

LOCATION SWANSEA

LEVEL 7

**EXAMINATION PERIOD
MAY 2015**

LLEOLIAD ABERTAWE

LEFEL 7

**CYFNOD ARHOLIADAU
MAI 2015**

**MODULE CODE: M7X00731
Ultrasonic Methods**

TIME: 2 HOURS

ANSWER ALL QUESTIONS

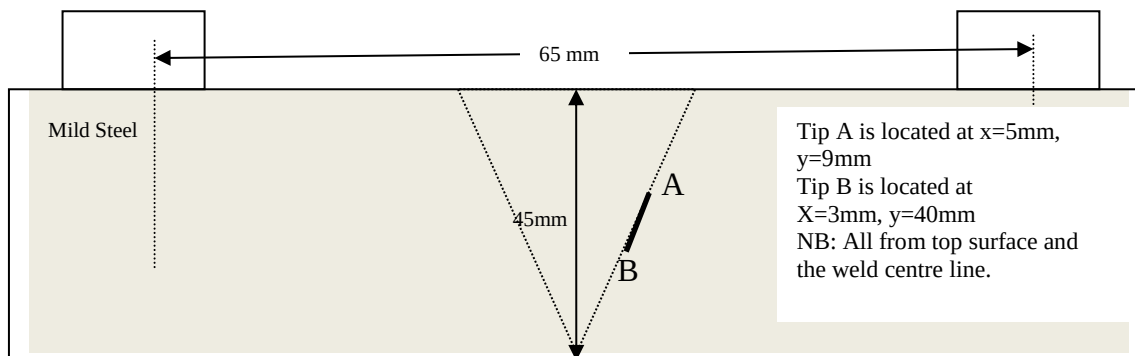
Formulae and Material Properties on last two pages

ANSWER ALL QUESTIONS

Question 1. Total Marks - 20

For the following TOFD inspection configuration

- Determine the arrival times for the lateral, tip diffraction and back wall signals. For simplicity disregard wedge delays and use probe index points only. **(6 marks)**
- Develop and sketch a TOFD depth/arrival time correlation curve for the TOFD configuration described previously. Use the basic TOFD assumption that defect signals are assumed to originate centrally between the probe pair, and use at least 5 equally spaced depth values. Mark on the illustration the theoretical minimum depth value calculated previously, and comment on the depth resolution characteristics of the technique. **(10 marks)**
- If the transmit pulse length is assumed to be 2 cycles at the probe centre frequency (7.5MHz), determine the system's theoretical near surface resolution limit. **(4 marks)**
- The probes used in the system are specified as having a 'Q' factor of 1.75. Determine the upper and lower spectral components. How does this relate to defect sensitivity. **(2 marks)**
- Briefly explain why any transmitter generated shear waves do not interfere with the general TOFD signal interpretation. **(2 marks)**



Question 2. Total Marks - 20

- What do we mean by the term 'Q' factor and how is it used with regards an ultrasonic probe specification. **(6 marks)**
- For an 8mm diameter PZT crystal of thickness 1mm, and given that the compression wave velocity for PZT is 3000m/s, determine the crystals near field distance when transmitting into Perspex. **(2 marks)**
- If the crystal is in direct contact with a mild steel surface, calculate the theoretical -6dB ultrasonic beam width for the crystal at a thickness in mild steel of 60mm. **(2 marks)**
- If a suitable Perspex delay line were to be used determine the change in -6dB half beam spread angle at a Perspex/mild steel interface. **(2 marks)**

- v) For an ultrasonic probe with a 'Q' factor of 1.6 and wavelength of 1.192mm in steel, estimate its centre frequency and spectral bandwidth. State the upper and lower frequency values that would have been used in its initial determination. How does this relate to minimum detectable defect size? **(4 marks)**
- vi) A 5MHz 45° single crystal shear wave mild steel probe with a Perspex wedge is used to inspect an aluminium component of nominal wall thickness of 150mm. Determine the full surface skip distance in the component. Estimate the error that would occur in this value if the incorrect angle was used. **(4 marks)**

Question 3. Total Marks – 20

- i) For a single element rectangular ultrasonic crystal, show that the field distribution in the far field can be given as:

$$A(\theta) = a_o d \frac{\sin(\alpha)}{\alpha}$$

Where a_o is the ray amplitude, $\alpha = k \frac{d}{2} \sin(\theta)$ where k is the wave number ($2\pi/\lambda$) and d is the aperture width. **(8 marks)**

- ii) A direct contact 64 element 10MHz array probe with an element pitch of 0.5mm is used to inspect a mild steel component. An aperture size of 16 elements is used to perform a linear B-scan. Using the fraunhofer 'far-field' approximation, produce a normalised directivity graph for the specified aperture size. Hint: Use angles from 0 to 10° with 1° increments. **(4 marks)**
- iii) Using your directivity derived values determine and plot the spatial intensity distribution at a depth of 70mm. **(4 marks)**
- iv) Estimate from the plots the -6dB and absolute beam widths at this depth and compare these to those that would be obtained using the half angle approximations. **(4 marks)**

Material Properties.

Material Units	Velocity (C) m/s x 10 ³	Velocity (S) m/s x 10 ³	Density kg/m ³	Acoustic Impedance
Air	0.33	-	1.2	0.0004
Aluminium	6.40	3.13	2700	17.3
Barium Titanate A	5.26	-	5700	30.0
Barium Titanate B	5.53		5700	31.5
Beryllium	12.89	8.88	1800	23.2
Brass	4.37	2.10	8450	37.0
Cast Iron	3.5 to 5.6	2.2 to 3.2	7200	25 to 40
Copper	4.76	2.33	8930	42.5
Glass (Crown)	5.66	3.42	3000	17.4
Gold	3.24	1.20	19300	63.0
Iron	5.96	3.22	7850	46.8
Lead	2.40	0.79	11300	27.2
Lead Niobate	2.76	-	5800	16.0
Lead Zirconate Titanate A	3.00	-	7600	22.8
Lead Zirconate Titanate B	3.00	-	7500	22.5
Lithium Sulphate	5.45	-	2060	11.2
Magnesium	5.74	3.08	1720	9.90
Mercury	1.45	-	13550	19.6
Molybdenum	6.25	3.35	10200	63.7
Nickel	5.48	2.99	8850	48.5
Oil	1.44	-	900	1.3
Perspex	2.68	1.32	1200	3.2
Platinum	3.96	1.67	21400	85.0
Polystyrene	2.35	1.12	1060	2.5
Steel (Mild)	5.96	3.24	7850	46.7
Steel (Stainless)	5.74	3.13	7800	44.8
Silver	3.70	1.70	10500	36.9
Tin	3.38	1.61	7300	24.7
Titanium	5.99	3.12	4500	27.0
Tungsten	5.17	2.88	19300	100.0
Tungsten-Araldite	2.06	-	10500	21.65
Tungsten-Carbide	6.65	3.98	10000 to 15000	66.5 to 98.5
Uranium	3.37	2.02	18700	63
Water	1.48	-	1000	1.48
Zinc	4.17	2.48	7100	29.6
Zirconium	4.65	2.30	6400	29.8

Formulae

Snell's Law: $\frac{\sin i}{V_1} = \frac{\sin r}{V_1} = \frac{\sin R}{V_2}$	Reflected Energy Equation: $RE = \frac{Z_1 - Z_2}{Z_1 + Z_2} \times 100\%$
Ultrasonic Beam Formulae: $NF = \frac{d^2}{4\lambda}$ Where: NF = Near Field Distance d = Crystal diameter or aperture width λ = wavelength	Far Field Approximation: $A(\theta) = \frac{\sin(\alpha)}{\alpha}$ Where $\alpha = k \frac{d}{2} \sin(\theta)$ K is the wave number ($2\pi/\lambda$) and d is the aperture width.
$\sin \frac{\theta}{2} = \frac{1.22\lambda}{D}$ Defines the absolute edge $\sin \frac{\theta}{2} = \frac{0.56\lambda}{D}$ Defines the 6 dB edge	$\sin \frac{\theta}{2} = \frac{1.08\lambda}{D}$ Defines the 20 dB edge
Q Factor $Q = \frac{f_0}{f_2 - f_1}$ Where: f₀ = the centre frequency f₂ = the upper -6dB frequency f₁ = the lower -6dB frequency	
Frequency thickness crystal constant: $f \times t = V/2$ Where, • f = desired frequency • t = crystal thickness, and • V = compression wave velocity in the crystal material	