Is there a need for a new standard for determination of steel cleanliness using hign frequency ultrasonic testing?

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Abstract

Increased use of high performance steel (HPS) for demanding applications calls for non-destructive ultrasonic testing methods which is covered by standards like SEP 1927 (1) and ASTM E588 (2). Here, an adaption of standards like increasing sensitivity and resolution of ultrasonic testing may be needed in order to improve determination of steel cleanliness.

Modern requirements on standardization in that field have been evaluated during the INCAFAT project "A novel approach for rating fatigue-initiating inclusions in highly demanding steel" which was funded by the European Commission.

Main results of this research show that an adapted standard should be open to different type of specimen due to the diversity in application. This includes a wide range from bars, rings and plates as well as different inspection sensitivities. An adapted standard should be open to the definition of the volume to be investigated and open to be selected by the user. Furthermore, for enhanced resolution the frequency range should be extended to higher frequencies. The use of focal beam probes shall be mandatory and probes should be selected according to the geometry of the specimen. Therefore, calibration procedures have to be improved significantly to allow proper sizing of indications. Indication height shall be directly transferred into an equivalent disc shaped reflector taking distance amplitude curves as well as signal amplitude distribution and signal travel time into account.

A new standard draft proposal taking all these requirements into account has been filed in the frame of the INCAFAT project and is now on discussion.

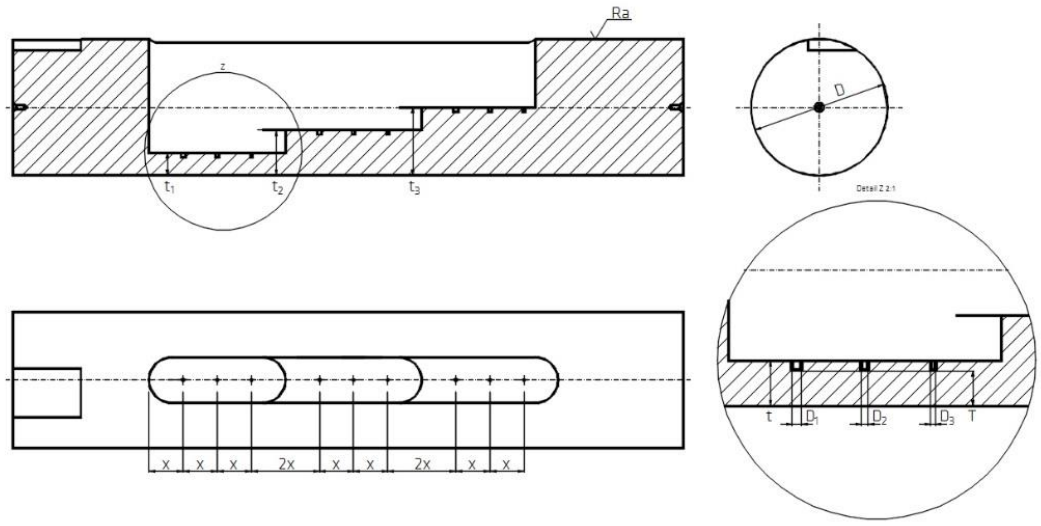
1. New standard proposal

The standard proposal addresses high frequency investigation using mechanized ultrasonic immersion testing as measurement method of the acoustic cleanliness grade of steel. Here, a defined volume of the specimen should be characterized for specific geometries. Measurements have to be carried out by using a minimum probe frequency of 10 MHz.

The new standard should follow SEP 1927 incorporating aspects of ASTM E588 (3). In addition, the standard should be open to different types of specimen and inspection frequencies to cover a wide range of products from bars, rings and plates as well as different inspection sensitivities.

To keep the standard draft as close as possible to its relatives, for specimen which fulfil existing requirements (e.g. bars) investigations should be carried out in dependence on SEP 1927 except using focal beam probes with optimized water path distance. Reference block design in this case shall follow figure 1. The evaluation of indications has to follow the guidelines of the new proposal.

The standard draft focuses on immersion focal beam probes in order to enhance resolution. The probes should be selected according to the geometry of the specimen which has to be proved by simulation tools (4). The frequency used for inspection shall be at least 10 MHz. For specimen thicknesses of less than 6 mm a frequency of at least 25 MHz shall be used.



D = diameter of calibration block
$T_{1,2,3}$ = material thickness
T = depth of FBH reflector

$D_{1,2,3}$ = Diameter of FBH reflector
Ra = roughness of surface
x = distance between artefacts

Figure 1: Reference block for bar type specimen (in style of SEP 1927)

Scanning grid has to be fine in order to achieve a high resolution. The mechanical resolution of the scanning system has to be at least in the range of the radius of the smallest flat bottom hole (FBH) which is used for calibration.

Defects larger than the sound field diameter at the region of reflection will be evaluated by area evaluation taking amplitude distribution and travel time into account. Defects smaller than the sound field at the region of reflection will be evaluated by maximum amplitude.

Calibration procedures have to be improved significantly compared to the standards like SEP 1927 to allow sizing of indications. Therefore, signal processing should be taken into account which is dependent on the type of specimen. The filed standard draft has to be open to future developments including improved measurement systems and signal processing. Therefore, it will give only examples as basic guidelines.

The novelty of the standard draft is to include more criteria for classification like signal amplitude, signal amplitude distribution and signal travel time based on 3D measurements and 3D evaluation.

Basis of investigation and of the standard draft is cleanliness of steel. Therefore, it is normally not necessary to cover the complete volume of the specimen and it should be sufficient to concentrate on a certain area. The standard draft will be open to the definition of the investigated volume to be set by the user. This makes evaluation more comparable to other methods, since inspected area is user defined.

Machining of the calibration blocks has to be performed at a high level of accuracy and sophisticated machining procedures has to be used. Reproducible quality of artificial flaws in the 100 µm regime is challenging. Laser drilling machining and EDM are two methods having the potential to fulfil the needs.

A test and calibration block with at least nine reflectors has to be used for detailed evaluation of the amplitude dependency and for calibration. The area of interest comprises three different reflector´s sizes in three different depths have to be present (see fig. 2). Calibration is done by evaluating the distance amplitude curves (DAC) on the calibration block. Damping shall be taken into account by measuring the damping factor on a sequence of backwall echos using the calibration block. The DAC should be proved and smoothed by simulation.

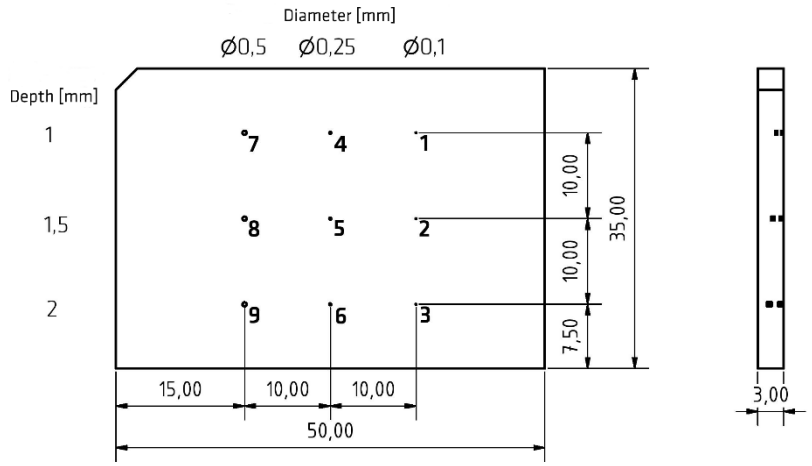


Figure 2: Calibration block for plate type specimen

Because the reflectivity and the real size of the flaws are unknown, the amplitude information of the reflected signal is used to evaluate an equivalent disc shaped reflector (EDSR). Hereby the recorded echo height shall be directly transferred into an EDSR by a distance amplitude curve. If the EDSR equals the sound field diameter or the affected area is larger than the maximum EDSR of the DAC, evaluation of size, shape and depth has to be carried out by assessment of the pixel cluster.

The standard draft proposal gives sensitivity equipollent sizing classes only. This proposal will not give any acceptance criteria.

Calculation of cumulative values for the purity grade in a certain volume shall be carried out using formulas given in standards SEP 1927, but taking travel time and specimen geometry into account additionally.

3. Conclusions

A new standard draft proposal for non-destructive high frequency UT testing has been created during the INCAFAT project. The proposal describes procedures to determine the acoustic steel cleanliness grade. The standard draft has been filed to be submitted to the European Committee for Standardization (CEN) to become a European standard. The filed document is proposed to be used as basic working draft which can be modified, finalized and agreed on by an international technical committee.

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