Damping Capacity in Fe–Mn Binary Alloys

Young-Kook LEE, Joong-Hwan JUN and Chong-Sool CHOI

Department of Metallurgical Engineering, Yonsei University, 134 Shinchon-dong, Seodaemun-ku, Seoul 120-749, Korea.

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The damping capacities of Fe–Mn binary alloys have been investigated in a wide range of manganese content from 5 to 30 wt%. The damping capacity increases with increasing manganese content, attains a maximum at approximately 17 wt% Mn, and decreases with further manganese content. It is suggested that the damping mechanisms of Fe–Mn alloys containing γ and ϵ phases are the stress-induced movement of the defects: stacking fault boundary in γ , stacking fault boundary in ϵ , ϵ martensite variant boundary, γ/ϵ interphase boundary. The appearance of the maximum damping capacity at around 17 wt% Mn in Fe–Mn binary system is well explained with the damping mechanisms. The contributions of the damping mechanisms to the overall damping capacities of Fe–17wt%Mn and Fe–21wt%Mn alloys are quantitatively analyzed, which indicates that ϵ martensite bears the major part of their damping capacities.

KEY WORDS: damping capacity; Fe–Mn alloys; austenite; ϵ martensite; γ/ϵ interphase; stacking fault; ϵ martensite variant.

1. Introduction

Machine designers have long sought to decrease the noise and vibration arising from moving metallic parts in machines and vehicles. One solution has been to employ materials with high damping capacity in manufacture of such components in order to keep the noise and vibration to a minimum. A large number of alloys with high damping capacity, such as Mn–Cu,¹⁾ Cu–Al–Ni,²⁾ Ni–Ti,³⁾ Fe–Co–Mo–Cr,⁴⁾ Mg–Zr,⁵⁾ Co–Ni⁶⁾ and gray cast iron⁷⁾ have been developed, some of which have been used in industry. As an example, a propeller of a submarine has been made of Mn–Cu alloy (SONOSTON). Thus, in addition to the good mechanical and corrosion properties, the vibration and noise arising from the shaft can be to a large extent dissipated within the propeller rather than being broadcast into the sea.

In a previous study⁸⁾ we have reported that some Fe–Mn alloys possess high damping capacity besides the above alloys, in which Fe–17wt%Mn alloy shows the best damping capacity. However, the damping mechanisms of Fe–Mn alloys have not yet been clarified, except that the damping capacity is closely related to ϵ martensite content.⁸⁾

In the present paper, therefore, the damping capacities of Fe–Mn alloys with manganese content from 5 to 30 wt% are investigated systematically as a function of manganese content, and the damping mechanisms of Fe–Mn alloys are discussed in detail. In addition, the reason why the maximum damping capacity appears at around 17 wt% Mn in Fe–Mn binary system is investigated, and the damping capacities of some Fe–Mn alloys are analyzed quantitatively on the ground of the damping mechanisms.

2. Experimental Procedures

Fe–Mn alloys containing manganese content of 5 to 30% in weight were melted in vacuum by means of a high frequency induction furnace using pure electrolytic iron and electrolytic manganese, and were cast into a metallic mould. The ingots were homogenized in a protective atmosphere at 1200°C for 24 h, and hot-rolled to bars with diameter of about 13 mm. From the bars, the specimens for damping capacity measurement, microstructural observation and X-ray diffraction test were prepared by rolling and machining. All the specimens were solution treated at 1050°C for 1 h and were subsequently quenched into water at room temperature.

The chemical composition and transformation temperatures of the alloys used in this study are listed in **Table 1**. The starting temperature of $\gamma \rightarrow \epsilon$ martensitic transformation, M_s , and the starting and finishing tem-

Table 1. Chemical composition and transformation temperatures of Fe–Mn alloys used in this study.

Alloy	Composition(wt%)			Transformation temperatures(°C)		
	Mn	C	Fe	M_s	A_s	A_f
5Mn	4.5	0.020	bal.			
10Mn	10.1	0.021	bal.			
11Mn	11.1	0.018	bal.			
13Mn	13.4	0.025	bal.	181	226	271
16Mn	16.2	0.028	bal.	151	206	252
17Mn	17.0	0.019	bal.	142	200	245
18Mn	18.4	0.023	bal.			
21Mn	21.3	0.021	bal.	102	182	228
23Mn	23.0	0.018	bal.	82	168	214
25Mn	25.3	0.020	bal.			
28Mn	27.8	0.021	bal.			
30Mn	29.5	0.020	bal.			

peratures of its reverse transformation, A_s and A_f , were determined by a dilatometer. For the evaluation of volume fraction of each constituent phase contained in the alloys, X-ray diffraction test was conducted. Using the integrated intensities of ϵ (10·1), γ (200) and α' (110), the volume fractions of ϵ martensite, γ austenite and α' martensite in the alloys were evaluated.^{9,10)}

The damping capacity was measured using Föpple-Pertz type torsional pendulum apparatus¹¹⁾ made in our laboratory. The damping specimen was 186 mm in total length, 7 mm in gauge diameter, and 157 mm in gauge length, and was vibrated freely at frequency of about 12 Hz. The damping capacity was represented in the logarithmic decrement (δ) defined as Eq. (1):

$$\delta = \ln \left(\frac{a_n}{a_{n+1}} \right) \dots \dots \dots (1)$$

where a_n and a_{n+1} represent n th and $n+1$ th strain amplitude, respectively.

Specimens for optical metallography were electro-polished in a solution of 90%CH₃COOH + 10%HClO₄, and etched with a 1.2% K₂S₂O₅ aqueous solution. Foils for transmission electron microscopy (TEM) were jet-polished in a 90%CH₃COOH + 10%HClO₄ solution, and the microstructures were observed in a JEOL JEM-200CX operated at 160 kV.

3. Results

3.1. Microstructures of As-quenched Fe-Mn Alloys

The Fe-Mn alloys used in this study have a wide range of manganese content indicated by the black bars in Fig. 1 which was drawn by Schumann¹²⁾ using dilatometry, X-ray diffraction and optical microscopy. Figure 2 shows the optical microstructures of Fe-Mn alloys quenched from 1050°C into water at room temperature. As expected from Fig. 1, a complete α' martensite was exhibited in Fe-5wt%Mn alloy, a mixed structure of ϵ martensite (bright part) and γ austenite (dark part) was shown in Fe-17wt%Mn, Fe-21wt%Mn and Fe-25wt%Mn alloys, and a complete austenite structure was observed in

Fig. 1. The starting temperatures of martensitic transformation of Fe-Mn alloys.¹²⁾

Fig. 2. Optical microstructures of Fe-Mn alloys quenched from 1050°C into water at room temperature. (a) 5 wt% Mn, (b) 17 wt% Mn, (c) 21 wt% Mn, (d) 25 wt% Mn, and (e) 28 wt% Mn.

Fe-28wt%Mn alloy.

Figure 3 shows the typical microstructure of ϵ martensite in Fe-Mn alloys. Although it has been well known that twelve ϵ martensite variants can be produced according to twelve $\{111\}\langle 112 \rangle$ shear system in martensitic transformation of f.c.c. to h.c.p.,¹³⁾ only four differently oriented ϵ martensite plates were observed in Fig. 3. It is considered that the four plates are probably aggregates of three $\langle 112 \rangle$ variants on each plane of four different $\{111\}$ planes of γ phase, as suggested by Wayman¹⁴⁾ and Takaki.¹⁵⁾

The volume fraction of each constituent phase determined by X-ray diffraction method^{9,10)} was plotted against the manganese content in Fig. 4. The ϵ martensite content increased with increasing the manganese content, showing a maximum value at about 17 wt% Mn, and then decreased with further manganese content. A few studies¹⁶⁻¹⁸⁾ were made on the amounts of phase constituents of Fe-Mn binary alloys. Since austenite grain size, impurity content of interstitial element (C, N) and cooling condition (air cooling or water quenching) were different depending upon investigators, the amounts of

phase constituents were not exactly accordant with one another. However, all the studies¹⁶⁻¹⁸⁾ including our work showed a maximum volume fraction of ϵ martensite at approximately 17 wt% Mn in Fe-Mn binary system.

It has been well known that the $\gamma \rightarrow \epsilon$ martensitic transformation occurs by passage of Shockley partial dislocations on every other (111) plane in γ phase.¹³⁾ If the stacking fault energy of γ phase is low, a perfect dislocation can be easily separated into two Shockley partial dislocations. Thus, it is expected that the lower the stacking fault energy, the easier the ϵ martensitic

transformation occurs. Schumann¹⁹⁾ has measured the stacking fault energy of γ austenite as a function of manganese content in Fe-Mn binary system, and reported that the stacking fault energy of γ decreases with increasing manganese content, attains a minimum value at approximately 17 wt% Mn, and increases with further manganese content. Adler *et al.*²⁰⁾ have also calculated the stacking fault energy of Fe-Mn alloys thermodynamically, and their result showed an almost same tendency as above. Therefore, it is believed that the appearance of the maximum amount of ϵ martensite at around 17 wt% Mn in Fig. 4 is probably caused by such a minimum stacking fault energy.

3.2. Damping Capacities of Fe-Mn Alloys

The damping capacities of Fe-Mn alloys measured at a maximum surface strain, 6×10^{-4} , were plotted as a function of manganese content in Fig. 5. The damping capacity increased with increasing manganese content, showing a maximum at about 17 wt% Mn, and decreased with further manganese content. The variation of the damping capacity with manganese content shows a nearly same tendency as the variation of ϵ martensite volume fraction shown in Fig. 4. This indicates that the damping capacities of Fe-Mn alloys are closely related to ϵ martensite content. In order to know the true relationship between damping capacity and ϵ martensite content, it is necessary to investigate the damping capacity as a function of ϵ martensite volume fraction in an Fe-Mn alloy, because the damping capacity can be influenced by the manganese content besides ϵ martensite content. For this purpose, Fe-17wt%Mn alloy was chosen, and the ϵ volume fraction was varied in a wide range of zero to 93 vol%. The variation of ϵ martensite content below 83 vol% (as-water quenched state) was accomplished by holding the alloy at temperatures between A_s and A_f for the partial reverse martensitic transformation, $\epsilon \rightarrow \gamma$, and subsequent cooling at 165°C above M_s temperature to keep the adjusted ϵ martensite contents unchanged. Then

Fig. 3. Microstructure of martensite of Fe-17wt%Mn alloy. (a) Optical micrograph of ϵ martensite structure, and (b) Illustration of arrangement of ϵ martensite plates

Fig. 4. Variation of volume fraction of each constituent phase with manganese content in as-quenched state of Fe-Mn alloys.

Fig. 5. Variation of damping capacity, measured at room temperature and 165°C respectively, with manganese content in as-quenched state of Fe-Mn alloys.

the damping capacity was measured at 165°C. In this case, ϵ martensite content was determined from the length change of the specimen associated with the reverse martensitic transformation using a dilatometer. On the other hand, the variation of ϵ martensite volume fraction above 83 vol% was achieved by cooling the alloy to -196°C (liquid nitrogen temperature), and then the damping capacity was measured at the same temperature as above, 165°C. All the measured values of damping capacity were plotted as a function of ϵ martensite volume fraction in Fig. 6. The damping capacity increased rapidly with increasing ϵ martensite content up to about 20 vol%, but increased gradually with further

Fig. 6. Variation of damping capacity, measured at 165°C, with the volume fraction of ϵ martensite in Fe-17wt%Mn alloy.

ϵ martensite content.

3.3. Microstructural Changes of Fe-Mn Alloys after Tensile Deformation

In order to investigate the damping mechanisms of Fe-Mn alloys, the room temperature tensile test was carried out for two specimens of Fe-17wt%Mn alloy with a relatively low ϵ martensite volume fraction (53 vol% ϵ) and a high ϵ martensite volume fraction (90 vol% ϵ) respectively, and the optical microstructures were observed before and after the tensile test (strain = 2%). Figures 7(a) and 7(c) show the microstructures before tensile test, where the bright parts represent ϵ martensite plates and the dark parts γ austenite. Figures 7(b) and 7(d) show the microstructures after tensile test, where the dark plates inside the bright ϵ parts are stress-induced α' martensites which were formed at an angle of 45° to the tensile direction.

As can be seen from Figs. 7(a) and 7(b), some of ϵ martensite plates in the 53 vol% ϵ specimen became thicker after the tensile deformation. This suggests that the migration of γ/ϵ interface associated with stress-induced martensitic transformation occurred under the tensile stress. On the other hand, it is observed from Figs. 7(c) and 7(d) that most of ϵ plates were coalesced to three big blocks (A, B, C) parallel to tensile direction due to their rearrangement during the tensile deformation. The coalescence of ϵ plates similar to this phenomenon has been also reported in Fe-Mn based alloys by other investigators.^{14,21)} Wayman *et al.*¹⁴⁾ reported that the plastic deformation of Fe-13.7wt%Mn-6wt%Si-8.3wt%Cr-5wt%Ni alloy consisting of the same phases as the Fe-17wt%Mn alloy was accomplished by the coalescence of ϵ variants due to their reorientation.

Fig. 7. Optical microstructures of the Fe-17wt%Mn alloy before and after 2% tensile deformation at room temperature.

(a) before deformation of a specimen with 53 vol% ϵ , (b) after deformation of the specimen with 53 vol% ϵ , (c) before deformation of a specimen with 90 vol% ϵ , and (d) after deformation of the specimen with 90 vol% ϵ .

Fig. 8. Transmission electron micrographs of Fe-17wt%Mn alloy.
(a) Stacking faults in γ austenite, and
(b) Stacking faults in ϵ martensite plate.

Recently, Jun *et al.*²¹⁾ have reported that the ϵ plates of Fe-17wt%Mn alloy were coalesced to big blocks elongated in parallel with the tensile direction due to the reorientation of ϵ martensite variants, and that since the coalescence was responsible for plastic deformation, the shape memory effect (SME) of the alloy increased with increasing ϵ martensite content above 60 vol%.

According to transmission electron microscopy, the stacking faults were observed both in austenite and in ϵ martensite of the Fe-17wt%Mn alloy, as shown in Fig. 8. It seems that the average density of stacking fault in ϵ martensite is much higher than that in the austenite.

4. Discussion

It has been well known that the thermoelastic martensitic alloys such as Cu-Al-Ni,²⁾ Ni-Ti³⁾ and Cu-Zn-Al²²⁾ exhibit high damping capacity. Xiao and Johari²²⁾ investigated the damping mechanisms of a thermoelastic martensitic Cu-Zn-Al alloy, and suggested that the movements of the martensite variant boundary and the martensite/parent phase interface are responsible for the damping capacity of the alloy.

As shown in Fig. 7, when the two specimens of Fe-17wt%Mn alloy consisting of γ and ϵ phases were deformed in tension (strain=2%), the γ/ϵ interphase boundaries were moved, and the ϵ plates were coalesced to big blocks due to reorientation of ϵ martensite variants. These phenomena are quite similar to the behaviors exhibited in the thermoelastic martensitic alloys, although it has not been known clearly to this time whether the Fe-17wt%Mn alloy is thermoelastic martensitic alloy or not. Thus, it is believed that the movements of the γ/ϵ interphase boundaries and the ϵ martensite

variant boundaries contribute to the damping capacities of Fe-Mn alloys containing γ and ϵ phases, as in case of the thermoelastic martensitic alloys.

Bruner²³⁾ investigated the damping capacities of f.c.c. metals such as Cu, Al and Al-0.25at%Cu alloy, and proposed that the damping capacities of these metals are attributed to the movement of partial dislocations constituting stacking fault boundaries. Therefore, according to Bruner's suggestion, the stacking fault boundaries observed in γ and ϵ in Fig. 8 can be also assumed to act as damping sources in Fe-Mn alloys containing γ and ϵ phases.

As a result, it is proposed that the damping mechanisms of Fe-Mn alloys containing γ and ϵ phases are the movements of the following defects:

- (1) γ/ϵ interphase boundary
- (2) ϵ martensite variant boundary
- (3) Stacking fault boundary in γ
- (4) Stacking fault boundary in ϵ

Since the microstructure and the damping capacity of Fe-17wt%Mn alloy were not changed even after vibration of 10^6 cycles with a strain amplitude of 6×10^{-4} , it is considered that these damping sources move back and forth to comply with such a small vibrational stress corresponding to the strain, 6×10^{-4} . However, if a specimen is vibrated with a large strain amplitude almost equal to a plastic strain, the damping sources will not move back and forth but move to only one side because of introduction of dislocations which hinder the movement of the boundaries.

Meanwhile, it is insignificant to consider the damping mechanisms for α' martensitic Fe-Mn alloys, since the 100% α' martensitic alloys such as Fe-5wt%Mn and Fe-10wt%Mn alloys showed very low damping capacities, as seen in Fig. 5.

Now, we can analyze the contributions of the damping mechanisms to the overall damping capacities of Fe-Mn alloys containing γ and ϵ phases.

In Fig. 9 where the damping capacity of Fe-17wt%Mn alloy was replotted as a function of ϵ martensite volume fraction, points A and B represent damping capacities of 100% γ phase and 100% ϵ phase, respectively. The dotted line between A and B is represented as follows:

$$\delta_c = \delta_\epsilon \cdot f_\epsilon + \delta_\gamma \cdot (1 - f_\epsilon) \quad \dots\dots\dots (2)$$

where δ_c is the damping capacity of the mixture of γ and ϵ , δ_ϵ the damping capacity of ϵ single phase, δ_γ the damping capacity of γ single phase, f_ϵ the ϵ volume fraction, and $(1 - f_\epsilon)$ the γ volume fraction since $f_\gamma + f_\epsilon = 1$. Because Eq. (2) is based on the assumption that the γ/ϵ interface has no influence on the damping capacity, the damping capacity expressed by the line AB is due to the motion of damping sources associated with γ and ϵ themselves, which are stacking fault boundary in γ , stacking fault boundary in ϵ , and ϵ martensite variant boundary, except γ/ϵ interphase boundary. Since the overall damping capacity of an Fe-Mn alloy containing γ and ϵ phases is attributed to the movement of the four damping sources mentioned in the damping mechanisms, the difference between solid curve and dotted line in Fig. 9 corresponds to the contribution of γ/ϵ

Fig. 9. Variation of damping capacity, measured at 165°C, with the volume fraction of ϵ martensite in Fe-17wt%Mn alloy. The damping capacity of the alloy is attributable to the movement of the four damping sources:
 ① γ/ϵ interphase boundary, ② ϵ variant boundary, ③ stacking fault boundary in γ , and ④ stacking fault boundary in ϵ .

Fig. 10. Variation of damping capacity of γ single phase, measured at 165°C, with manganese content in Fe-Mn alloys.

interphase boundary to the overall damping capacity of Fe-17wt%Mn alloy. Consequently, the overall damping capacity, δ , of an Fe-Mn alloy composed of γ and ϵ phases can be represented as follows:

$$\delta = \delta_c + \Delta\delta_{\gamma/\epsilon} = \delta_\epsilon \cdot f_\epsilon + \delta_\gamma(1 - f_\epsilon) + \Delta\delta_{\gamma/\epsilon} \quad \text{.....(3)}$$

or

$$\delta = \delta_\gamma + \Delta\delta_{\gamma/\epsilon} + f_\epsilon(\delta_\epsilon - \delta_\gamma) \quad \text{.....(4)}$$

where $\Delta\delta_{\gamma/\epsilon}$ is the contribution of γ/ϵ interphase boundary to the overall damping capacity.

The reason that Fe-17wt%Mn alloy shows the highest damping capacity in Fe-Mn binary system, as shown in Fig. 5, can be explained by evaluating each term on the right of Eq. (4) for Fe-Mn alloys.

Fig. 11. Variation of damping capacity, measured at 165°C, with the volume fraction of ϵ martensite in Fe-17wt%Mn, Fe-21wt%Mn, and Fe-23wt%Mn alloys.

In order to evaluate δ_γ of each Fe-Mn alloy, the damping capacity was measured at 165°C, after heating the alloy at 260°C above A_f temperature for the complete $\epsilon \rightarrow \gamma$ reverse transformation and subsequent cooling at 165°C above M_s temperature to retain the reversed γ phase. The results are shown in Fig. 10. The damping capacity of γ single phase of Fe-17wt%Mn alloy was higher than those of the other two alloys. This is probably due to not only higher probability of formation of stacking fault but also easier movement of stacking fault boundary in Fe-17wt%Mn alloy than in the other alloys, because of its lower stacking fault energy, as reported by Schumann¹⁹⁾ and Adler *et al.*²⁰⁾

To evaluate $\Delta\delta_{\gamma/\epsilon}$, the damping capacities of some Fe-Mn alloys were measured at 165°C as a function of ϵ martensite volume fraction, as shown in Fig. 11. The $\Delta\delta_{\gamma/\epsilon}$ of Fe-17wt%Mn alloy showed the largest value among Fe-17wt%Mn, Fe-21wt%Mn and Fe-23wt%Mn alloys, at all ϵ martensite contents. These results are well supported by the microstructures of Fe-17wt%Mn and Fe-23wt%Mn alloys before and after tensile test (strain = 2%) at room temperature (Fig. 12). The average widths of ϵ plates of each alloy before and after tensile test, which were measured using an image analyzer, are listed in Table 2. The difference in the average width before and after tensile test was greater in Fe-17wt%Mn alloy than Fe-23wt%Mn alloy. This suggests that the moving distance of γ/ϵ interphase boundary, on which $\Delta\delta_{\gamma/\epsilon}$ depends, is larger in the former alloy than in the latter

Fig. 12. Optical micrographs of the Fe-17wt%Mn and Fe-23wt%Mn alloys before and after 2% tensile deformation at room temperature.

(a) Fe-17wt%Mn alloy before tensile deformation, (b) Fe-17wt%Mn alloy after tensile deformation, (c) Fe-23wt%Mn alloy before tensile deformation, and (d) Fe-23wt%Mn alloy after tensile deformation.

Table 2. Average widths of ϵ martensite plates of the Fe-17wt%Mn and Fe-23wt%Mn alloys before and after 2% tensile deformation at room temperature.

	Fe-17wt%Mn		Fe-23wt%Mn	
	Before deformation	After deformation	Before deformation	After deformation
Average width of ϵ plates(μm)	1.47	3.38	0.91	1.76

Table 3. Contributions of $\Delta\delta_\gamma$, $\Delta\delta_\epsilon$, and $\Delta\delta_{\gamma/\epsilon}$ to the overall damping capacities of Fe-17wt%Mn and Fe-21wt%Mn alloys.

Alloy	f_ϵ	δ	$\Delta\delta_\gamma$	$\Delta\delta_\epsilon$	$\Delta\delta_{\gamma/\epsilon}$	$\Delta\delta_\gamma$ (%)	$\Delta\delta_\epsilon$ (%)	$\Delta\delta_{\gamma/\epsilon}$ (%)
Fe-17wt%Mn	0.83	0.205	0.029	0.170	0.006	14	83	3
Fe-21wt%Mn	0.62	0.197	0.065	0.124	0.008	33	63	4

alloy during the vibration at the strain amplitude, 6×10^{-4} .

The values of $(\delta_\epsilon - \delta_\gamma)$ for the Fe-Mn alloys are almost constant regardless of manganese content, because the dotted lines of the Fe-Mn alloys run parallel to one another, as shown in Fig. 11.

Finally, the ϵ martensite volume fraction, f_ϵ , of Fe-17wt%Mn alloy shows a maximum in Fe-Mn binary system as shown in Fig. 4.

Therefore, the reason that Fe-17wt%Mn alloy shows the highest damping capacity in Fe-Mn binary system is that the values of δ_γ , $\Delta\delta_{\gamma/\epsilon}$ and f_ϵ in Eq. (4) for Fe-17wt%Mn alloy are larger than those for the other alloys.

Equation (3) can be rewritten as follows:

$$\delta = \Delta\delta_\epsilon + \Delta\delta_\gamma + \Delta\delta_{\gamma/\epsilon} \dots\dots\dots(5)$$

where $\Delta\delta_\epsilon$ ($=\delta_\epsilon \cdot f_\epsilon$) is the damping capacity associated with ϵ martensite itself, $\Delta\delta_\gamma$ ($=\delta_\gamma \cdot f_\gamma$) the damping capacity in response to γ itself, and $\Delta\delta_{\gamma/\epsilon}$ the damping capacity due to the motion of γ/ϵ interphase boundary.

The contributions of the three terms to the overall damping capacity of an Fe-Mn alloy containing γ and ϵ phases can be analyzed quantitatively using Eq. (5) from Figs. 4 and 11. The $\Delta\delta_\epsilon$ and $\Delta\delta_\gamma$ are evaluated with

f_ϵ , δ_ϵ , and δ_γ corresponding to each alloy in Figs. 4 and 11. Then taking δ corresponding to f_ϵ of each alloy in Fig. 11, the $\Delta\delta_{\gamma/\epsilon}$ is obtained from Eq. (5) using $\Delta\delta_\epsilon$ and $\Delta\delta_\gamma$. Table 3 shows the contributions of $\Delta\delta_\gamma$, $\Delta\delta_\epsilon$ and $\Delta\delta_{\gamma/\epsilon}$ to the overall damping capacities measured at 165°C for Fe-17wt%Mn and Fe-21wt%Mn alloys. From the Table, it can be seen that the ϵ martensite bears the major part of the damping capacities of Fe-17wt%Mn and Fe-21wt%Mn alloys.

5. Conclusions

(1) It is suggested that the damping sources responsible for damping capacities of Fe-Mn alloys containing γ and ϵ phases are: stacking fault boundary in γ , stacking fault boundary in ϵ , ϵ martensite variant boundary, and γ/ϵ interphase boundary.

(2) Fe-17wt%Mn alloy possesses the highest damping capacity in Fe-Mn binary system. The reason is that the damping capacity of γ single phase (δ_γ), the damping capacity due to γ/ϵ interface ($\Delta\delta_{\gamma/\epsilon}$), and ϵ martensite volume fraction (f_ϵ) are larger in Fe-17wt%Mn alloy than the other Fe-Mn alloys.

(3) The quantitative analysis of the damping capacity

of Fe-17wt%Mn alloy shows that the contributions of ε , γ and γ/ε interface to the overall damping capacity of the alloy are 83, 14 and 3%, respectively, indicating that ε martensite bears the major part of the damping capacity of the Fe-17wt%Mn alloy.

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