Reliability of Constructions and Ultrasonic Weld Examinations. Procedure IBUS-NZ

Wladyslaw MICHNOWSKI, ZBM ULTRA, Wrocław, Poland
Jaroslaw MIERZWA, Wroclaw University of Technology, Wroclaw, Poland

Abstract. In this article we give a method - a procedure of a strict connection the results of ultrasonic examination of welds with gaining a high level of their reliability. The article contains elements of reliability theory, its reference to serial models (welds) and to the ultrasonic examination method called IBUS-TD [1]. Moreover the article contains the conclusions transformed into the IBUS-NZ procedure that describe the system of quality handle. In fact it is a dynamic database which is made of every information concerning an execution of welds by feedback and of results. This database reveals the sources of faults in welds executions. It makes possible references to organisational decisions on the producing level (assessment of welders and control) and on the level of global analysis as well. IBUS-NZ program together with the modified CUD flaw detector form a system which works irrespective of such changeable elements as various welders, time of working, ability of operators (examination persons) - because all of this is selected and can be modified. An important feature of the system is self-improvement ability and quick reaction on appearing abnormalities.

1. Introduction

The first polish power plant, built in Turoszow long time ago, with 200MW blocks, started with many leakinesses of pipe welds. The intensity of the leakinesses was near to disaster [2]. It caused a number of reactions, including an elaborating in the Technic Supervision Office the method of welds examinations, known as IBUS-R, and also the way of increasing their reliability. The method relies on:

- a selection of welds - it means the examination of the whole collection of welds and remove these ones with low reliability,
- delivering a method and equipment which make the selection possible.

A novelty as far as efficacy of the selection is concerned was an introduction of elements of the reliability theory. It enabled a notable increasing of the reliability level of boiler systems. There are documented examples that mass application the IBUS-R instruction raised on higher level the reliability of used power boilers and it eliminated a number of previous breakdowns and also prevented breakdowns in pipelines nets.
Today, the IBUS-Nz procedure, which uses modern possibilities of IT and electronics, allows an automation of all arduous descriptions of examinations. It makes possible an assement not only the quality of welds but also of whole technological process of welding

2. Need of the Small Thickness Welds Examinations

The most important argument for testing of thin welds is fact that resignation often causes a disaster. It took place many times. It concerns a building of pipelines to transport inflammable and explosive materials, a building and renovation of block boilers in power stations and usage of thermal net. The real examples below illustrate the need of testing.

The examples of real flaws in pipe welds (detected by examinations according to IBUS instruction) are presented in fig.1, 2 and 3.

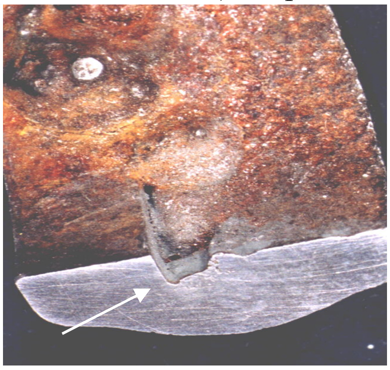

Fig.1 Lack of fusion in weld of pipe (∅38, thick-3mm)

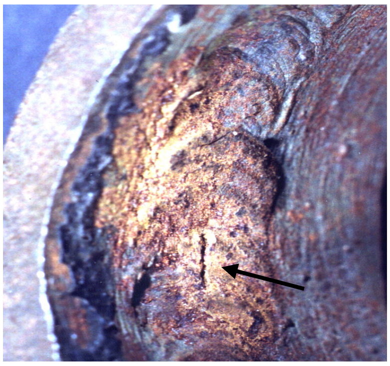

Fig.2 Circumferncial fracture in weld of pipe(∅38, thick-3mm)

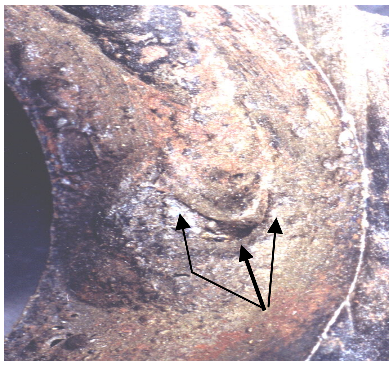

Fig.3 Lack of adhesion at the end of weld(∅38, thick-3mm)

From presented above three types of real flaws the hardest detectable one is a lack of adhesion (Fig. 3.) – in this example deepened with a crater of leakness.

This flaw is usually found at the beginning or ending of circumferencial weld. This is a small flaw most often occurring in these welds. It is also the most dangerous flaw because it often causes breakdowns. The detecting of this type of flaws is difficult but necessary. The usage of methods that are insufficient to detect such defect, is a serious technical mistake. Especially the radiography do not often detect such flaw. Ultrasonic examinations made according IBUS-TD instruction gives more than satisfying.

3. Mistake of the Intuition

In NDT is accepted an intuitive simple opinion that the purpose of the examinations is to determine the 'quality - wellness' of an examined element - a weld for example. It leads to:

- an acceptation of a criteria of quality of an element (e.g. weld) based most frequently on a standard,
- assumption that every set of elements which complies with established criteria is a good set (according to induction rule: if one of the elements is good and the rest are not worse, al the set is good).

It's not true for every set that consists of many elements. It is shown in many examples from the history of technology and unambiguous explanations given by the reliability theory.

In the history of technology a mistake of the intuition was made almost always with new, more complicated constructions demanding more elements for example: building of rockets (German and American groups of Werner von Braun), beginnings of computers constructing and also building of the first polish block power plant. Thanks to IT and initial problems in constructing of computers the reliability theory has appeared and developed. A mistake of the intuition lead to a popular tactics of successive approximations, that is searching the 'critical path', improving the mistakes revealed in this path and searching the next 'critical path'. The reliability theory recommends a more efficient way - this is global acting and improvement of reliability of all the elements working in serial systems.

4. Reliability of Welds

The application results of the system that assure high reliability of welds in power block boilers are presented in [2]. Despite of the passage of time the base rules of the system are not changed. It can even be said that they are more up-to-date in relation to new breakdowns and new formal regulations after joining the UE.

The reliability is a probability of a faultless work of a system in an intended time of functioning. Almost always pipe welds work in a serial systems of reliability. That means that a breakdown of one weld causes a breakdown of the whole system. A reliability of serial system is:

$$P = p^n < 1 \qquad (1)$$

where

P - a reliability of a serial system (a boiler, a pipeline),

p - a reliability of one element (a weld),

n - a number of elements.

There is a problem with a priori determination of the value *p* for welds. It seams that the only way to determinate *p* are post factum statistic examinations. They could be collected according to established rules and it would allow to estimate a reliability on the base of the examined objects. Unfortunately, the topic was probably not taken up. The examples relied on simple calculations with presumed values of *p* are sufficient to a quality-amount analyses illustrating of the issue.

4.1 Paradoxes of a Reliability

Exponential function of *P* quickly decreases with the growth of number of the welds. And the system (the boiler) quickly looses its reliability even if the quality of the welds will not lower (example 1).

Moreover *P* also decreases when there is only few unreliable welds (example 2) in a large set of welds. A liquidation of successive breakdowns and a reliable repairing of welds just slightly raise the reliability of the system (example 3).

4.2 Example 1

If we assume for the single weld $p = 0{,}999$ then it will seem that it is a good weld because a chance of its breakdown in intended time is lower than 0,001. But for one hundred of welds it gets smaller up to $P = 0{,}9$ (0,1), and for one thousand of welds $P = 0{,}36$ (0,64). It means that a chance of a breakdown in case of 100 of welds amounts to about 10% and for 1000 of welds - 64%. 10% is disputable but 64% is a value that excludes a faultless running of the system. The remedy is presented in example 4.

4.3 Example 2

Dividing the set *P* into two sets P_1 and P_2, for example

$$P = P_1 * P_2 = p_1^i * p_2^j < 1 \qquad (2)$$

Is assumed that a set of elements is unequal and there are (among the elements) some worse elements with lower reliability and the better ones, too. If the whole set $n = 100$ is divided in two subsets - first (with $p_1 = 0{,}999$ and $i=94$), second (with $p_2 = 0{,}900$ and $j=6$) then the reliability of the whole system drops to $P=0{,}48$ (according to the formula 1). There are only 6 unreliable welds and the reliability of one hundred of them is reduced up to below 50%.

4.4 Example 3a

Let's the same set of welds (example 2) is admitted to exploitation. Moreover if one of these six worse welds is defective and put into the repair, even if the repair is well done (p=0,999) the general reliability is growing slightly from the level P_0=0,48 before repair to the P_1=0,53 after repair. The next breakdowns will improve the reliability to P_2=0,59, P_3=0,66 and so on. In this example after three breakdowns the gained reliability will amount to about 0,66.

4.5 Example 3b

Let's assume to have a similar set of welds with the same probability but three times greater (n=3+94+3*18=300, p_1=0,999, p_2=0,9). The calculated reliabilities after repairing amount to next value P_0=0,11, P_1=0,12, P_2=0,14, P_3=0,15 and after 15 breakdowns P_{15}=0,54. In this example we operate with the reliability on a very low level. On this level the successive breakdowns do not help too much and a selection of bad welds follows very slowly.
The given examples prove that from the point of view of reliability:

- only the examinations of all welds make sense
- a selection of the unreliable elements has to be very good because a slightly rise of the number of unreliable welds can cause very low level of the reliability;
- the way of 'successive approximations' (or 'a critical path' or a 'breakdowning' of a new boiler) even though leads to arising of reliability, a positive effect tends to be insignificant. In general this is a slow, non-effective and very expensive way.

4.6 Example 4a

If we assume that workers have increased the efficiency of examinations and selection so all unreliable welds (18) were eliminated then the overall reliability will increase but the reached value P=0.74 is still not high (n=300, p=0,999).

4.7 Example 4b

The further improvement of overall reliability (P) can be achieved only by increasing reliability of single weld p. If p will be increased 10 times (p=0.9999) then overall reliability goes slower down although significant increasing of number of welds (table 1).

Table 1. Reliability P=f(N)

N=300	N=500	N=750	N=1000
P=0,97	P=0,95	P=0.93	P=0.90

4.8 Conclusions

The following conclusion comes from presented examples:

- the first and the second example shows that only examination of all welds (100%) give an acceptable level of reliability,
- this examination has to ensure the efficient selection of unreliable welds and their elimination,
- the efficiency of selection can be achieved by using special equipment [1],[3],
- the above rules are not sufficient for large amount of welds (the example 3 and 4). The next step for increasing the reliability of an construction is to increase the reliability of each single weld,

- for a set of welds can be found the reliability level of single weld that assures the acceptable overall reliability (example 4b),
- the improvement of reliability of single welds is possible in two ways:
  - through technological progress of welding (e.g. automation that enables repeatability),
  - on the current technical level that allows mass manual welding the elimination of accidental and unintentional events.

In practice, the satisfactory results were achieved by using system that processes all information about the welds and with feedback to examination results enables to find the sources of faults.

5. IBUS-NZ Procedure

The given examples indicate a necessity of control of welds already on the welding process stage. The using of a selection of welds for assessment of the work of welders or the state of preparing to welding is applied in various range and in various way. The purpose of the IBUS-NZ procedure is to unify these assessments and to use them for quality control of welding process. The usage of technical possibilities of IT and electronics gives a higher level of automation that enables an immediate transformation, selection and printouts of data.

The using of the IBUS-NZ procedure is simple. The database is initially filled with general data characterising the tested welds. The examination results can be transferred from flaw detector (FD) to database through wireless communication or a cable simply by clicking the ‘send’ key in FD. The database is updated in real times in this way and gives the possibility of immediate correction of welding process. The database can operate to many flaw detectors. The data transferred to database are listed below:

- a number of a weld,
- an identifier of a welder,
- an inspector of a welding preparation (option),
- an identifier of examination person (operator),
- a result of the examination (good/bad).

The examination of the last weld finish the examination of entire group of welds without a need for further summary studies as printouts of reports of statistic studies etc. The data of examination results incoming to the computer supplement/create a record for every weld. The database is accessed for authorised person (a password) immediately or any time later from any point of computer network or Internet.

The users have access to the basic data and the collective ones (as predefined database questions) - for example:

- who and when has welded the specified weld,
- who and when has examined the specified weld,
- which of the welds were examined till specified date,
- which of the welds were good till specified date,
- which of the welds were bad till specified date,
- which of the welds were corrected/should be corrected till specified date,
- who has welded the group of welds,
- who has examined the whole group of the welds,
- how many welds were examined till specified date - a stage of advance of the renovation
- a ratio of 'quality ' of welders - how many good welds and how many bad ones every welder has made,

- the ratios of 'quality' of an examination person - on the base of comparison of the examination persons made by everyone for the same group of welds,
- which of the unacceptable welds are not repaired - why and who has allowed it,
- a general result of the examined group of welds,
- a collective report of welding and examining for the group of welds. A wide possibility of modification the range of this report - depended on investor's wishes.

The presented list could be modified and adjusted to the local conditions.

6. Conclusions

With the using IBUS-NZ it is possible to achieve a high reliability level because every weld is not anonymous. The detected faults enables to find its source and later to eliminate them. Almost always the positives effects are seen after short time of IBUS-TNZ application – the number of defective and eliminating welds quickly decreases

References

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