

Complex defects detection software for oil refining industry

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Abstract. The article discusses the principle of determining complex defects in cast body parts of main oil pumps made of 20GL steel by an ultrasonic non-destructive testing method using a flaw detector and a 16-element digital-focusing antenna array. The equipment used, the structure of the antenna array, the principle of operation and its adjustment according to the standard sample of the enterprise are presented. The maximum admissible frontal images of defects of the "looseness" type are found. Based on the equations for finding the maximum length of defects and its actual dimensions, software has been written that can be used to reject various parts, including the body of a main oil pump.

Keywords: software, non-destructive testing, ultrasonic testing, antenna array, cast parts.

Introduction

Inspection of cast body parts by ultrasonic testing (UST) is one of the most difficult due to several factors:

- complicated shape of the part, associated with different curvature of the surface and changing thickness in different areas of the part,
- the emergence of difficulties in the orientation of defects and their sizes in the product,
- after solidification, the casting has a coarse-grained structure, reducing the efficiency of UST due to significant attenuation of ultrasound [1].

Such objects of control include the cast body of the main oil pump (MOP), during the control of which one has to deal with many of the above factors.

Today, the use of ultrasonic flaw detectors using digital-focused antenna arrays (DFAA) has already become the norm, because in comparison with traditional flaw detectors working with single-element piezoelectric transducers (PET), DFAA significantly expands the range of testing, allowing:

- visualize the internal structure of the product, presenting it as a cross-sectional image,
- monitor hard-to-reach places,
- change the operating frequency, solving the problem of attenuation of ultrasonic waves.

The aim of the work is to write software, a module for calculation based on research and equations for determining the permissible frontal and real dimensions of defects when inspecting a cast body part made of 20GL steel.

Equipment and control object

The object of control is the body of the oil pump (fig. 1). According to NTD, ultrasonic testing is mandatory and is carried out in 3 sections (fig. 2) for the entire thickness, which is 50mm, in some places reaching 100mm.



Figure 1. Casing of the main oil pump MOP

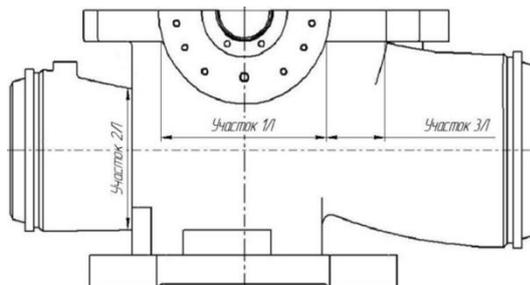


Figure 2. Control areas

The control is carried out for the presence of various defects in the casting of the body, the most common is a defect of the "looseness" type - a casting defect in the form of an accumulation of small shrinkage cavities [5]. A sign of this defect is that the image of the defect consists of a chain of small images.

Research and setting up equipment

An IntroVisor A1550 ultrasonic flaw detector (fig. 3) manufactured by "ASK" LLC in Moscow was chosen for the experiment. The technical characteristics of which allow you to perform this task [2].



Figure 3. IntroVisor A1550 flaw detector

The device also includes an antenna array sensor AA (fig. 4), which consists of a plurality of piezoelectric elements of the same type located along one line on the protector [3].

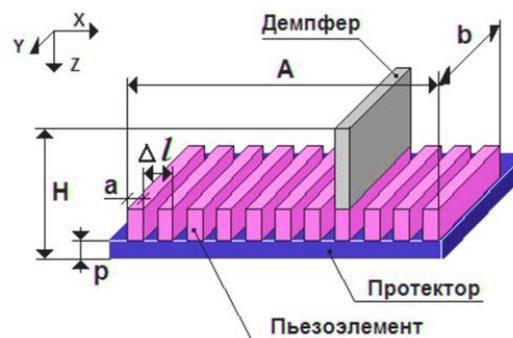


Figure 4. AA design

To calibrate and adjust the flaw detector, you need a standard enterprise sample (SES), which is a sample made of the same material as the test object, in the body of which there are holes - control reflectors (CR): 5 holes with a diameter of 6.2 mm, size which corresponds to the maximum size of the defect in accordance with the normative and technical documentation (NTD) for the controlled product.

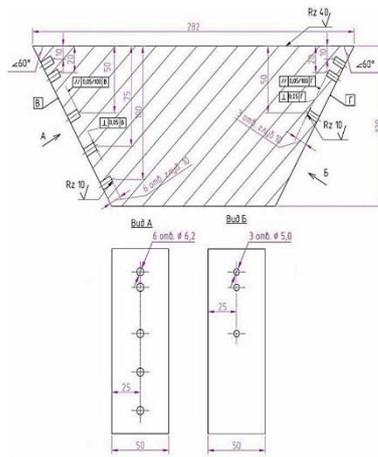


Figure 5. Standard Enterprise Sample (SES)

Using a flaw detector, it is necessary to obtain images of all control samples CR1, CR2, CR3, CR4, CR5. Depths Z of which are equal: 10, 25, 50, 75 and 100mm. Moving AA linearly, we find the maxima of CR (fig. 6), and using the flaw detector functions, we determine their frontal size, the dimensions of which are: $D_1=5,8\text{mm}$, $D_2=6,4\text{mm}$, $D_3=11,0\text{mm}$, $D_4=18,9\text{mm}$, $D_5=22,2\text{mm}$.

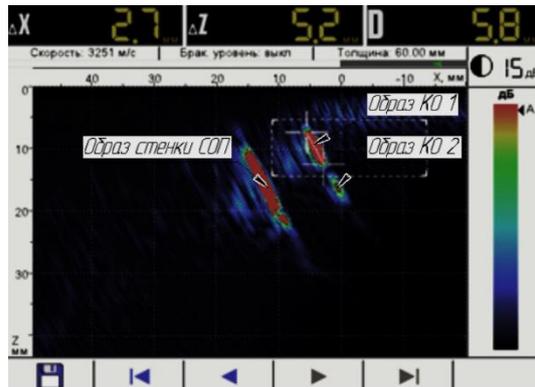


Figure 6. Results on the flaw detector screen

This implies the dependence of the frontal size of the CR image on the depth of occurrence, i.e. if an indication of a defect is found at a depth of 50mm, and the frontal size on the flaw detector screen is $D = 11.0\text{mm}$, then the actual size of the defect is 6.2mm.

Knowing this, it is possible to find the values of the maximum frontal dimensions of intermediate depths Z, it is necessary to approximate the size D [4].

The equation looks like this:

$$D_{\text{permissible}} = D_{\text{min}} + \frac{(D_{\text{max}} - D_{\text{min}}) * (Z_x - Z_{\text{min}})}{(Z_{\text{max}} - Z_{\text{min}})} \quad (1)$$

where, Z_x – defect depth, mm;

Z_{min} , Z_{max} – values assigned from the SES setting, the range where Z_x falls;

D_{min} , D_{max} – are selected from the depth values Z_{min} , Z_{max} .

For example, having found a discontinuity with a frontal length $D_x=7.8\text{mm}$ at a depth of $Z_x=44\text{mm}$, the frontal dimension falls into the interval between a depth of 25 and 50 mm, we calculate $D_{permissible}$ for a depth of $Z = 44\text{mm}$:

$$D_{permissible} = 6.4 + \frac{(11.0 - 6.4) * (44 - 25)}{(50 - 25)} = 10,08\text{mm}$$

The maximum allowable length of a defect at a depth of $Z = 44\text{mm}$ is equal to 10.08mm, therefore, the defect found is acceptable.

To find the real size of the defect, the formula (2) is derived:

$$D_{actual} = \frac{D_{CR}}{D_{permissible}} * D_x \quad (2)$$

where, D_{CR} – maximum permissible defect size, mm;

D_x – flaw detector screen data.

Using these data, we will write a program (fig. 7) that will help the NDT inspector determine the suitability of the product, without additional calculations.

The program interface consists of a tabular formula editor.

The program works as follows:

1. The found maximum lengths of the frontal images of defects are entered into the corresponding cell.
2. The depth of the defect at which it was detected is entered into the corresponding cell.
3. Using the functions, the calculation of the maximum permissible size of the frontal length and the actual size of the defect in the metal thickness are carried out.
4. The final stage is rejection, if the maximum length of the defect on the flaw detector screen does not exceed the calculated one, and the actual size of the defect is less than the specified NTD, then the defect is acceptable, if the resulting values exceed the permissible values, the detected defect is invalid.

Определение реальных размеров дефектов от глубины залегания и максимальной протяженности индикации дефекта на экране дефектоскопа					Дефект ->			Настройка браковочного уровня по СОП (за рубку 6,2мм 5шт.)							
					ГОДЕН	НЕ ГОДЕН									
↓→	Показания на дефектоскопе	Максимальная протяженность Dx	Глубина залегания Zx	СИ	Допустимая протяженность дефекта Dmax	Реальный размер дефекта D	СИ	Протяженность по СОП на экране дефектоскопа, мм		Глубина залегания искусственного дефекта, мм					
Количество обнаруженных дефектов								D1	5,8	Z1	10				
1		8	48	MM	10,69	4,64	MM	D2	6,4	Z2	20				
2		15	60	MM	14,16	6,57	MM	D3	11	Z3	50				
3		23,7	50	MM	11	13,36	MM	D4	18,9	Z4	75				
4		4	43	MM	9,93	2,5	MM	D5	22,2	Z5	100				
5		5	43	MM	9,93	3,12	MM								
6		14	68	MM	16,69	5,2	MM								
7		3	31	MM	8,09	2,3	MM								
8		22	24	MM	7,01	19,46	MM								
9		5	41	MM	9,62	3,22	MM								
10		12	19	MM	6,34	11,74	MM								
11		17	94	MM	21,41	4,92	MM								
12		15	54	MM	12,26	7,59	MM								
13		20	54	MM	12,26	10,11	MM								
14		19	35	MM	8,7	13,54	MM								
15		14	93	MM	21,28	4,08	MM								
												Максимально допустимый дефект по ГОСТ		6,2	

Figure 23. The program for determining real defects in the metal thickness during the UST non-destructive testing method

Conclusions

In the course of the work done, software was written for determining complex defects in cast body parts of mainline pumps. With the help of which, it simplifies and accelerates the search for the value of the permissible size for intermediate depths and real sizes of defects according to the formulas.

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