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Ultrasoinc Atenuation of a High Damping Alloy with Electromagnetic Acoustic Resonance
高減衰合金の超音波減衰の測定

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1. Introduction

The necessityof high damping material is recently increasing to cope with the problems in many fields, such as noise in enviroments, fatigue by resonance, nanotechnology in electronic device and so on[1)].

To controll noise and vibaration, two methods are applied. One is the application of structual damping, and the other is the utilization of material damping. In the material damping, there are the two kinds of basic mechanisms. The first is the hysterisis type and the other is the relaxation type. The former one is applied to normal high damping materials and classified into the following four groups; (1) high damping material with mangetic domains, (2) with movable dislocation, (3) with with movable twin interfaces and (4) with composites containing an energy absorbing constituent.[1)]

We studied the damping characterization (ultrasonic attenuation) under ultrasonic frequency range in a high damping alloy, called M2052[2)] with electromagnetic acoustic resonance (EMAR)[3)], which is the manganese-based alloy containing copper, nickel and iron. The damping mechansim of this alloy is as follows; static hysterisis which results in amplitude dependence of internal friction, dynamic hysterisis derived from the motion of twin interfaces and cubic-tetragonal structural phase transformation.[4)] We measured free vibration resonance frequencies and attenuation coefficients at room temperature with EMAR. EMAR is a combination of the resonant acoustic technique with a non-contact electromagnetic acoustic transducer (EMAT)[3)]. The measurement of attenuation coefficient is inherently free from any energy loss, resulting in pure attenuation in a metal sample. The ultrasonic characterizations, especially, ultrasonic attenuation, of M2052s served several kinds of heat treatment are discussed.

2. Material

The chemical composition of the material is shown in **Table 1**. the specimens were cut by electric discharging machining from rolling plate. The specimen size is 10-mm long, 5-mm wide, and 3-mm thick. We obtained two types of specimens which have the longitudinal directions paralleled (RD direction) and normal (TD direction) to the rolling direction. To these specimens, the following four kinds of heat treatment were carried out; i) heating at 1173 K for 1 h and water cooling (called RD1 and TD1), ii) heating at 1173 K for 1 h and furnace cooling for 10 h (RD2 and TD2), iii) heating at 1173K for 1 h, water cooling and aging at 723 K for 2h (RD3 and TD3), and iv) heating at 1173K for 1 h, water cooling and aging at 723 K for 10 h aging (RD4 and TD4). At room temperature, the 0.2 % proof stress of the material was 200 MPa, the tensile strength was 520 MPa, and the elongation was 32.0 %. As a reference sample, we prepared an austenite stainless steel, SUS304, which was carried out solution treat at 1273 K for 1 h.

Table 1 Chemical Composition of M2052 (at %).

Mn	Cu	Ni	Fe
73	20	5	2

3. EMAR

Figure 1 shows the system setup for EMAR measurements[3, 4)]. EMAT consists of two permanent magnets and a solenoid coil. The specimen is inserted the solenoid coil located between two permanent magnets. The solenoid coil is loose and the specimen is unconstrained. Mechanical contacts between the specimen and coil's inner surface are weak because no external force is applied except the specimen's own mass and therefore ideal free vibration occurs. The permanent magnets provide a static field for Lorentz-force coupling. Driving the coil with rf bursts causes eddy currents on the specimen surfaces, which interact with the magnetic field and generate the Lorentz forces. The forces are the sources of the vibration. After driving, same coil works to detect the vibration through the reversed mechanism of the generation.

The EMAT is excited at each resonance frequency to produce resonant conditions. Then, resonances after the excitation are measured to obtain an attenuation curve.[3)] The curve is approximated by the exponential function to

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determine the attenuation coefficient α (attenuation per unit time). Furthermore, internal friction $Q^{-1}=\alpha/(\pi f)$ (f: frequency) is calculated.

The natural frequency values of rectangular parallel-piped samples, the faces of which each correspond to the elastic symmetry plane, are categorized into eight vibration groups[5]. They indicate the symmetry property of the displacement components u_1, u_2, and u_3 against the axes X_1, X_2, and X_3 with the original point set at the center of each sample. EMAR can independently excite/detect seven vibration groups, depending on configuration of static field, solenoid coil. To measure these vibration groups separately, the solenoid coil and the static field were arranged. Three groups A_g (dilatation modes), B_{3g} and B_{2g} (shear modes) existed [6].

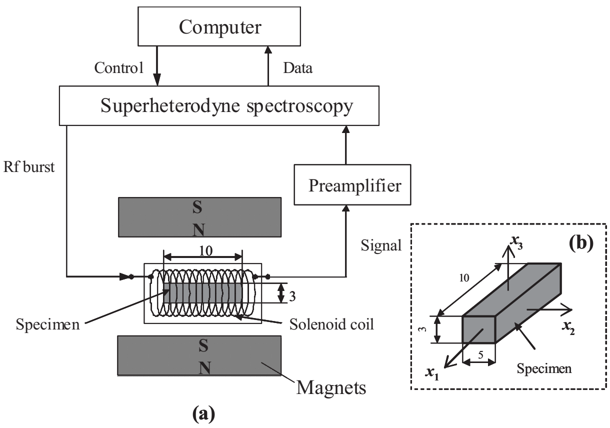

Fig.1 (a) Measurement setup for the EMAR method for measuring free-vibration resonance frequencies and attenuation coefficients of a solenoid coil, within which the specimen is located, and a pair of permanent magnets and (b) the specimen's orientation.

4. Results

We measured the resonance frequencies for the range of 0.25 to 3 MHz and their attenuations in M2052 alloys. **Figure 2** displays the frequency dependence of attenuation of A_g group in TD direction. The result of SUS304 is also shown. We observed that the attenuation α always increases with the resonance frequency. In measured frequency range, αs in TD1 are slightly larger than those in SUS 304. αs in TD2, TD3, and TD4 are 100 times larger than those in TD1. It shows that water cooling is less effective to damping performance. **Figure 3** shows the change of internal friction Q^{-1} under several kinds of heat treatment. Q^{-1}s in TD4 shows the highest value in these specimens. The aging treatment is effective to the damping performance. However, the difference of aging time is not clear. Q^{-1}s in RD direction and other vibration groups show the similar behavior in Fig.2. We will observe the microstructure with EBSD.

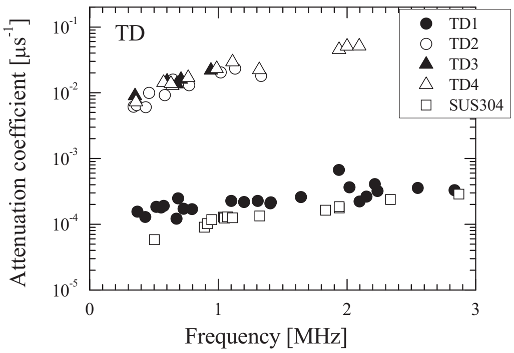

Fig.2 The frequency dependence of the attenuation coefficient, α, in M2052 alloys under several kind of heat treatment (TD direction).

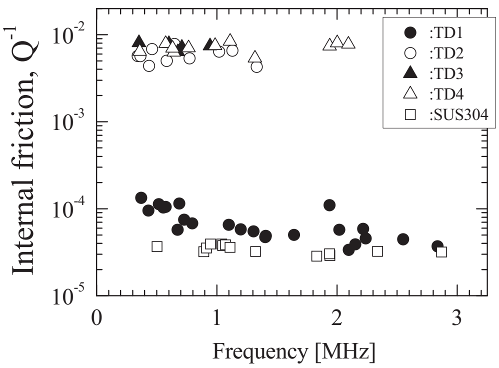

Fig.3 The change of internal friction, $Q^{-1}$of M2052 alloys under several kind of heat treatment (TD direction).

5. Conclusion

We evaluated ultrasonic attenuation in M2052 alloy served several kinds of heat treatment with free vibration resonance technique in the EMAR method. The attenuation of M2052 is 100 times larger than SUS 304. The aging treatment is effective to the damping performance.

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