THE INFLUENCE OF FREQUENCY ON ULTRASONIC TEST OF NUDULAR CAST IRON

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Cast Iron is the most common casting alloy which is utilized in different branches of industries. The micro structure consists of a mixture of graphite in the steel matrix. Although there are many tricks to improve the graphite's shape which lead to optimizing mechanical characteristics and developing applications of the cast iron, naturally the final alloys contain many types of discontinuities and defects, which will be increased directly by increasing the wall thickness. In other words, a numerous internal and external defects might be detected in cast iron parts (particularly with thick sections). As a result, a wide range of NDT methods are used to find out those internal and external defects in cats iron parts. Normal methods for internal defects are UT for medium and thick sections and RT for thin ones. It should be mentioned thatthick sections are more critical , not only by their structures but also by their applications.
For these reasons, NDT (specially UT) plays an important role for testing of cast iron parts, but performing UT on these alloys are so complicated and the indications are so sophisticated to interpret due to the micro structures and the presence of graphite (which is the main reason for some phenomena like the sound attenuation and diffraction in the cast irons). Although there are a lot of procedures and specifications to guide UT operators, no global settlement on detecting, sizing and making decision about the exact type of discontinuities can be found. Finally, it seems that more experimental efforts are needed to find out the outlines of UT method which is applied for Cast Irons. In this investigation, the influence of frequency as an effective parameter on UT has been reviewed. According to experimental works, the optimum range of frequency for UT of nodular cast iron parts has been introduced.

Introduction

Cast Iron is the most common casting alloy which is utilized in different branches of industries. The micro structure consists of a mixture of graphite in the steel matrix. Although, there are many tricks to improve the graphite's shape which lead to optimizing mechanical characteristics and developing applications of the cast iron, but naturally the final alloys contain many types of discontinuities and defects, which will be increased directly by increasing the wall thickness. A wide range of NDT methods are used to find out internal and external defects in cats iron parts. Normal methods for internal defects are UT for medium and thick sections and RT for thin ones. It should be mentioned thatthick sections are more critic al, not only by their structures but also by their applications. For these reasons, NDT (specially UT) plays an important role for testing of cast iron parts. Although there are a lot of procedures and specifications to guide UT operators, no global settlement on detecting, sizing and making decision about the exact type of discontinuities can be found. In this investigation, the influence of frequency as an effective parameter on UT will be reviewed.

Test Equipments

For making reliable experimental tests, it is necessary to minimize the effect of other parameters (except frequency). Kruthkramer type USM 25 was used as the UT equipment. As transducers, the normal probes in different sizes and frequencies single crystal have been selected. In table No.1, the characteristics of each probe have been mentioned. Also in figure No.1 the beam shapes of each probe have been shown. To minimize the effect of other parameters and making constant conditions, all probes have been chosen of the same brand (GE/Karuthkramer).

Table 1: Selected probes characteristics.

Probe Name	Transducer	Frequency (MHz)	Probe Diameter (mm)	Beam Shape
B1S	Single Cristal	1	24	1-24
B2S	Single Cristal	2	24	2-24
B4S	Single Cristal	4	24	4-24
MB2S	Single Cristal	2	10	2-10
MB4S	Single Cristal	4	10	4-10
MB5S	Single Cristal	5	10	5-10

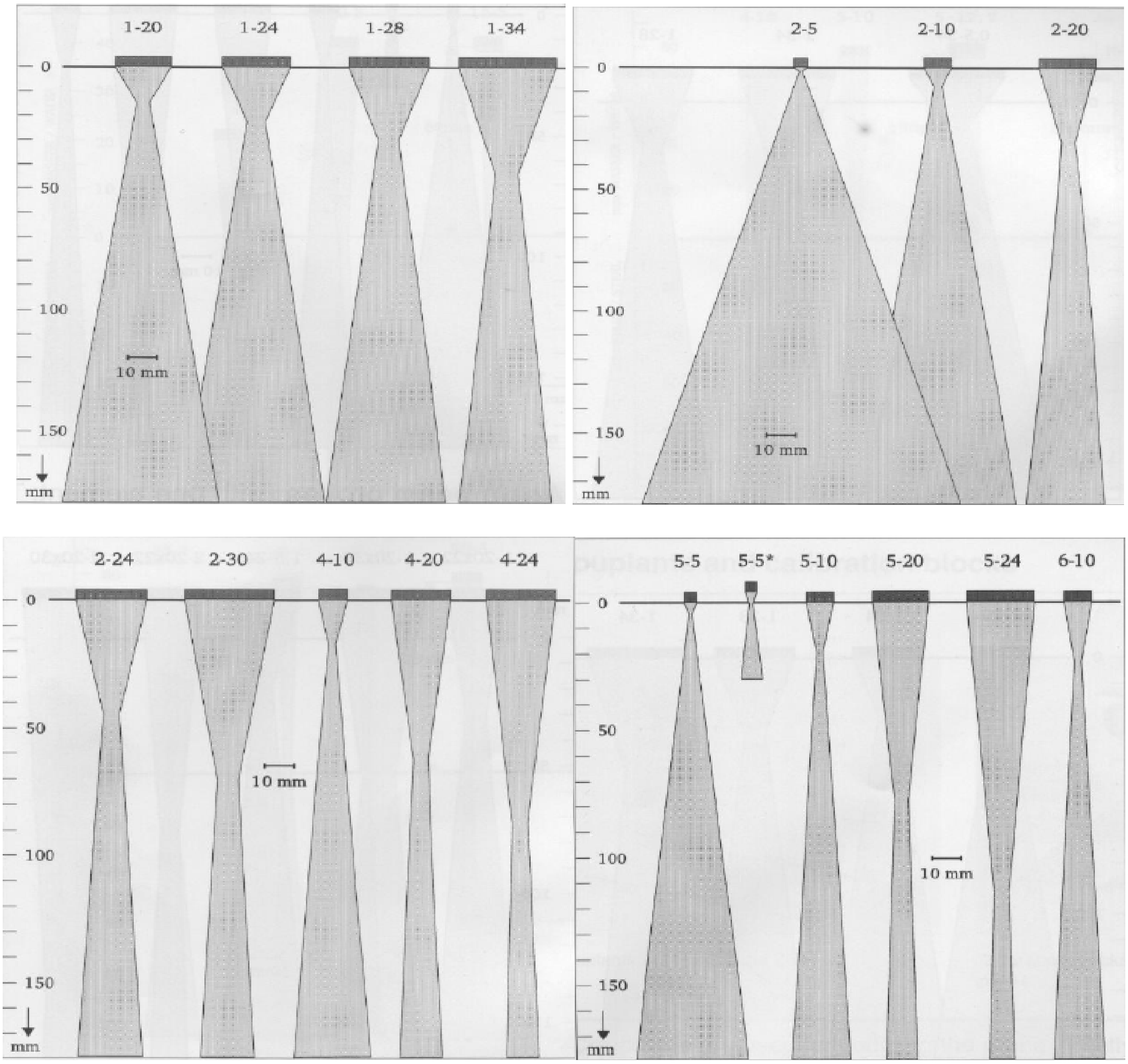

Figure 1: Probes beam shape.

Table 2: Dimensions of the made blocks.

Block code	FBH diameter (mm)	FBH distance from scanning surface (mm)	Block diameter (mm)	Backwall distance (mm)	Reference standard
GGG40-3-19.1	3	19	50.8	40	ASTM E428
GGG40-3-50.8	3	50	50.8	70	ASTM E428
GGG40-5-95.3	5	95	50.8	115	ASTM E428
GGG40-8-148.1	8	148	50.8	168	ASTM E428

According to ASTME428, four blocks has been selected with dimensions acc. to table No.2. By this way, the different thickness of nodular cast iron has been simulated.

Ultrasonic Examination

Sound Attention Test:

Due to the microstructure of the cast iron (presence of the graphite), it is so susceptible to have a high attenuation in ultrasonic waves. Although, there are many techniques to modify the graphite's shape which lead to optimizing mechanical characteristics and developing applications of the cast iron, but the attenuation seems a lot compared with the other ferrous alloys (carbon and low alloy steels). Therefore, measuring the sound attenuation in cast iron is important.

Attenuation has been assumed by the amount of dB when the back wall echo reaches the 50% height of the screen as shown in figure No.1. The test has been repeated for all of the probes on different blocks (various sections) and the relative dBs have been shown in tables No. 3.

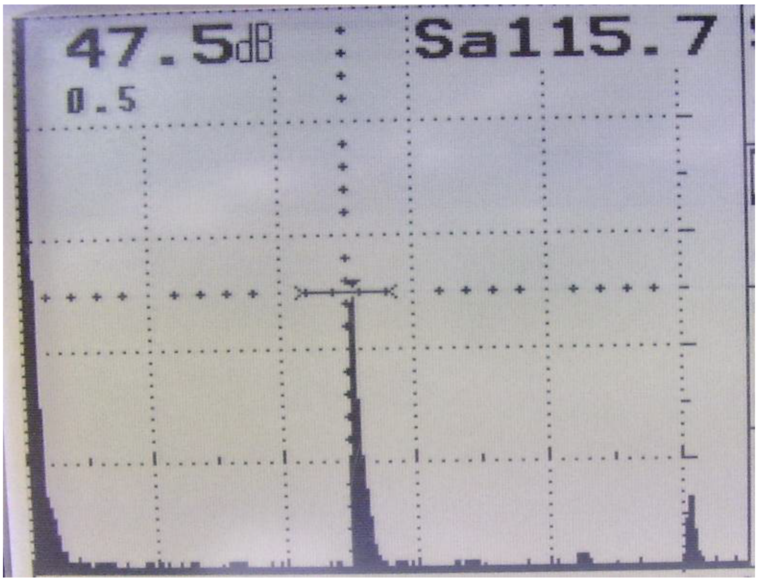

Figure 2: The typical picture of the screen in attenuation test

Table 3: dB of 50% BW for different sections

Thickness (mm)	Type of probes					
	B1S	B2S	B4S	MB2S	MB4S	MB5S
168	42	48.5	56	47	57.5	57.5
115	42	46	47.5	40.5	50	51
70	38	42.5	44.5	37	43	46.5
40	34	44.5	54	33.5	41	37.5

Detect ability Test:
In this case, the detectabilty has been assumed as the amount of dB when the echo of an artificial defect (FBH) equals to 40% of the screen height as shown in figure No. 2. The results of this test for all of the probes are mentioned in table No. 4. At the same time, the amount of back wall echo has been measured and mentioned in the table No. 5.

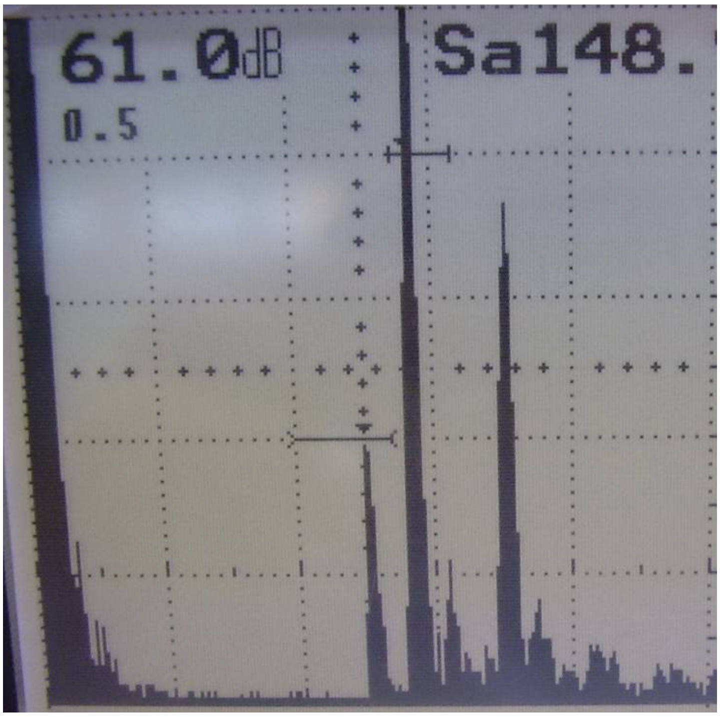

Figure 3: The typical picture of the screen in detecability test

Table 4: dB of 40% for different sections

Thickness (mm)	Type of probes					
	B1S	B2S	B4S	MB2S	MB4S	MB5S
168	63	61	58.5	60	66	68.5
115	61.5	60.5	55	57	57	62.5
70	58.5	61	63	54.5	57	53
40	50.5	66.5	64	40.5	45.5	43

Table 5: Height of B.W. echo for different sections

Thickness (mm)	Type of probes					
	B1S	B2S	B4S	MB2S	MB4S	MB5S
168	100	100	42	100	50	37
115	100	100	25	100	53	48
70	100	100	100	100	36	41
40	100	100	100	38	23	32

Results interpretation:

Figure No.4 shows the variation of sound attenuation by increasing the frequency in different sections for normal probes-single crystal 24mm. As it shows, the attenuation will be increased by using more frequency in constant situation and it is the same for big normal probes in each section. This phenomenon correlates to the relation of the wave length and the frequency. Increasing the frequency leads to shorter wave lengths so it is more difficult to pass the barriers of the microstructures (particularly graphite). It means more diffraction and absorption will be represented as attenuation of the sound beam.

Figure No.5 shows the variation of sound attenuation by increasing the frequency in different sections for normal probes-single crystal 10 mm. In this case, results have shown the same behavior. The difference is only at the end of the diagram for 40 mm thickness. Although 5 MHz transducer has more frequency than 4 MHz, its attenuation has been measured less. This exception may be related to the beam shape of the transducers of two probes in this depth (40 mm). As it seems, the beam shape of 5 MHz is more concentrated and finer, than 4 MHz, which means more reflected beam. Finally, less attenuation due to thin section means that in this section of nodular cast iron (<40mm), the material microstructure has less influence on attenuation than the beam shape.

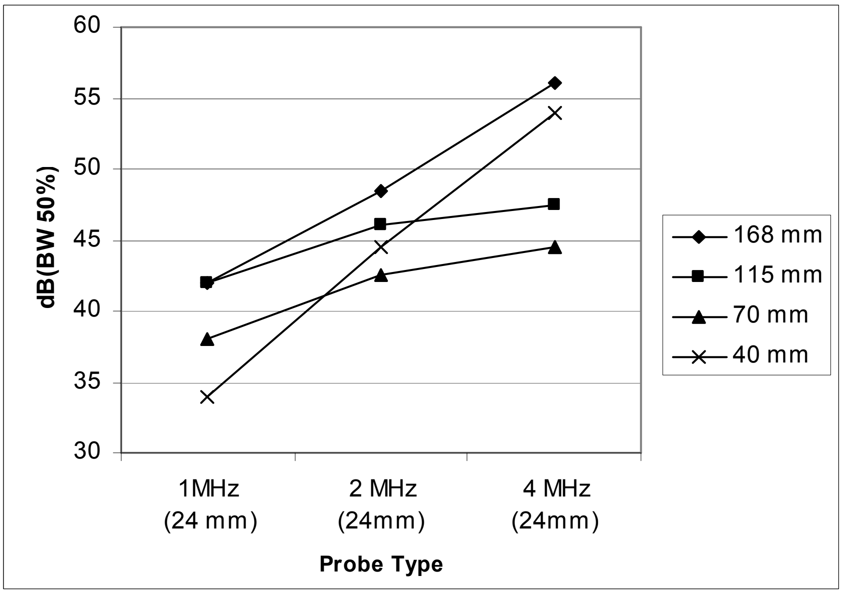

Figure 4: The effect of frequency on attenuation of big (24mm) normal probes.

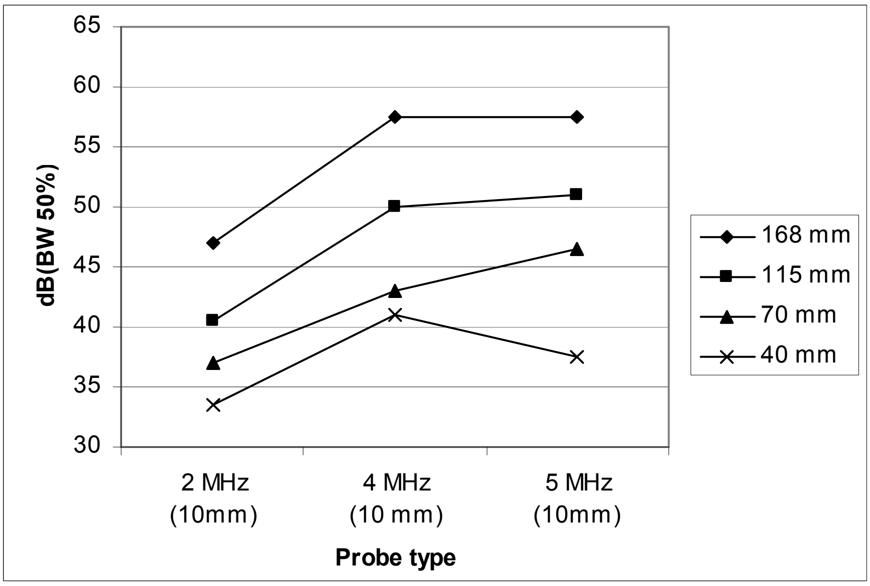

Figure 5: The effect of frequency on attenuation of small (10mm) normal probes.

Figure No.6 shows the variation of required dB for FBH echo 40% of the screen, in different sections for normal probes-single crystals. For thick sections (more than 95mm) and the same FBH (3mm), the required dB for 40% FBH will be decreased by more frequencies. It is due to better resolution (the ability of finding small indications) for more frequencies which itself is the result of more concentrated beam. This interpretation also can be confirmed by referring to the beam shapes on figure No.1.

On the opposite side, for sections less than 95mm, the relation is vice versa and it means that the required dB for FBH 40% will be increased by addition of the frequency. As shown in figure No.1, in 19 mm distance, FBH is located in near zone of both 2&4 MHz probes and there is the same situation for 4MHz in 50mm.

Although better resolution for more frequencies can be attained in thick sections, another effective factor for detectability is the remaining BWE during detecting the indications, as shown in table No.2. In some cases better resolution/more concentrated beam shape leads to missing BWE which means thatthe scanning is not reliable.

Figure No.7 shows the variation of dB by increasing the frequency in different sections for normal probes-single crystal 10 mm. In this case (small beam size), increasing frequency leads to not only more required dBs for 40% FBH but also the remaining BWE is negligible. As a result, for this beam size (small normal probes in any sections of nodular cast iron), due to attenuation of the microstructure, detecability will be decreased by more dB.

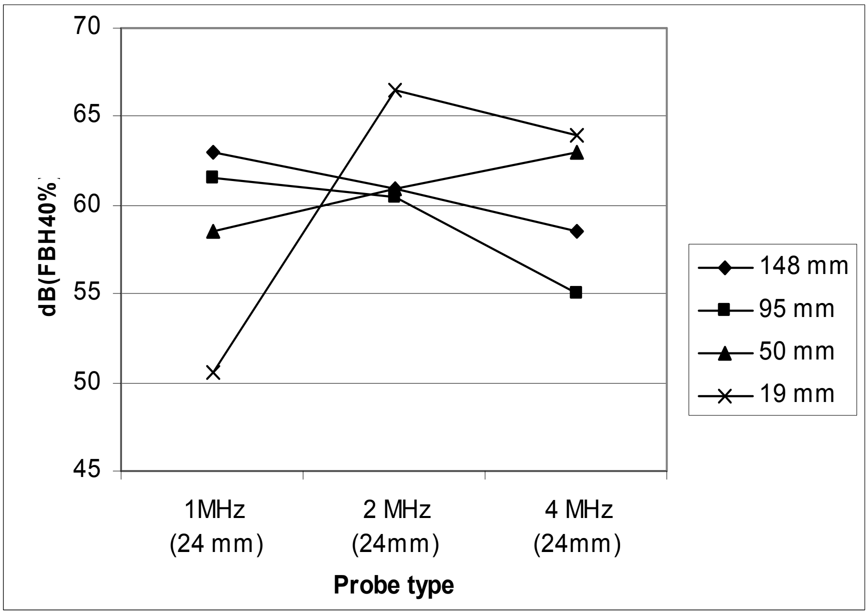

Figure 6: The effect of frequency on resolution of big (24mm) normal probes.

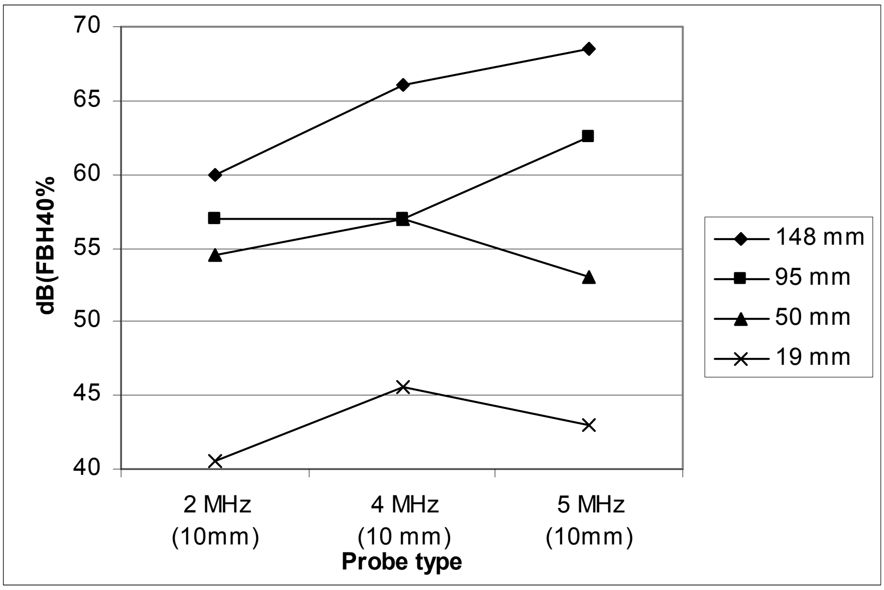

Figure 7: The effect of frequency on resolution of small(10mm) normal probes.

Conclusions

1. The attenuation of sound will be increased by additional frequencies in nodular cats iron.
2. In thin sections of nodular cast iron, the effect of the microstructure will be less in comparison to other parameters.
3. Detectability will be influenced by resolution and attenuation of the sound beam.
4. Resolution/sensitivity will be increased by increasing the frequency.
5. In thick sections of nodular cast iron, resolution will be influenced by not only the frequency but also the microstructure.
6. For small normal probes, microstructure of nodular cast iron has the major effect in UT.
7. The results will be varied in any section which is located in near fields of the normal probes.
8. The most optimum frequency for UT of nodular cast iron by normal probe is 2.
9. More investigations will be needed about the other effective parameters on ultrasonic testing of nodular cast iron to find out the outlines of this test.

References

1. M. Sanami, M. Jafari& A. Ardeshiri, NDT role in cost reduction and prevention of possible integrity damages of casting turbine parts for power plants, 5th Middle east NDT Conference, Bahrain -Nov .2009.
2. M. Sanami& M. Jafari, Ultrasonic Inspection of Nodular Cast Iron Parts Utilized in Fabrication of Power Generation Turbines, 18th Annual ASNT Research Symposium & Spring Conference, Saint Louis-USA16- 20 March 2009.
3. M. Sanami& M. Jafari, Reviewing and Detecting of Volumetric Discontinues in Nodular Cast Irons, 2nd International Conference on Technical Inspection and NDT, October 21st & 22nd, 2008.
4. M. J. Golis, ASNT Level III Study Guide Ultrasonic Method, ASNT Inc., Sep.
5. ASNT Hand Book, Vol. 7, Ultrasonic Testing, 2007.
6. Explanations for the probe data sheets, Krautkramer-Branson Company.
7. Ultrsonic Testing Training Coarse, Persian Pioneers of Technique NDT Training Center, 2004.