TESTING OF HEXAGONAL AND OTHER EDGE PROFILED MATERIALS BY USING ULTRASONIC PHASED ARRAY PROBES ARRANGED ANNULARLY

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1. Introduction

Many manufacturers of semi-finished goods produce hexagonal, square and other profiles, as well as standard round bars. There is a requirement for an easy and fast method of ultrasonic testing of such profiled bars. The technologically advanced ROWA phased-array system uses curved probes concentrically arranged around round bars and these create virtual probes to achieve a special sound beam to allow the testing of bars of other profiles in the same line. The complete process requires only electronic adjustment of the system to the profile of the bar. As a result, various profiles can be tested in the same conveyor line with short change-over times.

Currently angle shaped bar material (e.g. square / hexagon / rectangle) is tested to detect core flaws by using e.g. ROWA (phased array type) and ROB (rotating single crystal) testing machines. Those machines employ circular moving sound fields for ultrasonic testing (ROWA electronic moved – ROB mechanic moved).
With round bar material the ultrasonic testing with these machines is able to perform full body testing by both normal beam (core flaws) and angle beam method (surface and sub-surface flaws).

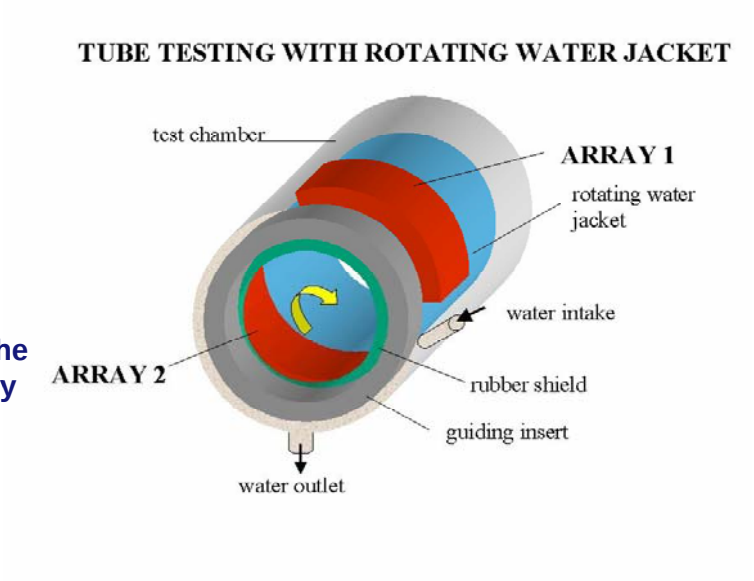
In profiled bar material, the ROWA system is currently able to test in repeatable way only the core area by normal beam method.
To enlarge the ROWA (phased array type) test performance from only center core area testing the following procedure shall be used:
During the test process, the test specimen bar material (e.g. square / hexagon / rectangle) is moved in linear direction through a circular phased array device e.g. ROWA mechanics in a way that the flat surface areas always remain precisely in the same geometric orientation to the circular orientated phased array probes.

The geometric orientation of the specimen's flat surface areas in reference to the position of each of the phase array single elements is detected by ultrasonic signals. This is the basis of an accurate focal law calculation. A numerical algorithm is used based on the Fermat principle.
This algorithm calculates the needed focal laws to provide a sound beam orientated perpendicularly to the specimen's flat area for every virtual phased array aperture of the circular array probe arrangement. For each virtual probe there is an individual focal law setting. So flaws parallel to the flat area are detectable in a repeatable way and in a significantly increased volume fraction.

2. ROWA concept – rotating water ring

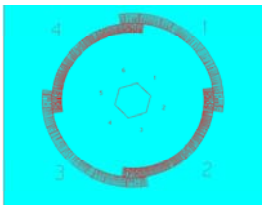
The rotating water jacket guarantees uniform sound coupling into the material

The stationary inspection transducer arrays replace the rotating mechanics normally required for circumferential scanning around the bar



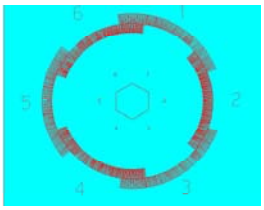
Picture 1 : ROWA concept

3. ROWA bar tester family



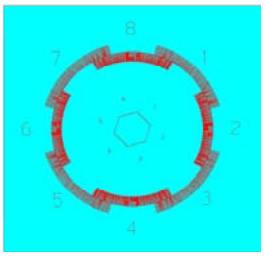
R35 / 4 max bar dia. 35 mm
R40 / 4 max bar dia. 42 mm
R56 / 4 max bar dia. 60 mm
1 Frame 19" with 4 PMs

Economy



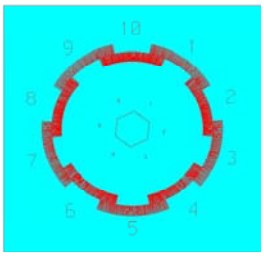
R40 / 6 max bar dia. 40 mm
R48 / 6 max bar dia. 50 mm
R56 / 6 max bar dia. 60 mm
R72 / 6 max bar dia. 80 mm
1 Frame 19" with 6 PMs

Economy



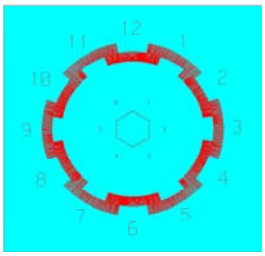
R48 / 8 max bar dia. 50 mm
R56 / 8 max bar dia. 60 mm
R72 / 8 max bar dia. 80 mm
R100 / 8 max bar dia. 110 mm
2 Frames 19" with 8 PMs

Higher speed / bigger dia.



R72 / 10 max bar dia. 80 mm
R120 / 10 max bar dia. 130 mm
2 Frames 19" with 10 PMs

Higher speed / bigger dia.



R70 / 12 max bar dia. 78 mm
R85 / 12 max bar dia. 90 mm
2 Frames 19" with 12 PMs

High Speed solution

UT testing:

Round bar : core flaw / surface / subsurface flaws

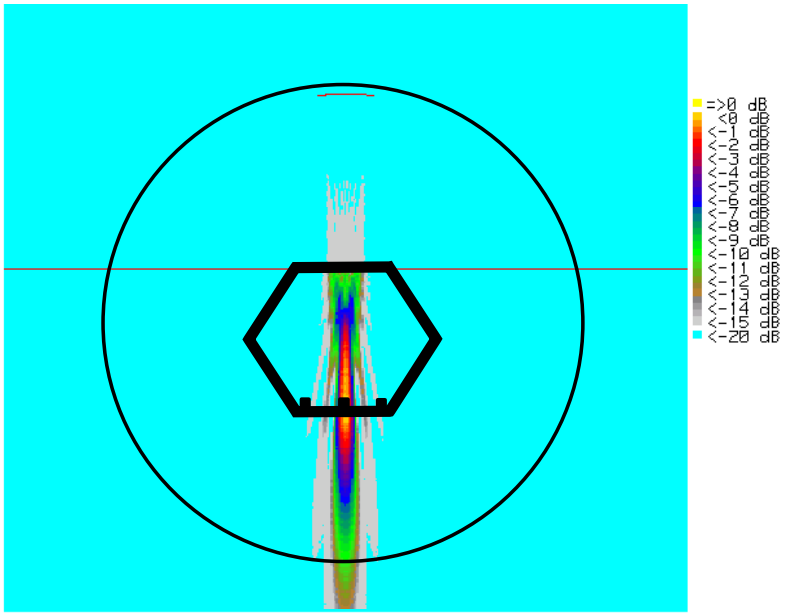
*Hexagon/square/rectangle bars : core flaw **

*(* but physical limits must be estimated case by case)*

Picture 2 : ROWA bar tester family

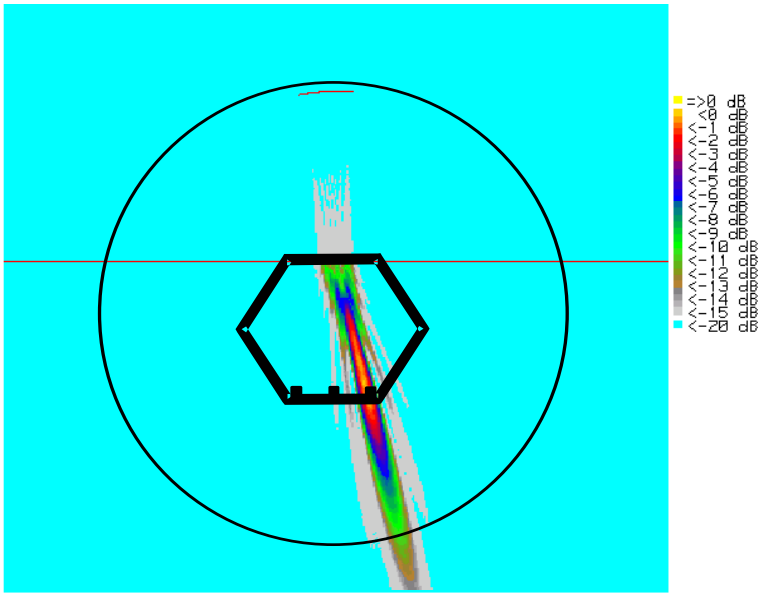
4. Principle Idea

Currently angle shaped bar material (e.g. square / hexagon / rectangle) is tested to detect core flaws by using e.g. ROWA (phased array type) and ROB (rotating single crystal) testing machines. Those machines are using circular moving sound fields for ultrasonic testing (ROWA electronic moved – ROB mechanic moved).
With round bar material the ultrasonic testing with these machines is able to perform full body testing by both normal beam (core flaws) and angle beam method (surface and sub-surface flaws).
In angle shaped bar material currently the ROWA system is only able to test in repeatable way the core area by normal beam method. The test reflector to adjust for core flaw testing is in common a flat bottom hole reflecting perpendicular to the flat area of the test specimen.

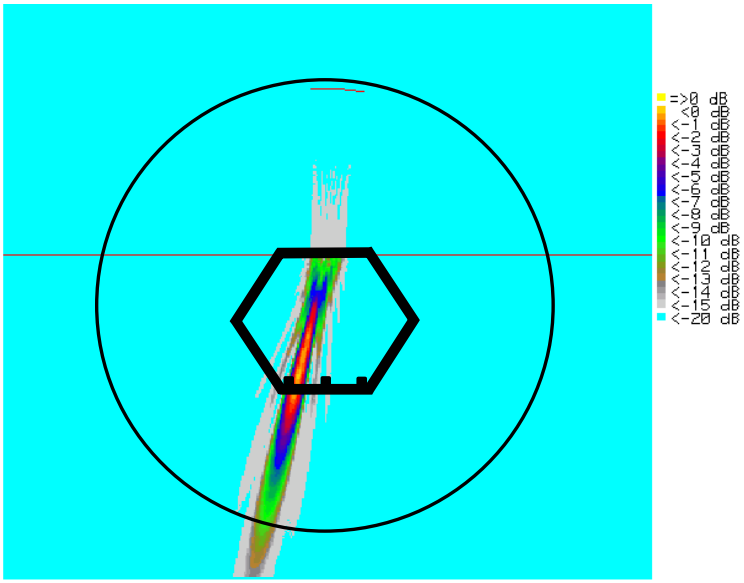


Picture 3 : Center Target

Test reflectors which are located out of the center core area shall not be detected in a repeatable way caused by the surface diffraction effect. The flat bottom holes outside the center line will not be hidden perpendicularly.



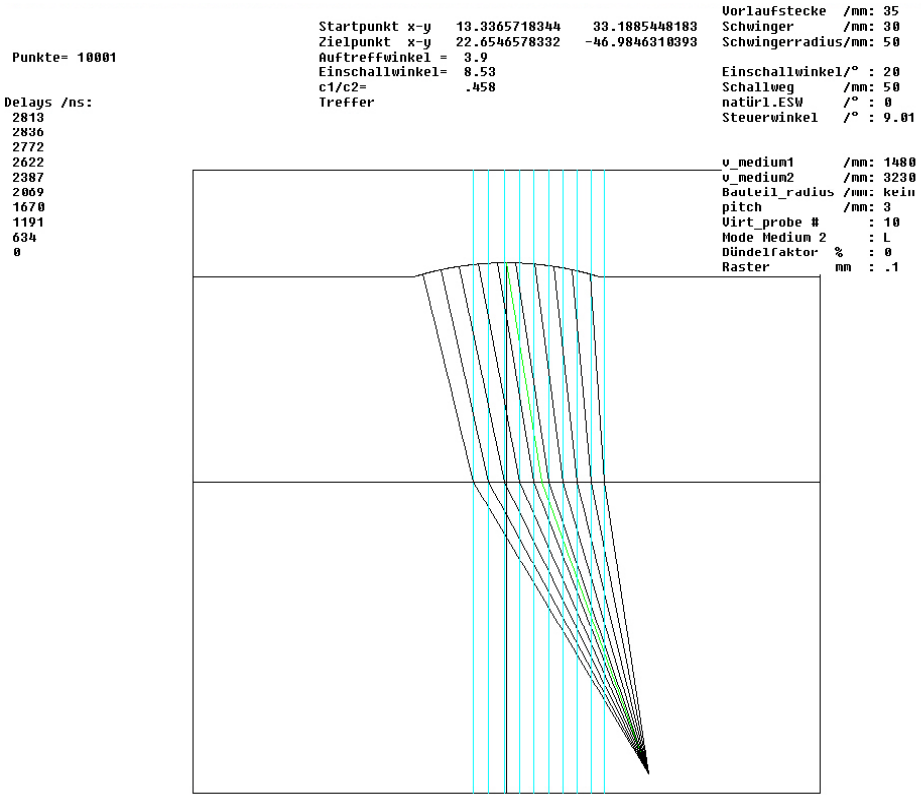
Picture 4 : Right side Target



Picture 5 : Left side Target

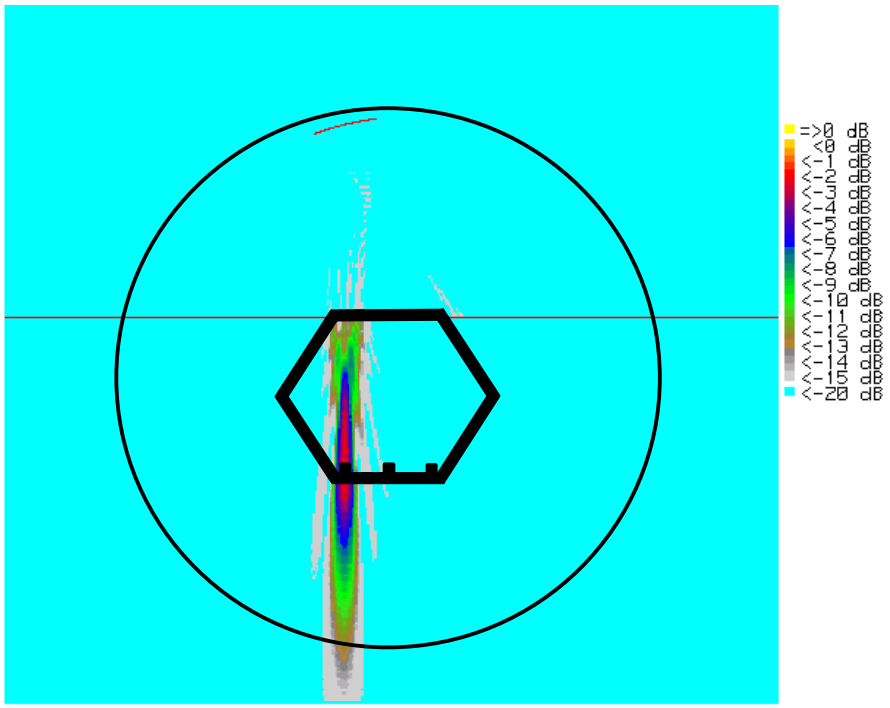
To enlarge the ROWA (phased array type) test performance from only center core area testing to nearly full body testing the following procedure shall be used:
While the test process the test specimen angle shaped bar material (e.g. square / hexagon / rectangle) shall be moved in linear direction through a circular phased array device e.g. ROWA mechanics in a way that the flat surface areas always remain accurate in the same geometric orientation to the circular orientated phased array probes. This is reached by using special guiding bushes in inlet and outlet position of the ROWA mechanics. The geometric orientation of the specimen's flat surface areas in reference to the position of each of the phase array single elements so is known and fixed. This is the basis of an accurate focal law calculation.

A numeric algorithm is used based on the Fermat's principle - This algorithm shall calculate the needed focal laws to provide a perpendicular to the specimen's flat areas orientated sound beam for every used virtual phased array aperture of the circular array probe arrangement.

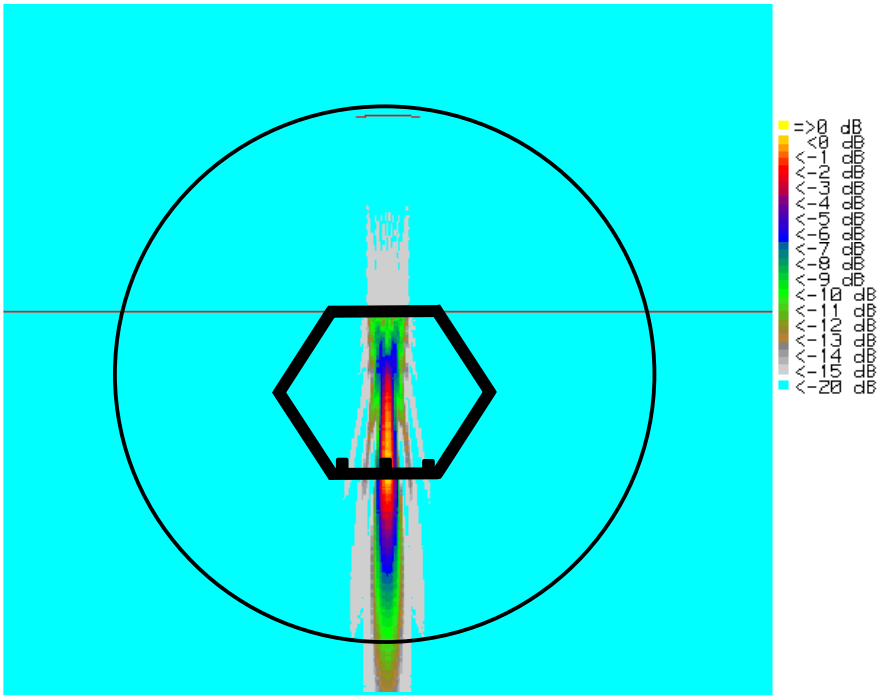


Picture 6 : Focal Law Display

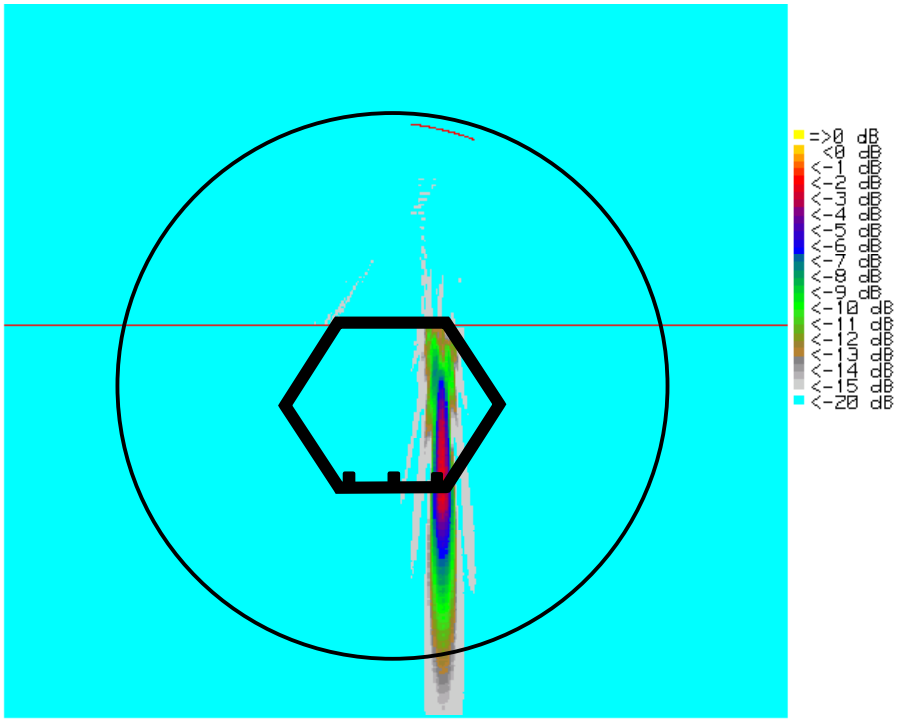
For each virtual probe shall be used an individual focal law setting. So all parallel to the flat area orientated flat bottom holes shall be detectable in a repeatable way.



Picture 7 : Left side Target



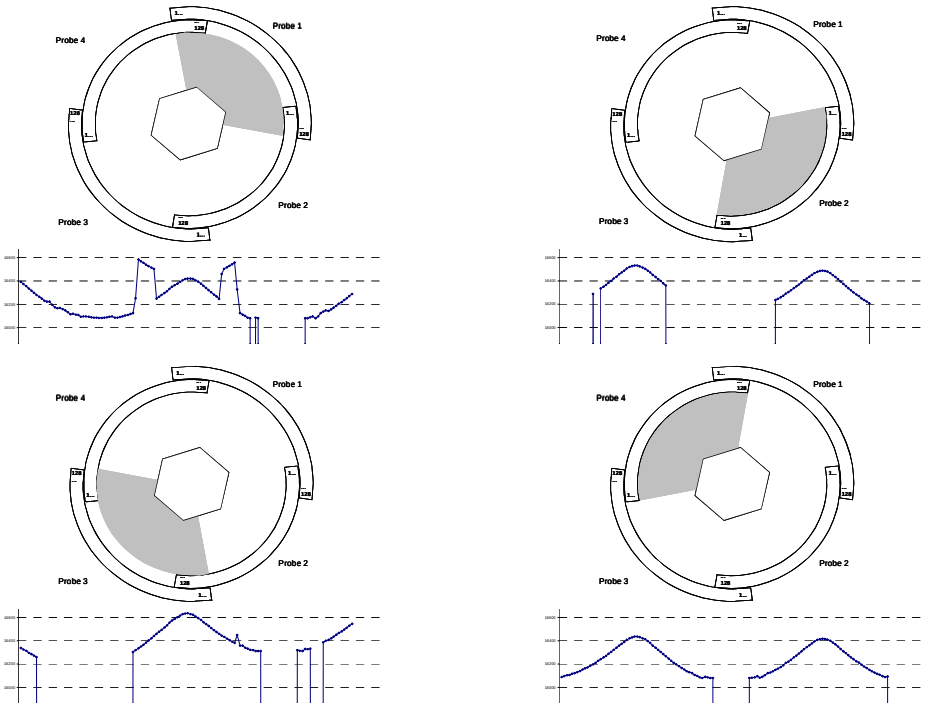
Picture 8 : Center Target



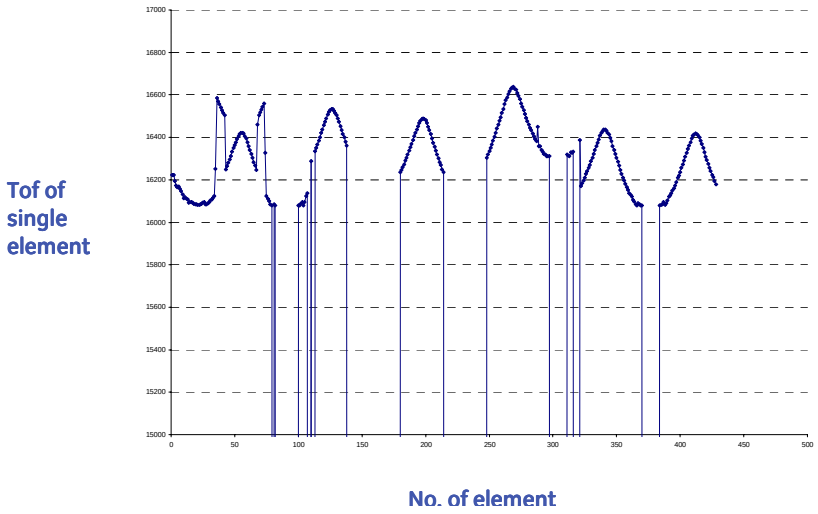
Picture 9 : Right side Target

5. New software features

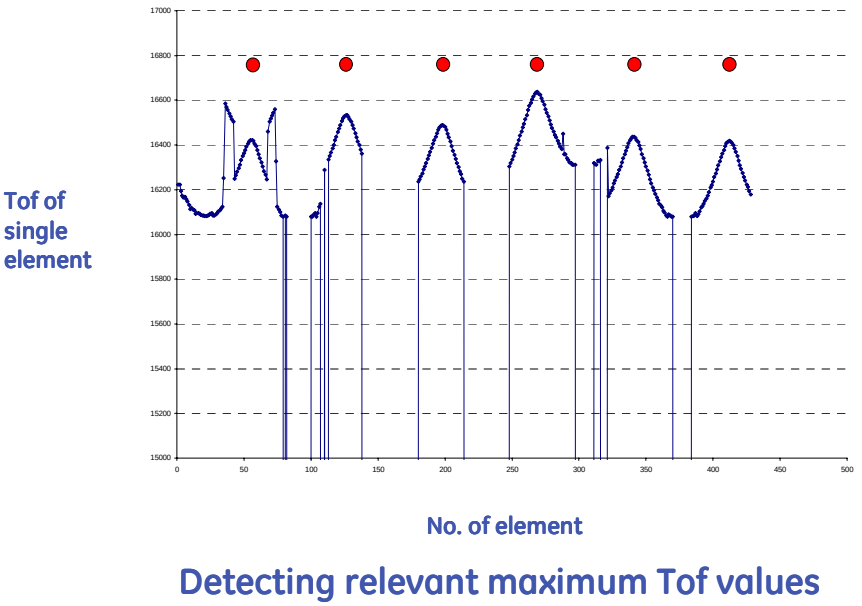
5.1 Semi-automated finding of the material orientation by TOF measurement



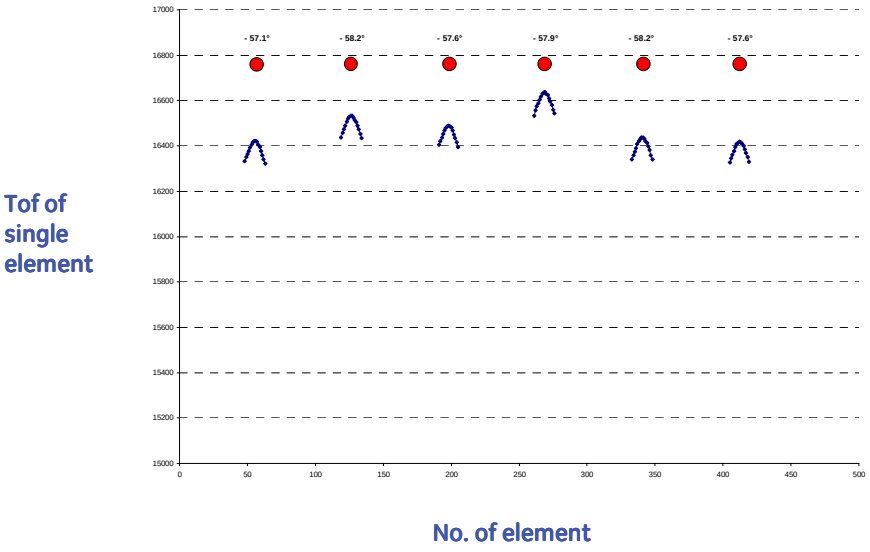
Picture 10 : Step 1 – Recording TOF of each single element (4 probes)



Picture 11 : Step 2 – Connecting TOF values of the 4 probes

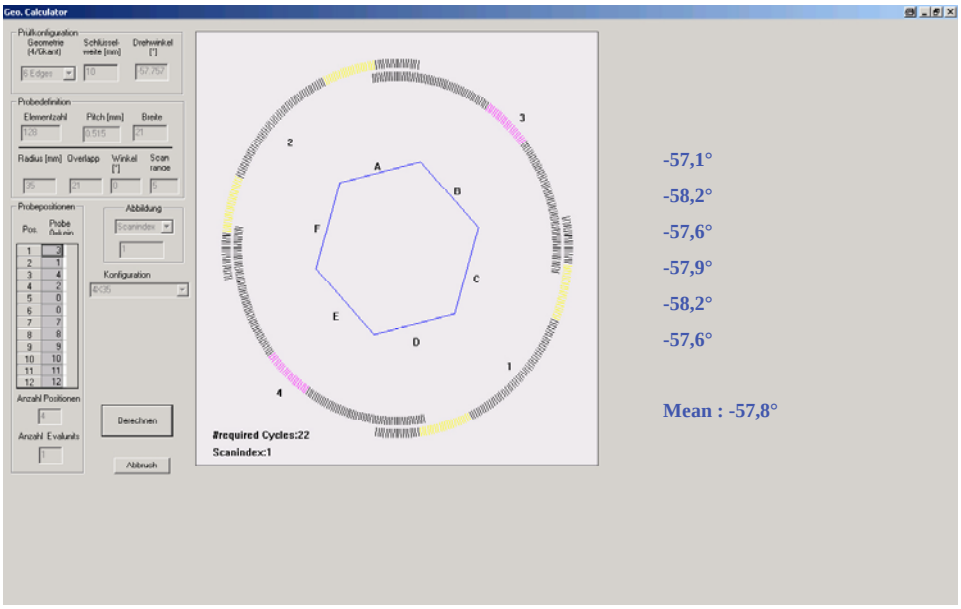


Picture 12 : Step 3 – Detecting relevant maximum TOF values



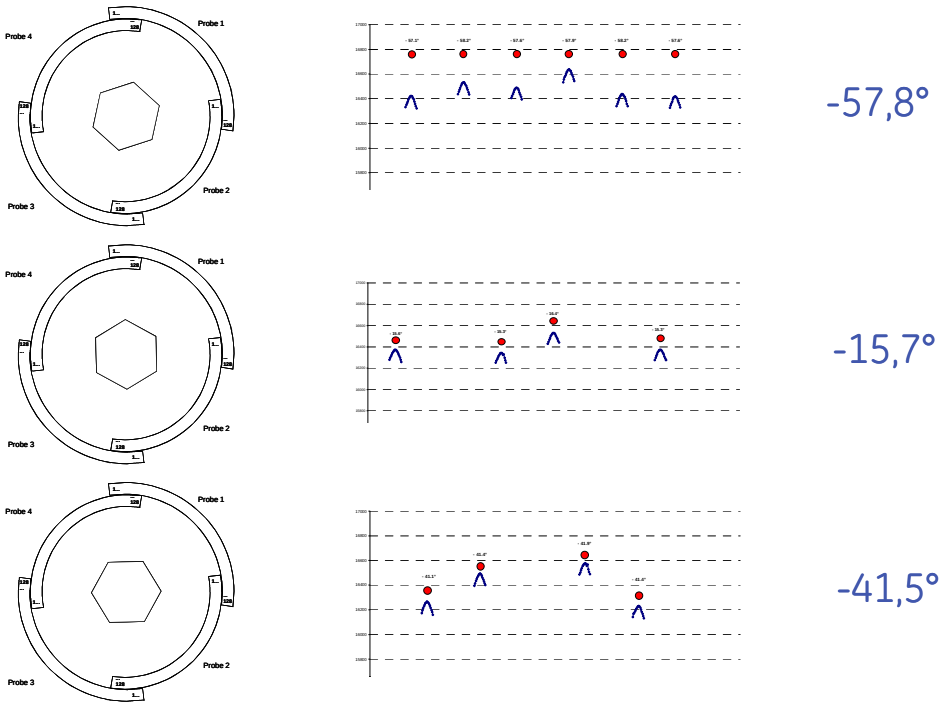
Picture 13 : Step 4 – Detecting the geometric orientation of the hexagon's flat areas

5.2 Automatic setting of the cycle mapping and focal laws



Geometric calculator prepares cycle mapping tables with aperture and focal laws for each virtual probe

Picture 14 : Step 5



Picture 15 : Detecting the geometric orientation of the hexagon's flat areas

6. Evaluation results normal beam testing

Probe Data:

117 Element Array

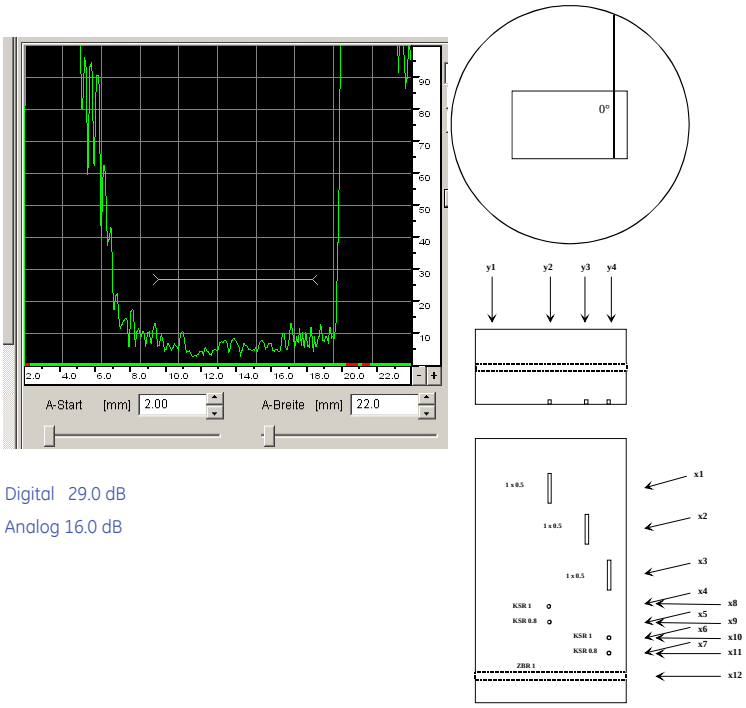
R85 – 12 probes

Pitch 0.515 mm

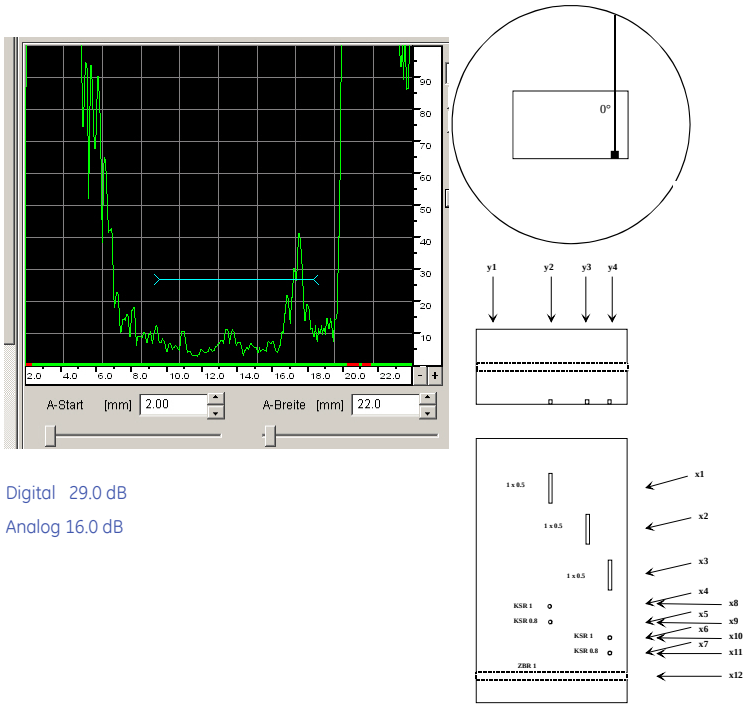
5 MHz

Aperture (20x0.515) x 12

Results:



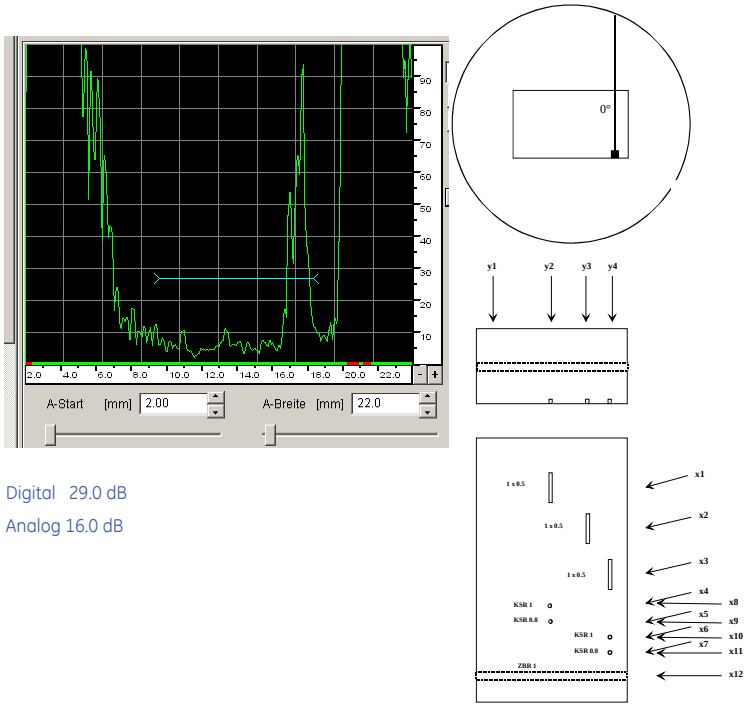
Picture 16 : without Flaw



Digital 29.0 dB

Analog 16.0 dB

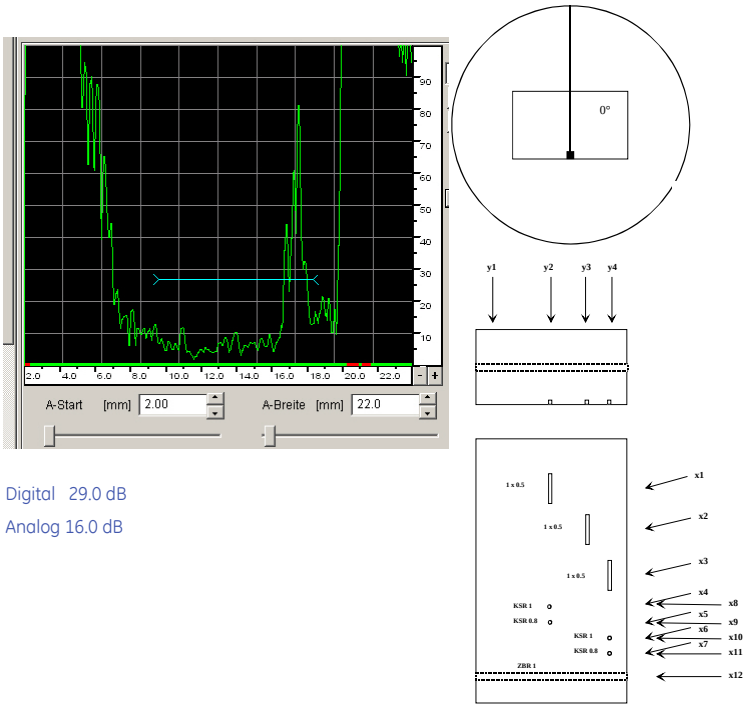
Picture 17 : FBH 0.8 mm outside



Digital 29.0 dB

Analog 16.0 dB

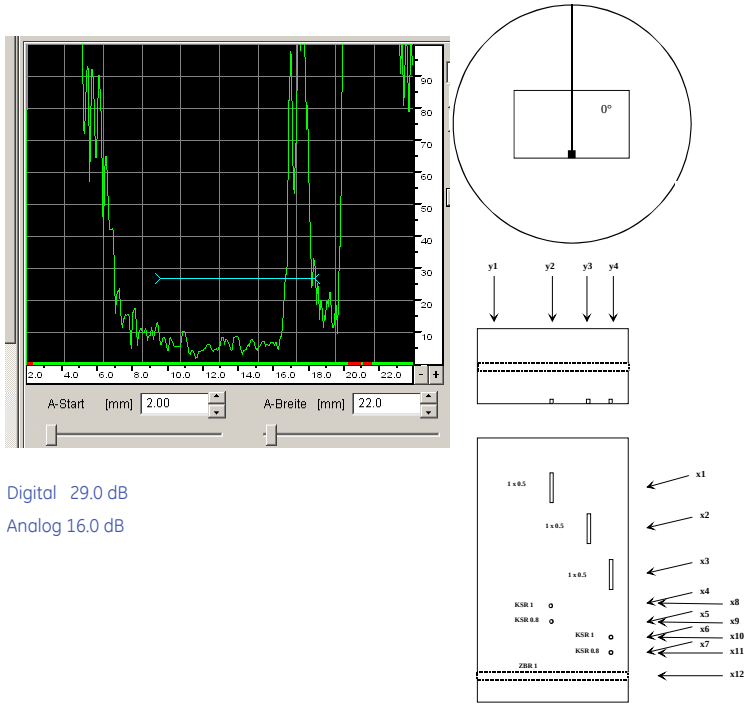
Picture 18 : FBH 1.0 mm outside



Digital 29.0 dB

Analog 16.0 dB

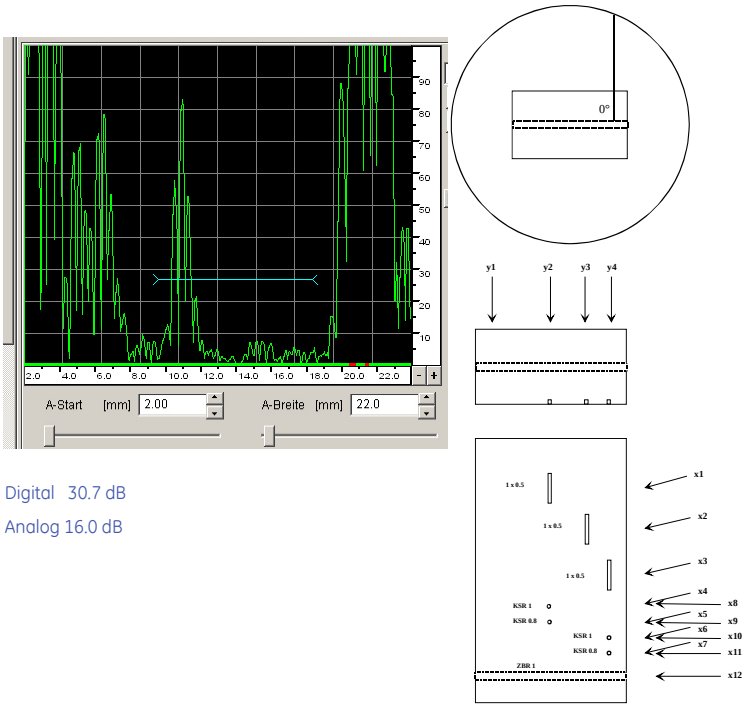
Picture 19 : FBH 0.8 mm center



Digital 29.0 dB

Analog 16.0 dB

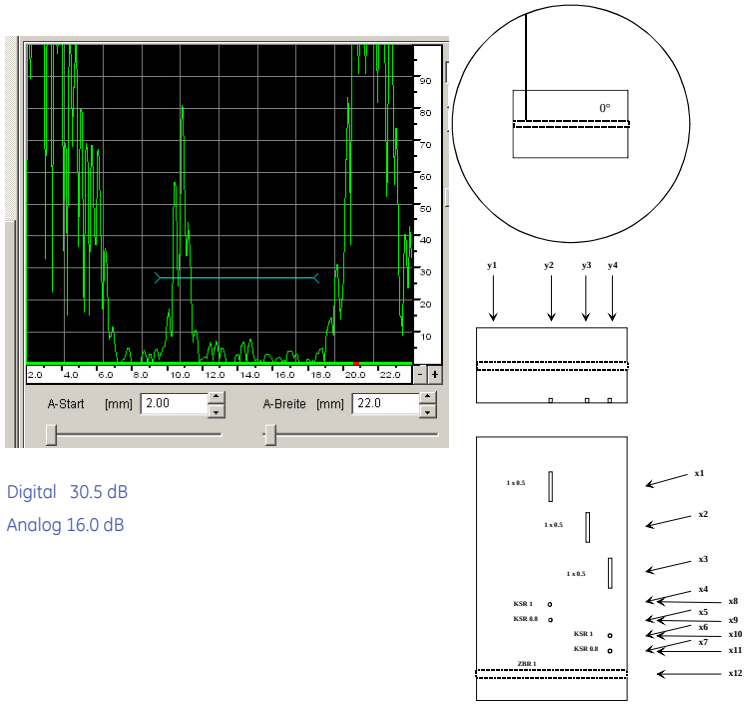
Picture 20 : FBH 1.0 mm center



Digital 30.7 dB

Analog 16.0 dB

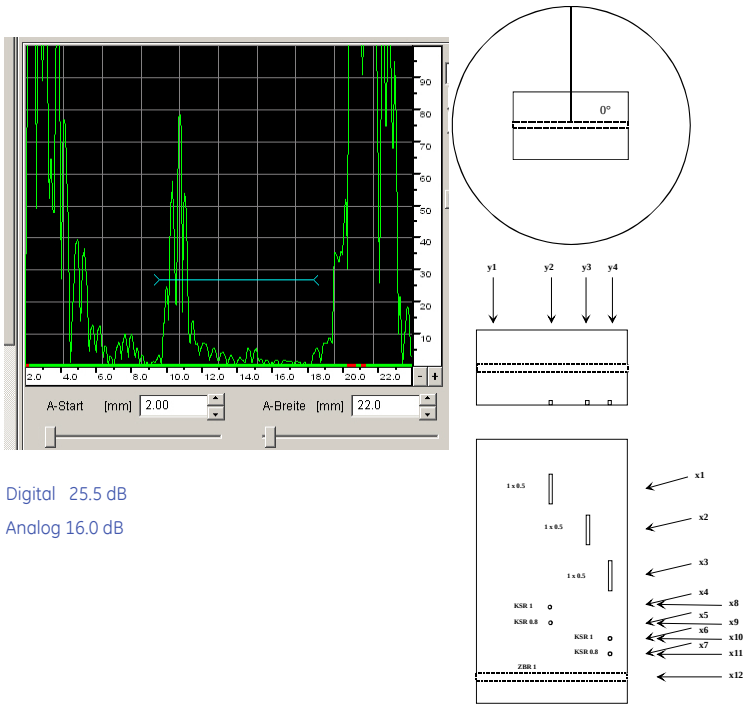
Picture 21 : SDH 1.0 mm outside right



Digital 30.5 dB

Analog 16.0 dB

Picture 22 : SDH 1.0 mm outside left



Digital 25.5 dB

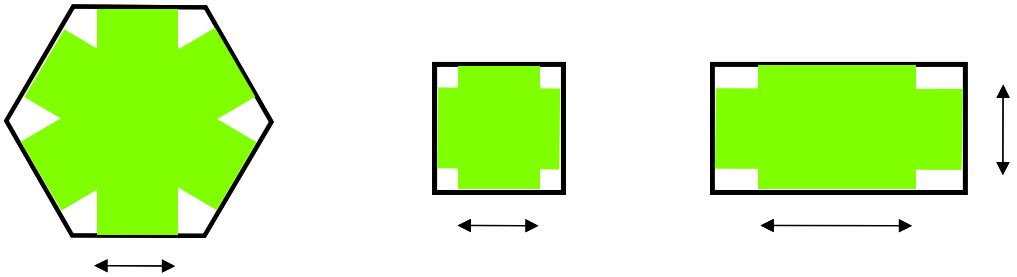
Analog 16.0 dB

Picture 23 : SDH 1.0 mm center

7. Core Flaw tested areas

Tested and untested Areas with the ROWA system

provided that ROWA diameter > 2.4 x width across flats



Appr. 80% Vol. is tested for Core Flaws

Picture 24 : Core Flaw tested areas

8. Result and Outlook

- with this new ROWA concept for flat material our customers are able to test round material 100% in volume for core and subsurface flaws and flat material approximately 80% in volume for core flaws with the same mechanics and probes which can be an economic effort in costs and needed place in the line

- in next step we will introduce also shear wave testing into the flat material applications for further decrease the untested areas

- in future the dimension range of the ROWA family shall be increased to bar materials up to 250 mm diameter and decreased to bar diameter down to 6 mm