UT OF STEEL FORGINGS BY TRANSVERSE WAVES. COMPARISON OF EVALUATION AND ACCEPTANCE LEVELS OF FRENCH NUCLEAR PRACTICE (RCC-M) AND NEW EUROPEAN STANDARDS.

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Abstract: According to European standard EN 10228-3, for UT of ferritic forgings by transverse waves, the reference level shall be set by reference to a Distance Amplitude Curve (DAC) for a Ø 3 mm side drilled holes or by the Distance Gain Size (DGS) method based on a disc shaped reflector (DSR).

In accordance with the RCC-M code (Design and Construction Rules for mechanical Components of PWR Nuclear Islands) the reference level is set by reference to a DAC curve for a Ø 2 mm side drilled holes for the thicknesses over 100 mm and by reference to notches having a depth linked to the thickness when this dimension is less or equal to 100 mm.

Therefore, EDF and FRAMATOME, in the frame of AFCEN (French Society for Design and Construction Rules for Nuclear Islands Components), decided to launch a study in order to:

- compare the amplitude obtained on different types of reflectors scanned with a 45° refraction angle probes,
- determine the influence of the probe frequency and transducer size.

This paper presents the results obtained on reference blocks of thicknesses ranging from 15 to 100 mm which contain different type of artificial reflectors.

Finally, this study should lead to the introduction in RCC-M code of European standard EN 10228-3 dealing with UT of ferritic forgings by transverse waves. The selection of the method to be used for reference level setting and the choice of the quality classes shall permit to maintain the quality level.

1. Goal of the study

The goal of study is to compare the conditions of evaluation of indications detected in steel forgings with Transverse Waves (TW) according to RCC-M code and to European standard EN 10228-3. Then the introduction of these European standards in RCC-M code is considered.

This study deals with the UT examination of ferritic steel forgings from families 3 (hollow cylindrical parts) or eventually 4 (complex shaped parts) for which the RCC-M code and the EN standard call for a scanning with transverse waves.

2. Comparison of prescriptions of RCC-M and EN 10228-3

The table given in appendix 1 recapitulates the type of artificial reflectors, recording level and acceptance levels stipulated in RCC-M code and in EN 10228-3 standard.

3. Reference blocks. Probes used. Amplitude evaluation of artificial reflectors.

Two reference blocks have been prepared.

The block N°1 is a “steps” block with different thicknesses from 16 mm to 120 mm. This block N°1 contains Ø 2 mm Side Drilled Holes (SDH) and rectangular notches having a length of 70 mm, a with of 1 mm and depths of 1 or 1.5 mm.

The block N°2 has a thickness of 120 mm; one of the lateral sides makes an angle of 45° with the horizontal plan. It contains Ø 3 mm Side Drilled Holes (SDH) and Ø 3 mm Flat Bottom Holes (FBH) machined on the 45° lateral side.

The tests have been performed with 2 and 4 MHz transverse wave probes. For each frequency 2 nominal sizes probes have been used 20x22 mm (WB probes) and 8x9mm (MWB probes).

For each probe and each artificial reflector, the amplification value required to adjust the echo amplitude at 80% of screen height has been recorded together with the corresponding acoustic path length.

4. Results analysis

The graphic presentations of the data gathered are given in appendix 2.

4.1 Forgings ≤ 100mm (notches vs. SDH ∅3mm)

The notches have a higher reflectivity than the SDH that cause higher amplitude of the signals.

The transition from notches reflectors to Ø 3 mm SDH leads to a more stringent recording level. For the same acceptance level, the examination performed with a setting using notches is therefore less severe.

Moreover, for the extended and grouped indications (concept non-existent before), the acceptance level of EN 10228-3 is equal to the recording level, that here again gives a more severe examination.

These facts seem however compatible with the quality level usually obtained on this type of product.

For the same type of reflector and the same ultrasound path, the gain settings are different for the frequencies of 2 and 4MHz. However, the difference of gain settings between 2 types of reflectors for the same ultrasound path and the same frequency stays almost constant.

This situation leads us, contrary to the standard EN 10228-3, not to modulate the levels of recording and acceptance according to the frequency. It is thus necessary to change quality class according to the frequency of the implemented probe.

To keep recording and acceptance levels at least equivalent to the present prescriptions which do not differentiate the materials of various RCC-M classes, the following table should apply:

Frequency MHz	EN 10228-3 Quality Class
1	2
2	3
4	4

4.2 Forgings ≤ 100mm (Notches vs. FBH ∅3 mm)

The notches reflect the ultrasound beam much more than the FBH ∅3mm (from 6 to 12 dB according to the frequencies and the type of probe).

The transition from the RCC-M's notch reflector to the quality class 3 of the standard EN 10228-3, for the method DGS (evaluation level Ø 3mm, acceptance level Ø5mm) and for the thicknesses ≤ 100mm, leads to more severe recording and acceptance levels. Such prescriptions nevertheless exist in RCC-M code for the examinations with Longitudinal Waves (LW) 0 °. So, to keep the same levels of stringency the following criteria can be envisaged for the examinations with Transverse Waves:

RCC-M Class	EN 10228-3 quality class	Recording level	Acceptance level isolated indication
1	3	Ø 3mm	Ø 5mm
2 & 3	2	Ø 5mm	Ø 8mm

4.3 Forgings > 100mm (SDH ∅2mm vs. SDH ∅3mm)

The SDH Ø 3mm reflect the ultrasound beam better than the SDH Ø 2mm of about 1 to 3dB according to the frequencies of probes.

The transition from SDH Ø 2mm to the SDH Ø 3mm for the thicknesses > 100 mm makes less severe the recording level in the same proportion.

To keep recording and acceptance levels at least equivalent to the current prescriptions, it is necessary to modulate the EN 10228-3 quality class according to the frequency of the implemented probe.

Frequency MHz	EN 10228-3 Quality Class
1	2
2	3
4	4

Let us note that for the isolated indications, if we keep an acceptance level equal to 100 % of the reference we thus lead to a bit less severe examination. On the other hand, for the extended and grouped indications (non-existent notion previously) an acceptance level equal to 50 % of the reference leads to a more stringent examination.

In a global way, for the forgings > 100mm, the transition to the European standard in the conditions proposed above is compatible with the aimed quality level and that industrially obtained.

4.4 Forgings > 100mm (SDH Ø 2 mm vs. FBH Ø3 mm)

Considering the divergence (expansion) of the acoustic beam for the depths superior to 100 mm the reflective surface of a 2 mm SDH, due to its length, is clearly more important than a FBH of Ø 3mm.

As a consequence, for the thicknesses superior to 100 mm the transition from a SDH Ø 2 mm to a FBH of Ø 3 mm leads to a more severe examination.

For the examinations with LW 0 °, the current RCC-M defines different levels of severity according to the RCC-M class of the part.

By coherence with this approach, the recording level and the following acceptance criteria can be envisaged for the transverse waves.

RCC-M Class	EN 10228-3 quality class	Recording level	Acceptance level isolated indication
1	3	Ø 3mm	Ø 5mm
2 &t 3	2	Ø 5mm	Ø 8mm

5. Discussion

According to the RCC-M code presently applied, for the ultrasonic examination with Transverses Waves, the recording and acceptance levels are identical whichever the RCC-M class of the material.

This approach is different from that retained by the RCC-M code for the examination with LW 0 ° who distinguishes the various RCC-M classes.

The European standard introduces this notion of modulation of criteria according to the quality class of the product.

By coherence, we examine below the possibility of such a distinction for the examinations with Transverse Waves.

5.1 Thicknesses ≤ 100mm

As mentioned previously, the transition from RCC-M's notches to SDH Ø 3mm or TFP Ø 3mm leads to more severe recording and acceptance levels.

This greater severity seems acceptable for the class 1 RCC-M, at the same time a modulation of the criteria can be envisaged as regards the RCC-M classes 2 and 3.

As a consequence, we propose the following criteria according to the technique implemented:

		RCC-M class 1	RCC-M classes 2 & 3
		EN 10228-3 quality class	
DAC Ø 3mm	Frequency MHz		
	1	2	Not applicable (1)
	2	3	2
	4	4	3
DGS	Not applicable (2)	3	2

(1): There is no material level 2 or 3 for which the RCC-M prescribes a frequency of 1MHz.
(2): For this technique the standard EN10228-3 does not distinguish the criteria according to the frequency of the probe.

5.2 Thicknesses > 100mm

The transition from 2mm SDH to the Ø 3mm SDH makes a little less stringent (1 in 3dB) the recording and acceptance levels. On the other hand the transition to a FBH Ø 3mm leads to a more severe examination.

Moreover the European standard introduces criteria for the extended and grouped indications with an acceptance level equal to 50 % of the reference, what increase the stringency of the examination with regard to the previous practice.

Considering what precedes, the application of the DAC (3 mm SDH) or DGS (3mm FBH) methods is technically acceptable. The joint application of these various requirements guarantees a quality level globally equivalent to that of the previous practice.

In these conditions the criteria proposed for the thicknesses ≤100mm can also be applied for the thicknesses >100mm with the same modulation according to the RCC-M class of the materials.

6. Conclusion

The amplitudes obtained on different types of reflectors (notches, SDH, FBH) scanned with a 45° refraction angle have permitted to compare the stringency of the different methods for the evaluation of indications detected on ferritic forgings by ultrasonic testing with Transverse Waves.

It appears clearly that the transition from the rectangular notches (1 to 1.5 mm) to 3 mm SDH or FBH, for the selected recording and acceptance levels, leads to a more stringent examination but still compatible with the quality level currently obtained on forgings.

Through our tests we haven't verified for the DAC method the pertinence of a modulation of the criteria according to the frequency.

For the two standardized methods (DAC, DGS), the results allow to select the quality classes according to EN 10228-3 in order to get comparable stringency and, in any case, to maintain the previous quality level of the forgings.

The subsequent modifications will be introduced in RCC-M code.

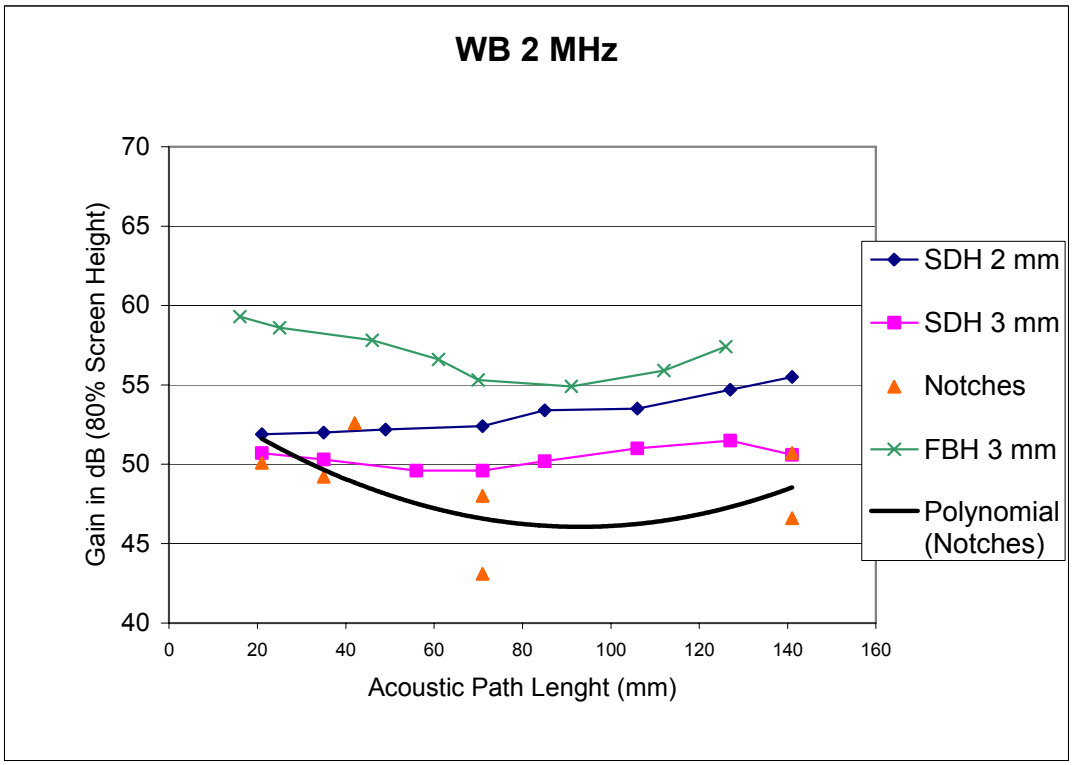
Appendix 1: Forgings. UT by transverse waves. Comparison of prescriptions of RCC-M code and European standard EN 10228-3

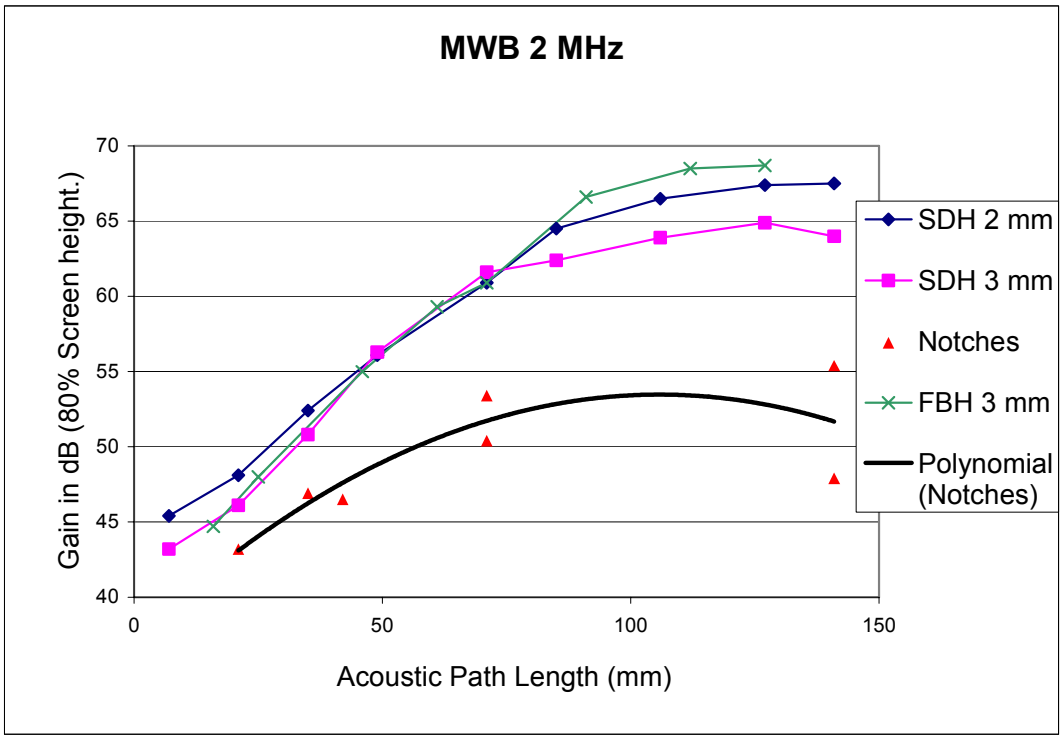
	Reference Artificial Reflectors	Recording Level	Acceptance Level
RCC-M Code	t ≤ 100 mm :Rectangular Notches Depths in mm : t ≤ 20 p = 5% e with 0,1 min. 20< t ≤ 50 p = 1 50< t ≤ 100 p = 1,5 t > 100 mm : SDH Ø 2 mm	50% of reference 50% of the reference	100% of reference 100% of the reference
NFA 04-308 French standard	Rectangular or Triangular Notches Depth 3% t, with 7mm max.	50% of the reference	100% of the reference
EN 10228-3 European standard	Diagram of reflectivity Method : DGS[1] method. No need of Reference Bloc[2]	Quality Class : 2 > d_{eq} 5mm 3 > d_{eq} 3mm 4 > d_{eq} 2mm	Quality Class : 2 ≤ d_{eq} 8 / 5mm^3 3 ≤ d_{eq} 5 / 3mm^3 4 ≤ d_{eq} 3 / 2mm^3

	Distance Amplitude Curve Method (DAC): SDH Ø 3 mm	Quality Class : 2 1 MHz: 50% ref. 2 MHz: 100% ref. 3 2 MHz: 50% ref. 4 MHz: 100% ref. 4 2 MHz: 30% ref. 4 MHz: 50% ref.	Quality Class 2 1 MHz: 100 / 50% ref.[3] 2 MHz: 200 / 100% ref.[3] 3 2 MHz: 100 / 50% ref.[3] 4 MHz: 200 / 100% ref.[3] 4 2 MHz: 60 / 30% ref.[3] 4 MHz: 100 / 50% ref.[3]

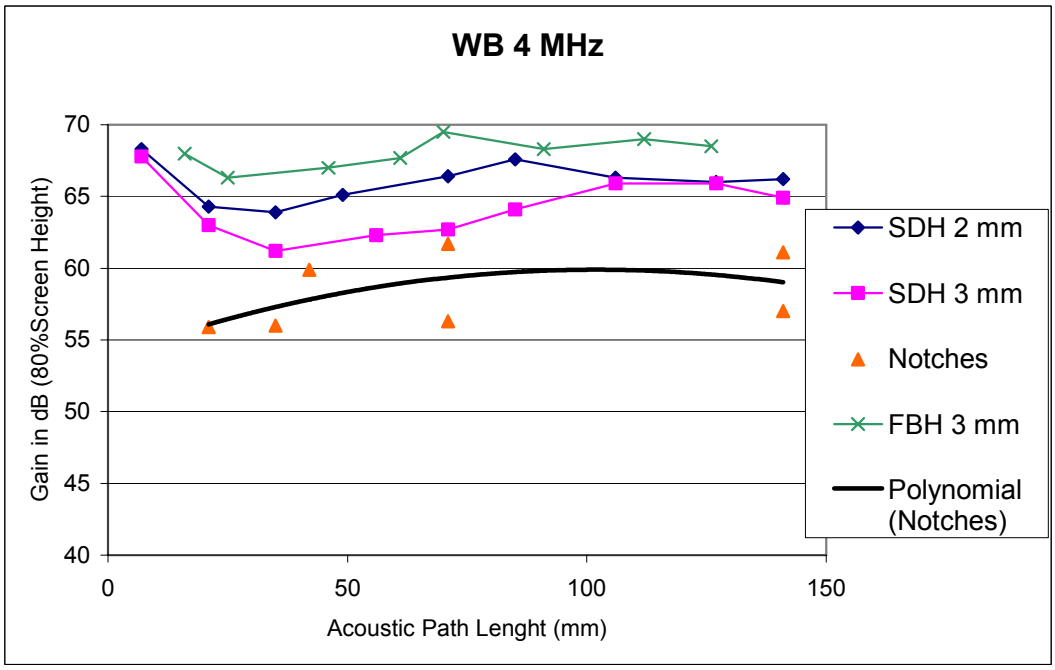
1) DGS = Distance, Gain, Size.
2) Reference block should not be used for the DGS method, unless this is explicitly required in order to check a particular diagram of reflectivity.
3) Isolated Indication / Grouped or Extended Indications.

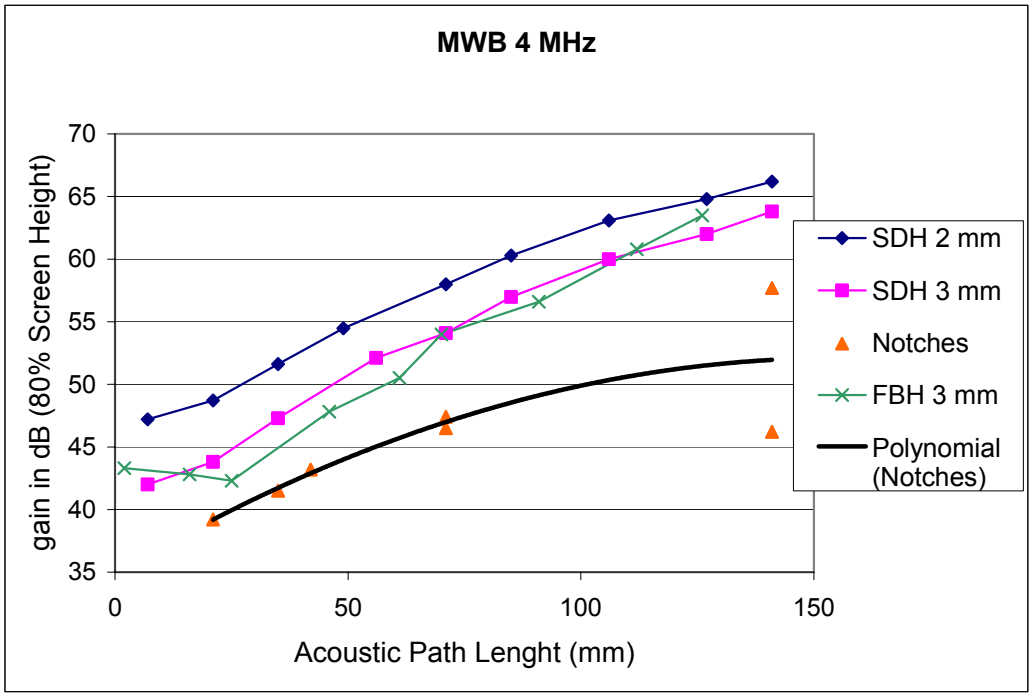
Appendix 2: Forgings. UT by transverse waves. Tests results.





Appendix 2 (continued): Forgings. UT by transverse waves. Tests results.




MWB 4 MHz
gain in dB (80% Screen Height)
70
65
60
55
50
45
40
35
0
50
100
150
Acoustic Path Lenght (mm)
SDH 2 mm
SDH 3 mm
Notches
FBH 3 mm
Polynomial (Notches)