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► To cite this version:

S. Takahashi, K. Takahashi. Stress Dependency on the Ultrasonic Wave Velocity and Attenuation of Fe-C System. Journal de Physique IV Proceedings, 1996, 06 (C8), pp.C8-845-C8-848. 10.1051/jp4:19968182 . jpa-00254619

HAL Id: jpa-00254619

<https://hal.science/jpa-00254619>

Submitted on 1 Jan 1996

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Stress Dependency on the Ultrasonic Wave Velocity and Attenuation of Fe-C System

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Abstract. The purpose of this study is to investigate stress dependency on ultrasonic wave propagating in stressed Fe-C systems containing 0.1 to 0.5mass% carbon. The Lamé constant, Poisson's ratio and Young's modulus were calculated from the data of the pulse echo method using 2MHz and 5MHz transducers for longitudinal and transverse waves. It was confirmed that the ultrasonic wave velocities changed with applied stress and this behavior can not be explained by the linear elastic theory.

1. INTRODUCTION

A fixed relation is recognized between stress and wave velocity by precise measuring the ultrasonic wave velocity propagating in the tensile stressed practical steels. Above experimental results were theoretically analyzed on the base of the Murnaghan's theory [1] [2]. In this report, stress-wave velocity and stress-attenuation relations were studied on the Fe-C system samples containing little impurity under compressive stress.

2. EXPERIMENT

2.1 Test specimen

Each of 0.1, 0.3, and 0.5mass%C was added to molten iron with 99.99% purity, melted and molded under the vacuum of 10^{-4} torr, hot pressed at about 1100°C, annealed at 910°C for 3hrs, air cooled out of the furnace, and then machined into cubes with a side 38mm long for compression test. The specimen was set in the Instron type tensile testing machine as shown in Fig.1 which gave compressive load by rising cross-head. The stress and strain were measured by the load cell and the strain gauge adhered on the specimen surface respectively.

The influence of interface friction between the loading rod and the specimen was reduced by specially designed jig using bearing balls. This jig was also necessary for setting the transducer on the specimen.

Figure 2 Sensor arrangement.

Figure 1 Compression test instrument.

Figure 3 Block diagram of measurement instrument.

Figure 4 Relation between stress and changing ratio of ultrasonic wave velocity for Fe-0.5%C
 ○; transverse wave propagating along the direction perpendicular to compression,
 Δ; transverse wave propagating along the direction of compression,
 ●; longitudinal wave propagating along the direction perpendicular to compression,
 □; longitudinal wave propagating along the direction of compression.

Table 1 Second order elastic constants, wave velocity, density and attenuation of Fe-C system at 20°C.

Carbon content (mass%)	Lamé constants λ (kgf/mm ²)	μ (kgf/mm ²)	Young's modulus (kgf/mm ²)	Poisson's ratio	Ultrasonic wave velocity(m/s) longitud. transverse	Density (g/cm ³)	Attenuation (dB/mm) 5MHz Transv.
0.1	11013	8253.8	21226	0.2858	5923.39 3243.89	7.8437	-0.2479
0.3	11178	8228.1	21196	0.2880	5933.74 3237.85	7.8485	-0.1848
0.5	11361	8199.8	21162	0.2904	5943.01 3229.97	7.8598	-0.1024

2.2 Sensor arrangement

Fig.2 show the arrangement of the strain gauges and ultrasonic wave transducers used for this experiment.

2.3 Measurement apparatus

The Matec instruments MBS-8000 ultrasonic test system was used for the measurement of ultrasonic wave velocity and attenuation. Fig.3 shows the schematic diagram of this system. An ultrasound pulse is introduced into one end of a sample. The first and the second echoes are received and the time of flight is obtained from these two measured echoes and digitized after mathematical correction.

Figure 5 Attenuation-stress relations of 5MHz longitudinal (solid line) and transverse (dotted line) wave propagating along the direction perpendicular to compression for Fe-C systems.

□; Fe-0.1%C, △; Fe-0.3%C, ○; Fe-0.5%C.

Figure 6 Attenuation-stress relations of 2MHz and 5MHz transverse wave for Fe-0.3%C.

3. RESULTS AND EXPLANATIONS

Fig. 4 shows the changing ratio of the propagating velocity of the longitudinal and transverse waves along the compression axis and perpendicular to it for Fe-0.5%C. The ultrasonic wave velocity changed with the applied stress and the similar results were obtained for two other specimens. These behavior can not be dealt with the linear elastic theory. Fig. 5 shows the attenuation-stress relations of Fe-C systems. The attenuation decreased with the increase of carbon content and that of longitudinal wave was smaller than that of transverse wave. It was also recognized that the attenuation changed with the applied stress. Fig. 6 shows the attenuation change with stress for Fe-0.3%C using 2MHz and 5MHz transducers.

Table 1 shows the second order elastic constants calculated from the measurement results and the attenuations of 5MHz transverse waves for each of stress free samples. From the Table, it is recognized that the values of λ , μ , Young's modulus and Poisson's ratio are slightly dependent on carbon content. The stress dependency of ultrasonic propagating velocity was found for each specimen, however the obtained nonlinear elastic constant were rather larger than expected. This is the subject for a future study.

Acknowledgments

The authors would like to thank T. Mitsui of National Research Institute for Metals and Showa Denko Co., Ltd. for preparing the samples.

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