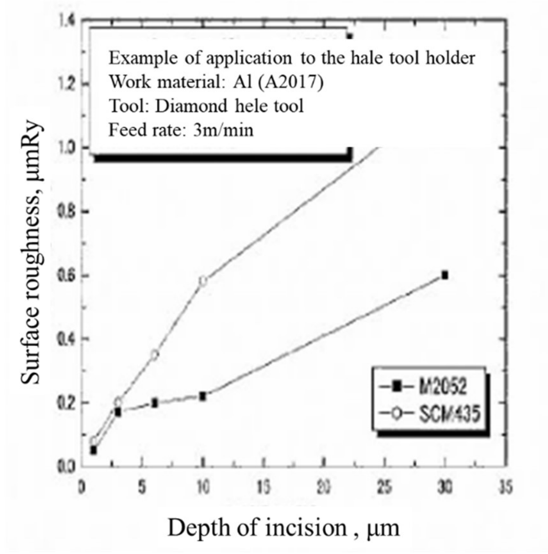

Figure39 Results with the Hale tool holder

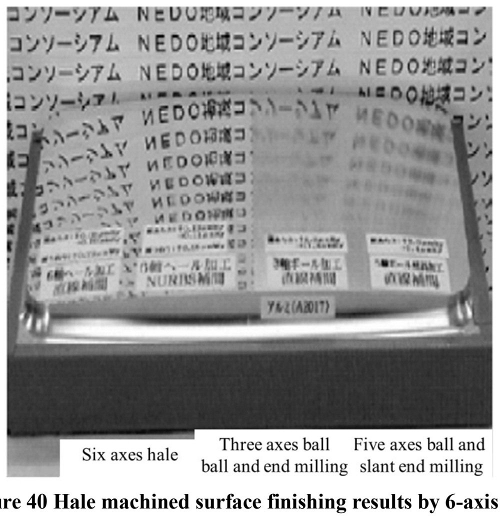

Figure 40 Hale machined surface finishing results by 6-axis control

7.2.2 Spacers for underlay of cutting tool

Figure 41 shows an example of a spacer made of M2052 placed underneath a turning tool in the lathe machining process. This is the result of an experiment in which an SS6 square beam was cut with a HSS tool[11]. Marks □■ are common mild steel spacers and ○● are data from M2052. The data filled in the marks indicate that "chatter" occurred under those cutting conditions. If the protrusion of mild steel spacers exceeds 35 mm, regardless of the number of workpiece rotations, chatter occurs. However, with the M2052 spacer, chatter only appeared at the hardest condition in this experiment, i.e., when the quantity was 50 mm and the workpiece speed was 1900 rpm, but not other condition. Just a 1mm thick spacer placed underneath the bite improves dimensional accuracy and surface finish. Similarly, it is known that some chatter has been detected, but within the finishing accuracy, as in the case of the anti-chatter results of a sleeve used for center milling and the results of center milling of a single crystal with a tool diameter of 5 mm and a protrusion of 150 mm.

Figure 42 shows an example of a measurement from another precision instrument manufacturer. It is used as a sleeve spacer. The influence of the inner and outer plates made of thin plate on the strength of vibration when they are inserted around the bearing is examined. The strong vibrations at around 5000 Hz are clearly suppressed.

Figure 41 Effect of using spacers for cutting tool

Dramatically reducing "chatter" in thin plates and pipes, as in the example above, is difficult for rubber, the king of damping materials. The rubber is extremely low in strength

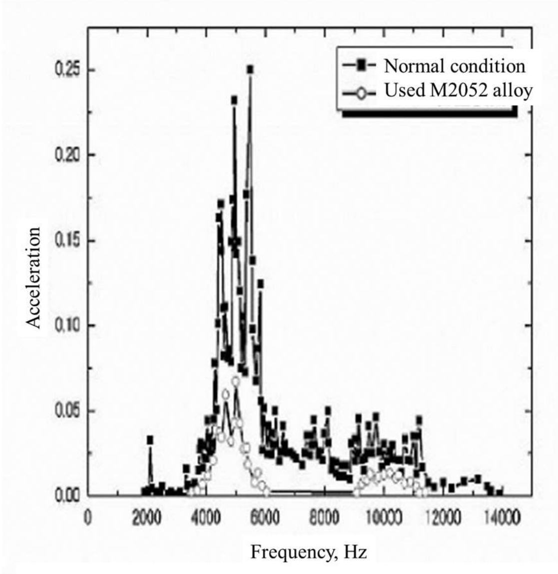

Figure 42 Example of use with bearings 1

and is not strong enough to resist the "chatter" pulse signal when used underneath a bite. In particular, as the thickness of the plate increases, the stopping power decreases. Rubber is unsuitable for such heavy duty applications. It should be noted that, even in alloy M2052, the increase in thickness is effective in absorbing low frequencies, but the "chatter" control force due to its elastic deformation may be reduced. Thin materials are suitable for micro vibrations.

7.2.3 Mount of machine tool

Various types of mounts are used to support machines and equipment. One of the purposes of these mounts is to reduce vibration, and cast iron and polymer mounts are commonly used. In the case of the M2052 alloy, it is necessary to create an environment in which the elasticity of the M2052 alloy can be deflected to the extent that it flexes in order to achieve effective damping at low frequencies. This inference was substantiated by modeling experiments on the mount. Using the shape of the mount shown in Fig. 43, it was installed under a test surface grinder weighing one ton in four places, and adjusted with a torque wrench so that each of the mounts was loaded evenly. The excitation was evaluated by tapping

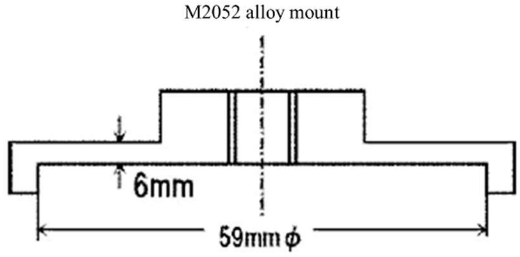

Figure 43 M2052 alloy mount

[11] The feed rate was 0.15 mm/rev and no cutting oil was used.

the back of the column of the spindle head with an impulse hammer, fixing an eddy-current displacement gauge on an aluminum flange on the work table, which was assumed to be the grinding wheel, and detecting the cross-receptance between the wheel and the table. The result is shown in Figure 44. Four different types of tests were conducted with combinations of mount and mounting bolt materials, which yielded some interesting facts. Resonance peak is seen around 25Hz, but when both the mount and the bolt are steel, maximum displacement of 0.244 is shown at around 25 Hz and even if only the bolt is changed, it decreases to 0.221. However, using the M2052 as a mount, the displacement declines dramatically to 17%. This result seems noteworthy. Importantly, this is an example of how even a rigid body such as an alloy can reduce low frequencies by reducing the spring constant if the material has high damping performance.

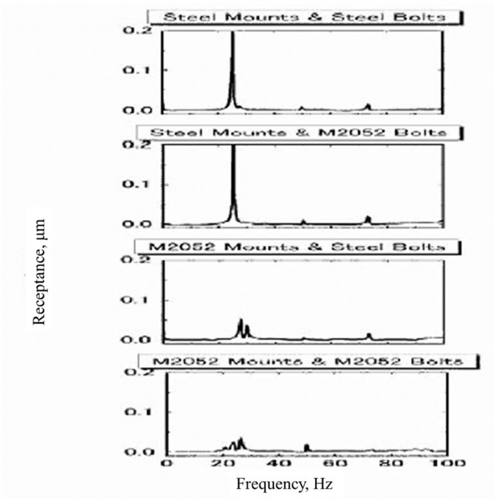

Figure 44 Damping effect of M2052 mounts

The rate at which vibration from the source is transmitted to other parts of the system is called the transmission coefficient. When the ratio (ω/ω_n) of the frequency of the vibration (ω) to the natural frequency of the system (ω_n) is 1, the resonance occurs. And since the transfer rate is less than 1 for conditions where it is more than $\sqrt{2}$, we have taken various measures to damp the vibration by increasing (ω/ω_n) in the system. In order to do so, increase this ω_n, or add coil springs, air springs, dash pots, and orifices to the transmission points in hopes of achieving a damping effect. In practice, when the damping ratio is high, the transmission rate becomes unfavorable at the high point of (ω/ω_n), so the damping ratio is from 0.1 to 0.15 is recommended and high attenuation conditions are not necessarily acceptable. Rubber does not have this kind of damping ratio problem. The M2052 alloy is not difficult to use because it doesn't have it either.

8 Precision Equipment

8.1 γ-ray detector

Gamma-ray detectors are often used to measure radiation. This M2052 sleeve was adopted as a part of the γ-ray detector. Figure 45 shows a detailed view of it, the black sleeve being the one in black. The vibration of the compressor on the right side disturbs the gamma-ray incidence window on the left side, resulting in the detection sensitivity significantly lower. Figure 46 shows the data with its vibration propagation reduced by the damping alloy and a 10% increase in accuracy, this detection device was marketed.

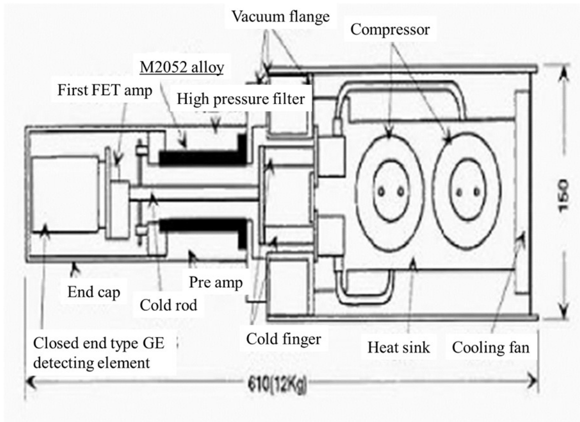

Figure 45 Onboard γ-ray detectors

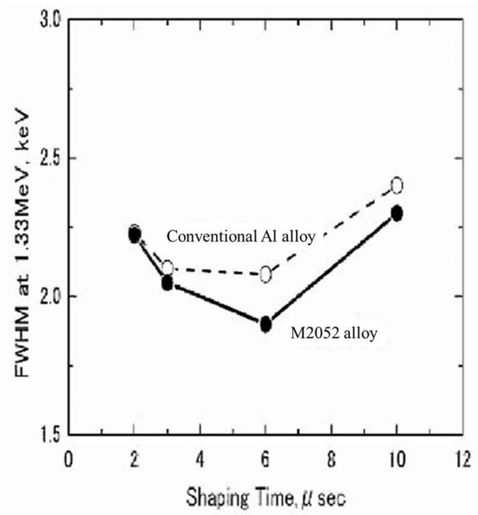

Figure 46 Improvement of accuracy of γ-ray detectors

This type of sleeve also functions as a structural member, an example of which is nearly impossible to achieve with rubber.

8.2 Finely machined parts by the etching method

This alloy is very good at forming processes, so micron-sized foils can be obtained. Therefore, a method similar to photo-etching can be used to achieve a fine finish, and this special parts unique to the alloy can be acquired. Figure 47 shows an example of a product that has been etched out.

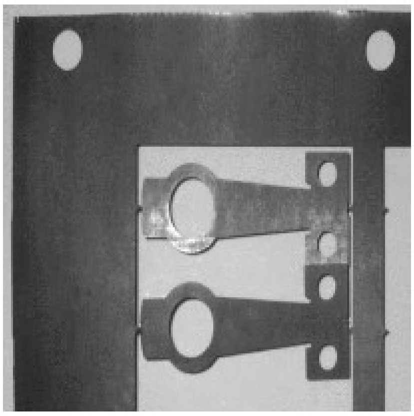

Figure 47 Example of extraction of a 0.1 mm thick plate by etching method

Using this method, for example, it is possible to make a screen made of metal foil for use in a vacuum environment. Figure 48 shows a screen enclosed in a CRT, which operates in a vacuum and is constantly vibrating and Sometimes large vibrations occur and last for several minutes. To counteract this, as shown in the figure, the screen, which tends to swing easily, is fixed with two tungsten wires welded to the top and bottom. When the screen turned white, the line (called the damper line) was identified, and since this line was completely nonsensical from a functional point of view and was not to be used if at all possible, we were asked to consider countermeasures.

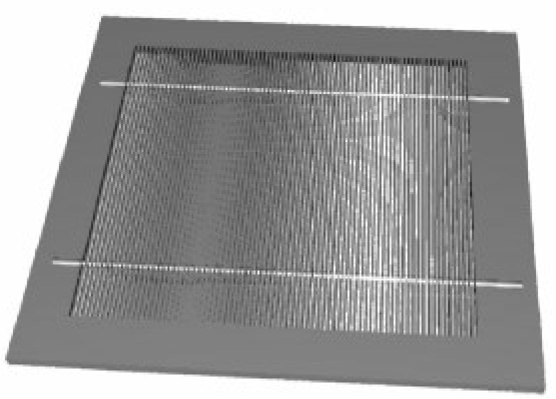

Figure 48 Metal blind screen in CRT

The screen is made up of dozens of grids with a thickness of 0.1 mm in each of the thickness of the plates, the spacing between the grooves, and the width of the grids. At that time, we had no experience in black plating or manufacturing foils of severe smoothness and their heat treatment. We are now at a point where we can accept it. The vibration problem seems to exist not only in the screen type CRT but also in the shadow mask type. From this, it is assumed that it can be used as a sealing (packing or gasket) with a thin and precise structure and damping effect. Mostly rubber or copper strips are trying to fulfill their purpose, but sealing with this alloy that also serves as a damping device is also expected to have a unique demand.

8.3 Bearing

Vibrations from bearings often cause serious problems in improving accuracy. As a countermeasure to this problem, there are examples of its use in the inner-outer of a bearing and in a stand. Figure 49 shows an example of the measurement of the outer of a ball bearing. Compared to the standard vibration, the two examples of M2052 alloy are both more effective in damping vibrations at higher speeds.

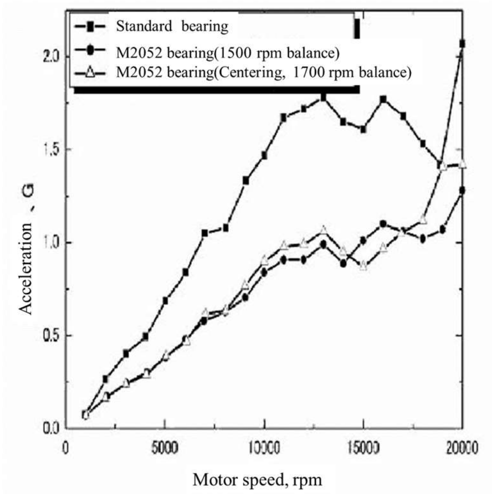

Figure 49 Example of use with bearings 2 :

It is more effective to use it as an inner layer than an outer layer. It is important to note that the design should not exceed the yield strength of this alloy. The thicker the plate, the more effective it is for absorbing vibration. Although too thick is effective for low-frequency absorption, the thicker the material, the greater the elastic displacement, so thinner is recommended to avoid this. When targeting only high frequencies, it is thin.

Elastic displacement under load is a fatal problem in the case of rubber. However, it is not so serious with damping alloys, whose strength is orders of magnitude higher than that of rubber.

8.4 Surface polishing machine

Slight runout of the rotational axis can be a problem when surface grinding finishes are required to be precise. Grinding of lenses and silicon wafers is a typical example. Figure 50 shows an example of a thin ring of M2052 alloy that solves the problem of rotational runout. A similar problem was solved by using a ring of M2052 thin plate (large washer) between the existing holder and the spindle to prevent the boring tool from shaking, as shown in Figure 51. Thin plates are essential. The thicker the plate, the greater the ability to absorb vibration, but the more elastic deformation of the plate itself, which has other effects.

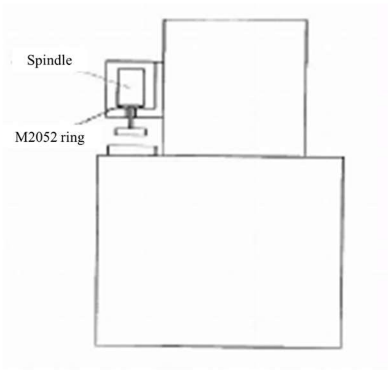

Figure 50 Improving the accuracy of surface polishing

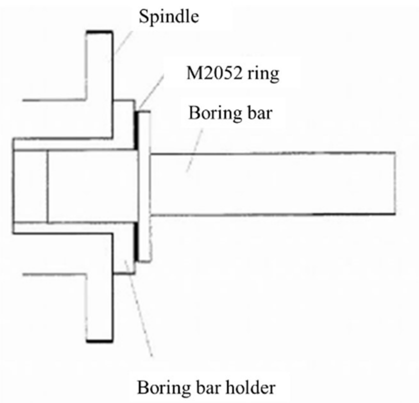

Figure 51 Boring arm vibration control

8.5 Computer

As computers compete for higher and higher speeds, micron-sized vibrations cannot be ignored. In particular, anti-vibration measures for hard disks are fierce. The use of these alloy washers in combination with the hard discs in the case has proved to be a revolutionary improvement and they are strongly recommended. Disk vibrations have a negative impact on head seeking the stronger the miscellaneous vibrations are in accessing the disk. In other words, a negative impact on the head seeking prolongs the time it takes to reach the desired track, and in addition, increases the probability of a misread. Figures 52 and 53 are examples of this effect. Figure 52 shows that it takes half the time to pinch just two washers, and Figure 53 shows that all of the washers have increased the speed of file transfer as an effect of the washers. Although the effect is often thought to be marginal, further speeding up of the disk and CPU will make a significant difference. With the recent increase in the speed of disk rotation, more complex hydraulic mechanisms have emerged. In some cases, the M2052 alloy washer can be used for this purpose easily. The M2052's applications are not limited to hard drives, but can also be used for DVDs, CDs, power supplies, fans, and even the legs of the casing.

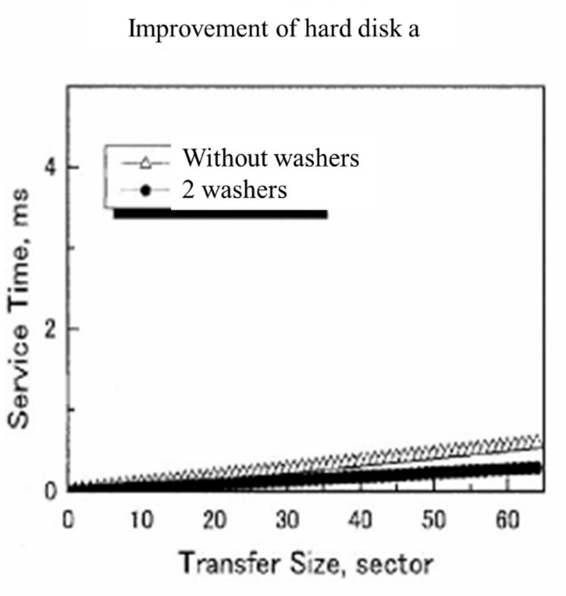

Figure 52 Hard Disk Seek Time Shortening Effect

9 Automobiles

9.1 Application to engines

As shown in the schematic diagram in Figure 54, Nissan has adopted M2052 washers as a measure to improve injector seating noise as part of its efforts to make direct-injection engines quieter, and these washers have already been

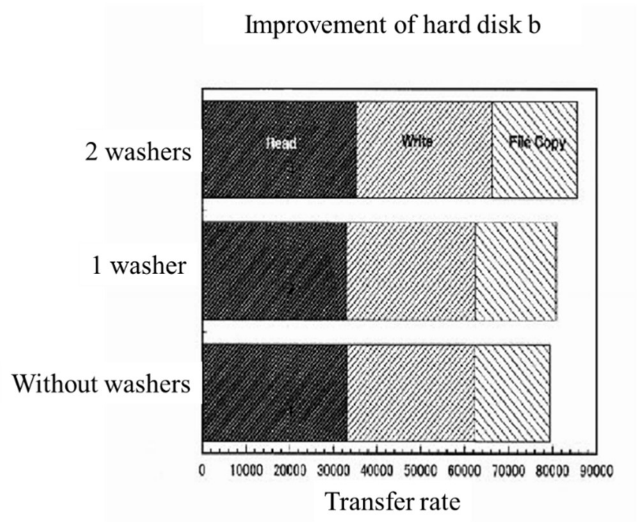

Figure 53 Improved hard disk transfer speed

installed in a luxury car (Cima) and have been well received. As shown in Figure 55, this is because a 5dB reduction in the muffled sound near 1kHz was achieved. The application to other parts is also being considered.

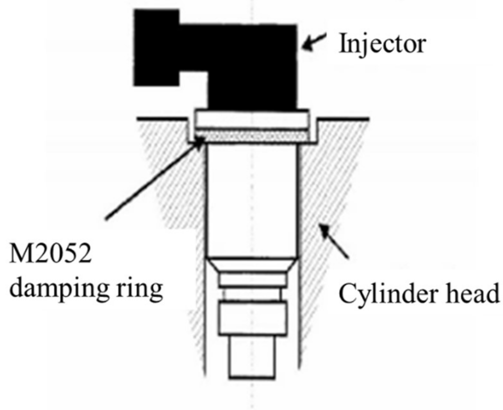

Figure 54 Damping rings used in direct-injection engines

Other major car manufacturers have reviewed the alloy's performance and have indicated that they will soon adopt it. While anti-vibration rubber is widely used in the automotive industry, there are some parts of rubber that are problematic. The lower the frequency and the more minute the vibration, the more the weakness of the rubber is exposed. so it is conceivable that it could be used as part of mounts, torsion bars, suspensions, bushings, dampers, etc.

10 Ultra-high vacuum equipment

One of the requirements for materials used in an ultrahigh vacuum is the issue of gas release from the material. Candidates for damping materials that can be used in such an environment are scarce. M2052 was selected as one of the target alloys for the TAMA300 project (research on

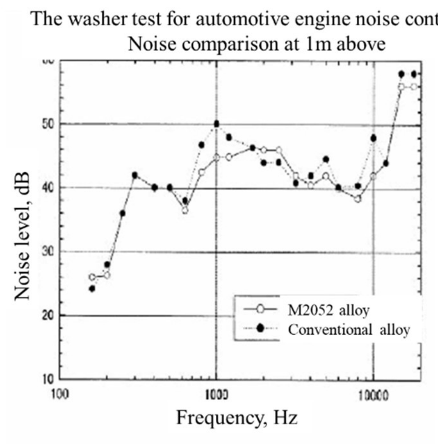

Figure 55 Noise reduction near 1kHz in vehicles

damping materials for ultrahigh vacuum equipment to verify gravitational waves), and the basic data and possibilities were obtained and reported.

10.1 Comparison by frame structure

In order to use M2052 alloy as the structure of the TAMA300 project, a frame to suspend the optical elements was considered, and the frame shown in Fig. 56 was made of stainless steel and M2052 alloy and its effect was studied. The frame consists of a top plate, a bottom plate and four pillars. The results of a test with the frame mounted on a shaking table are shown in Figure 57. The obvious difference is seen in the height of the resonance, with the M2052 alloy having a lower resonance peak and the damping effect was excellent.

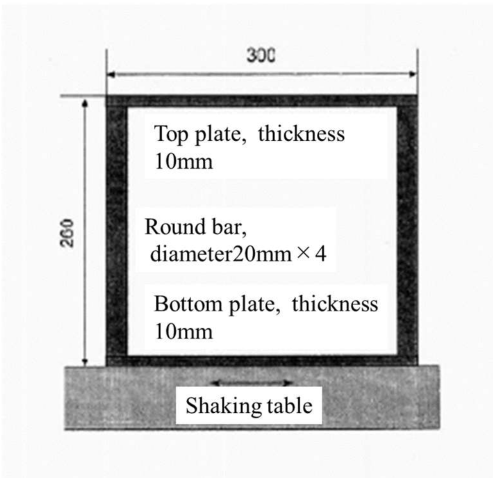

Figure 56 Example of use in the frame of a suspension device

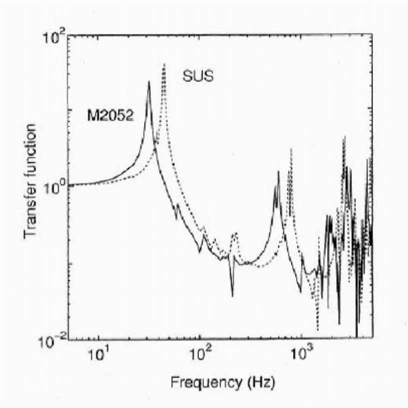

Figure 57 Damping Effects of Different Frame Materials

10.2 Gas in an ultra-vacuum

The vacuum characteristic of the material is important in a high vacuum environment. The gas release from the surface of M2052 alloy by the thermal desorption method was investigated. Although the gas release rate is about 10 times higher than that of 18-8 stainless steel, it has been judged that the material is sufficiently suitable for ultrahigh vacuum with appropriate surface treatment and baking.

10.3 Damping of the suspension system

In the TAMA 300 project, a number of devices are suspended in order to avoid vibrations coming from various sources. One of them, the M2052 alloy, was tested on a telescope apparatus for mode matching. A schematic diagram is shown in Figure 58. The main optical elements are two off-axis parabolic mirrors with accompanying mirrors and a mechanical adjustment mechanism. All of these optical elements are assembled on a single aluminum plate, which is suspended from a frame supported it. Stainless steel springs and tungsten wires were previously used for the suspension. In this test, the tungsten was replaced with M2052 alloy. Figure 59 shows an enlarged version of this section. In the past, the wire oscillated, which took a long time to reduce the oscillation and caused problems during observation. The measurement results of the new installation are shown in Figure 60. Three cases were tested, which are tungsten wire only, M2052 alloy wire only, and both wire and damper in M2052 alloy. As shown in the figure 60 below, the effect of the M2052 alloy was evident and it was found to decay more than 10 times faster than before. This system was judged to be practical and has been incorporated into the TAMA 300 and is working well.

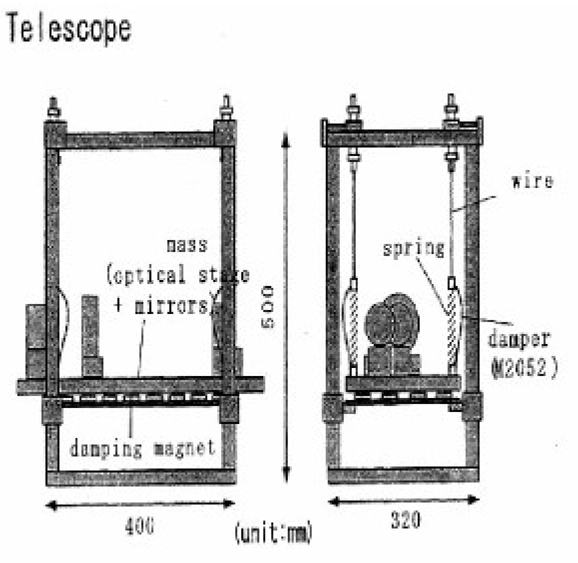

Figure 58 M2052 alloy tested on telescopes

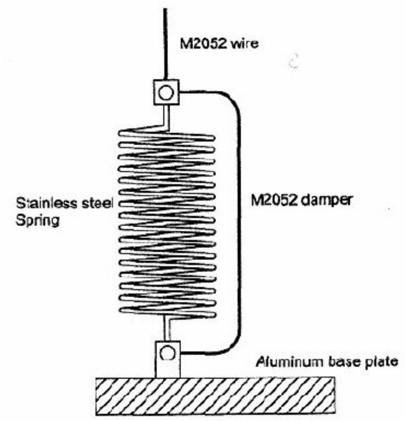

Figure 59 Enlarged view of the damper section of the telescope

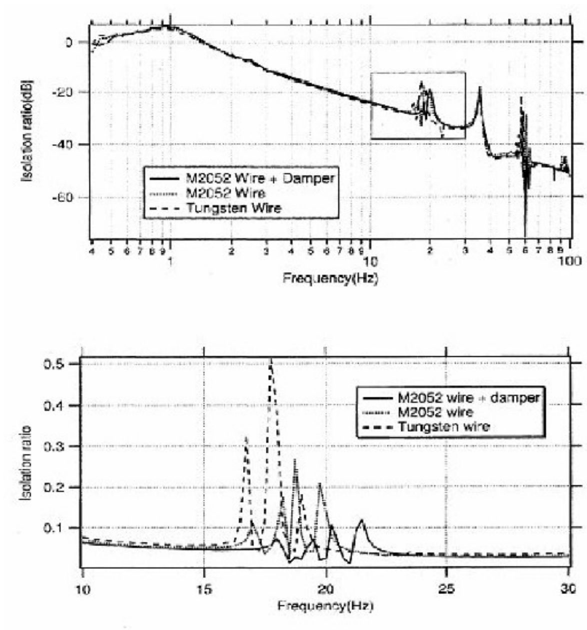

Figure 60 Results of the M2052 alloy in telescopes

The data for the springs are shown in Figure 61 and 62. The damping performance of a coil spring made of stainless steel and M2052 is shown in Figure 61 and 62, respectively. The comparison is made when the coil and wire diameters are

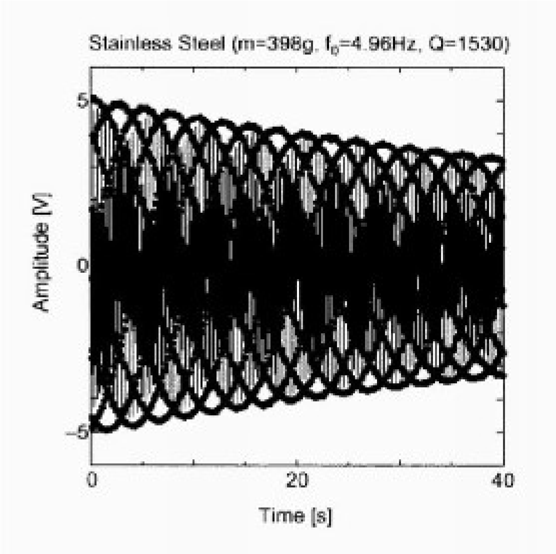

Figure 61 Damping of stainless steel coils

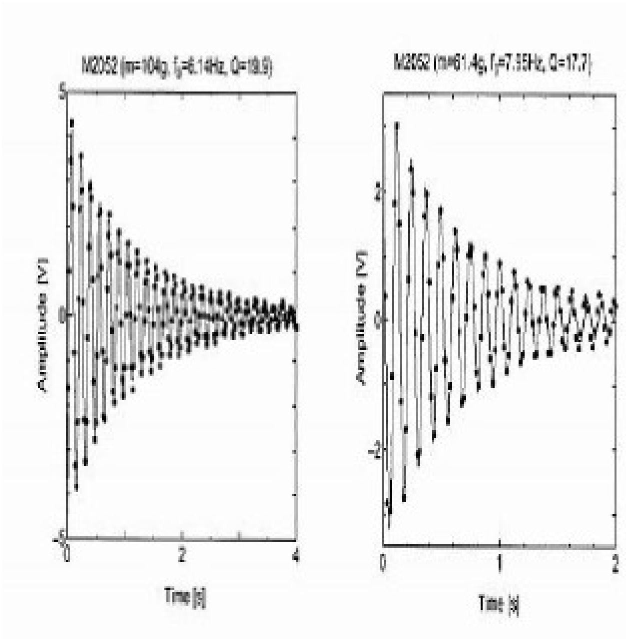

Figure 62 Damping of M2052 coil

approximately equal, and the damping alloy is damped at an overwhelmingly fast rate. While the stainless steel still showed strong residual vibrations after 40 seconds, the M2052 alloy stopped after about 2 seconds. This is a natural consequence of the fact that ordinary metal coil springs have almost no damping properties in themselves. A unique application is possible by using a damping alloy as the shape of the coil.

11 Common Countermeasure Effects

11.1 Effect of the washer to stop the bolt from loosening

There is a concern that the fastening force of bolts and nuts made of high-strength alloys may decrease during use, which is called "loosening". It is expected that the use of an alloy that absorbs vibrations would alleviate this concern. It was found to be correct. The results are shown in Figure 63 and Table 4. A combination of M10 x 60 bolts and nuts/washers of different materials is used to fasten them together and repeated impact loading, after that, looseness was detected from the values of the strain gauges applied at a given position.

It is clear from Figure 63 and Table 4 that the effect of the iron-based damping alloy (Fe-Mn-Cr system) is tremendous, and while more than 10 kN of tightening is required for S45C alone, only 4 kN is found to be sufficient when the damping alloy is used. In the experiment with the M2052 alloy, the bolts and nuts were S45C steel, and only one M2052 washer with a thickness of only 1 mm was used, but despite this, only 6 kN was sufficient for the tightening force. When compared in terms of the volume of the damping alloys used in the tests, the results of the 1 mm M2052 alloy certainly outperformed the iron-based alloys. If it is two 1mm or more thick plate washers, we can infer that further effect is certain. The M2052 alloy is most promising if all of the bolts and nuts are made of M2052 alloy, but since its strength is about the same as that of mild steel, the cross-sectional area must compensate for the use of high strength and tightening, and it is not suitable for applications where this is not allowed. If you only intend to stop it from getting loose, one M2052 washer is enough to meet your expectations.

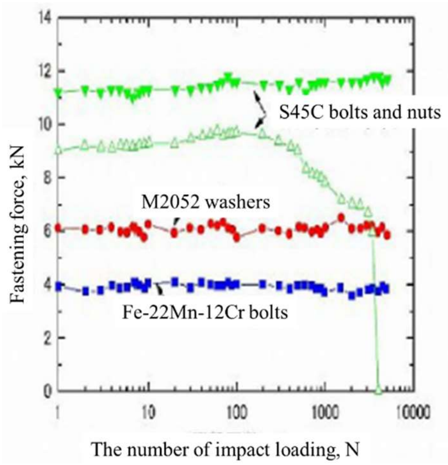

Figure 63 Effects of damping alloys on bolts and nuts

Table 4 Anti-loosening effect by various combinations

Bolts	Nuts	S45C washers	M2052 washers	Limit stress(kN)
S45C	S45C	-	-	10
S45C	Fe-Mn-Cr	-	-	9
Fe-Mn-Cr	S45C	-	-	4
Fe-Mn-Cr	Fe-Mn-Cr	-	-	4
S45C	S45C	Use	-	8
S45C	S45C	-	Use	6

The high loosening prevention effect of the bolts and nuts is directly related to the simplification of maintenance and ensuring safety. The M2052 alloy requires only one 1mm washer to make it happen.

11.2 U-plate absorbing low frequency

Rubber tends to be easily used to counteract minor vibrations. Sometimes it works, but if the conditions are different, a "rubber dance" can occur and the tremendous resonance can destroy the parts. Figure 64 shows a device holding a box consisting of a powerful low-frequency vibration source. Here is an example of the difficulty in preventing the vibration from being transmitted to the various equipment and materials in the vicinity. When no countermeasures were taken at all, as shown in the top graph of Figure 65, the acceleration was slightly right-handed, centered on 3G, and appeared to be generally low and not a problem. However, small peaks appear in small increments of 70Hz, 130Hz and 200Hz, and these vibrations interact with other vibrations to cause problems. So, they operated with rubber installed at key locations, but as shown in the data in the center of the figure, there was a strong resonance of 18G at 25 Hz, and this resonant wave induced various problems. As a countermeasure, a trial to reduce the spring constant was carried out using M2052. Rubber was used for the black areas in Figure 64, and a U-bent plate of this alloy was applied to the black areas. The results are shown in the data below in Figure 65, where the resonant acceleration is reduced to almost half that of the rubber case, and the rest of the high-frequency component is almost gone. Although this test was merely a result of bending a hand-held plate, if the optimum conditions are met by changing the plate thickness, width, radius of curvature, length, etc., we can infer that groundbreaking results are certain to be achieved.

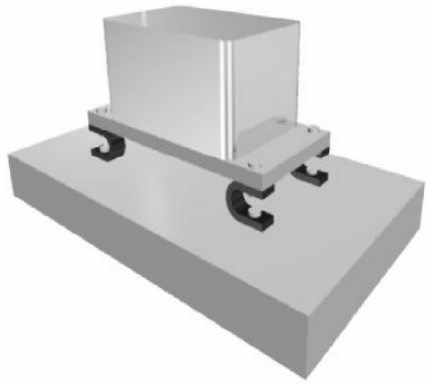

Figure 64 Substitution of rubber with a U-shaped plate

12 Summary

If you are familiar with polymers, especially rubber, for vibration control, you don't usually have damping alloys in mind. The damping performance is not as good as that of rubber, but the cost is higher and the use of the material is more complicated. However, the M2052 alloy is an insane alloy, and as shown in Table 5, when the manufacturing process and raw material selection were optimal, a logarithmic decay rate of 0.73 was obtained. When converted to a manufacturing loss factor, it is equivalent to 0.23. It can be understood that this is the same as rubber. In these days of today's quasi mass production regime, an average loss factor of 0.11 is offered. It is not necessarily an exaggeration to say that the performance is close to rubber, even if it does not reach the maximum performance of rubber. In addition, as shown in Table 6, the alloy has an order of magnitude higher strength than rubber, which can compensate for the shortcomings of rubber.

Table 5 Differences in strength between polymeric materials and metals

Material	Specific gravity	Tensile stress, MPa	Tensile elasticity, MPa
Natural rubber	0.92~1.04	24.2~31.7	3.3~5.86
Butyl rubber	0.92	>13.8	0.34~3.45
Polyurethane	0.56~0.64	17.2~20.1	758.4~1103.2
Polyvinylchloride (RIGID)	1.20~1.58	41.4~55.2	2413.2~6894.8
M2052 alloy	7.25	400	~50000
Mild steel	7.87	400	~200000

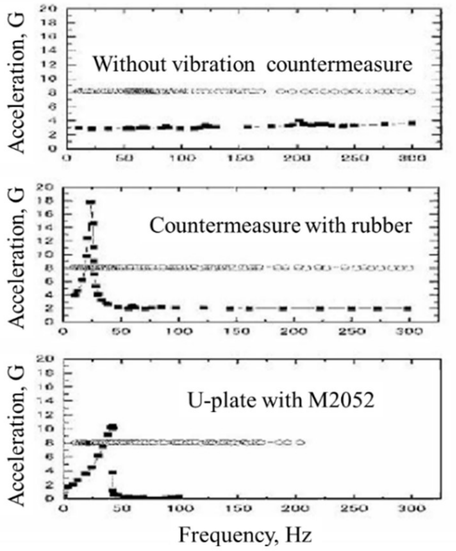

Figure 65 The effect of replacing rubber with a U-shaped M2052

Table 6 Loss factor of rubber and M2052 alloy

Rubber type	Loss factor
Natural rubber	0.05~0.15
Chloroprene	0.15~0.3
Nitrile rubber	0.25~0.4
SBR	0.15~0.4
Butyl rubber	0.25~0.4
(M2052 alloy)	(0.23)*1

*1)Highest Price. Usually 0.06 to 0.16

Rubber can cause the following problems in vibration control.

1. The lower the frequency, the less it is absorbed.
2. The smaller the amplitude, the less it is absorbed.
3. The temperature range in which high performance appears is relatively narrow.
4. Strength is an order of magnitude lower than metal.
5. The rubber must be selected to match the environment
6. Fears of "dipping" and "dancing" and quality degradation follow.

Although M2052 alloy is inferior in terms of loss factor, it completely overcomes all the problems of rubber.

1. The frequency can absorb vibrations over a wide range from 0.01 Hz to MHz in the ultrasonic range.
2. It can be considered to absorb vibration whose amplitudes range from nm for small displacements and from mm to cm for large displacements if the shape is well designed.
3. Vibration absorption capability over a wide range of temperatures, from the upper limit of 200°C to the lower limit of the helium liquefaction temperature.
4. The elastic modulus ratio is 12,500 times higher for the M2052 alloy than for butyl rubber, obviously, the function is a structural member.
5. It is sensitive to weak acids on bare surfaces, but its corrosion resistance can be improved with a surface coating, and nickel, gold, copper, black oxide, FA, zinc, and various paint treatments are available.
6. "Dipping", " dancing" and quality deterioration are unlikely to occur.

The new alloy has features not seen in conventional damping alloys, and also offers high performance never before reported for damping alloys, and it can be used in any casting or molding process, and can be used to weld or otherwise bond products. Therefore, there is a wide variety of options for the size and shape of the object, and it can be used as an alloy suitable for structural members for vibration damping. By taking advantage of this feature, we can not only solve the current problems, but also subsidize new designs at times, which will contribute in some way to existing or new fields of industry.