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The WIT Method

The nondestructive way of steel brittleness grade, mechanical properties and structure description evaluation

It is obvious to claim that materials diagnostics has always been considered to be of preventing dangerous failures. However, one might get struck by the idea the truth is not that obvious. For despite strict research performed with the help with more and more perfect equipment and techniques, we can still occasionally hear about expensive and dangerous damages, such as: boiler drums and other parts in power stations, industry pipelines cracking or crumbling, a rail crack, a car leaving the road unexpectedly. The experts usually say: the driver fell asleep when driving, the rail was very old (fatigue process). And which in some cases it might be true as well. After such incidents, however, everything comes back to normal and again, after some time, we hear about another damage. Seldom does an expert decide on the cause of the failure being low steel impact resistance (or intensity steel brittleness). This, in turns, happens for many reasons, the main of which being the fact that it is nearly impossible to assess the steel brittleness caused by heat treatment with the help of nondestructive methods. Let us give an example: if Titanic had sailed for decades, it would have probably been claimed that the ship cracked up because of her age (senility). It is widely known today it was enough for the ship to get scraped against an iceberg to start breaking off. In other words: low steel impact resistance was to blame. We can say: if Titanic was examined with the WIT Method, it would never have left the port. It still happens to the ships: from time to time we are able to observe the crack-broken tankers or cracked shipboards.

There has been not much record of technical checks into brittleness as there was no proper technology to assess it. It is probably the 1960s cracking mechanics development, as well as more and more dangerous failures happening, which forced the directive for a material to be examined in terms of brittleness. The first record comes from 97/23/EC EU [1] directive and, let us hope, serves as the announcement of a much more efficient and proper diagnostics. Our company was in favour of such recommendation already in the early 1990s.

However, the directive might only be executed with the help of a destructive method - examining a material sample. This means the thorough material examination is impossible. And such is the case of multi-part devices, for which one material sample may not necessarily be representative of other elements of the device, even if the kind of material for each part is the same. A nondestructive method proves its rationale here. Such method allows assess material brittleness without having to cut off the material sample that, at the same time, makes it possible to examine each element in many places. And such method is The WIT Method.

The WIT Method Origins

The Method was created at a research station of Office of Technical Inspection in Poland in the years 1974 – 1980. The supervisor's dissertation constituted the starting point, though the first research (1974) was much simplified.

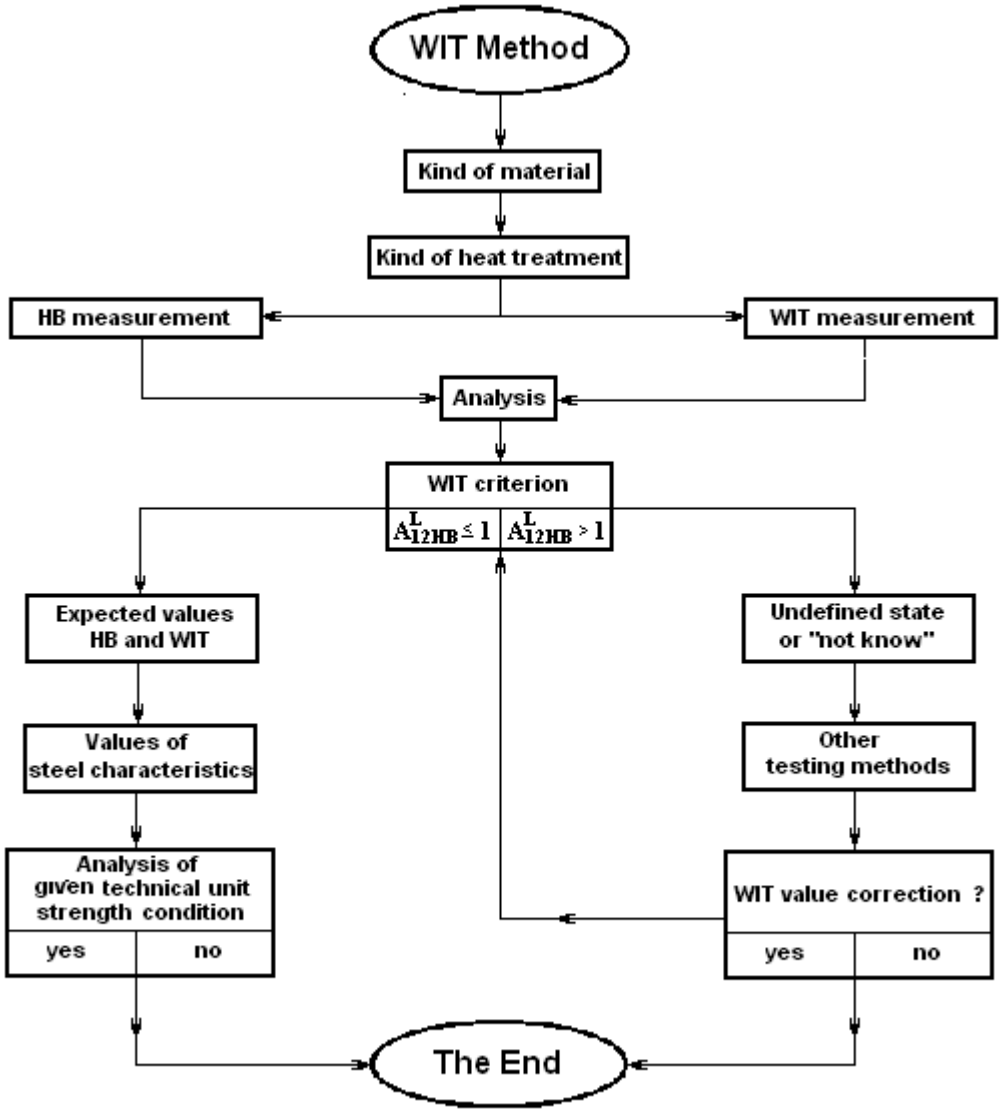

Fig. 1

The WIT Method Basis (assumption)

1. Each of material condition (it refers to low carbon or low alloying steel) has its own attenuation coefficient of longitudinal wave for specified frequency (12 MHz in this situation). This assumption is an effect of basic research which taking into account correlation between attenuation coefficient and carbon concentration amount in normalized carbon steels (0,12 ÷ 0,55) % and structure grains size (19 ÷ 250) μm. In WIT method exists WIT value definition: α^L_{12} - attenuation coefficient of longitudinal wave for 12 MHz frequency.

2. Direct evaluation refers to steel with smaller then 30 μm average structure grain size. The WIT value depends on steel grain size strongly. Thus, WIT method procedure determines way of process for such cases. Moreover, practice shows for this grain size which WIT method is

applied is no more then 30 μm. This section refers to more then 90% meeting steel kinds - otherwise applying of this method would have met serious practical difficulties.

The WIT Method idea

The WIT Method algorism and application are shown in fig. 1.

1. Material identification

WIT method does not identify the chemical composition of tested steel. Numerical mechanical property values of steel kinds have comparable this values. For example WIT value and hardness for A-106 gr. B (low carbon steel) and A387 gr. B (low alloy steel) could be identical, but other properties are different, especially creep resistance. Therefore steel kind or its chemical composition have to be identified to make possible to get appropriate mechanical properties from special WIT curves (or diagram).

2. Heat treatment identification

Although calculation program chooses automatically appropriate WIT curves according to individual code for steel kind and hardness, material heat treatment identification is also significant in the WIT method. Heat treatment identification is important for further test results interpretation. The disrespect of technological procedures by technical equipment producers is common occurrence. For instance boiler-equipment low alloy steel parts should be normalized and tempered. Whereas, it happens, one delivery of identical material property devices is possible to have different hardness - even to one hundred and more Brinell (or Vickers) units. The experts do not need any further explanation how such a difference might influence the mechanical properties, especially creep resistance. The problem refers to deliverers all over the world, even the well known ones.

3. WIT value and HB hardness measurement

a) WIT value

The WIT value measurement (α^{L}_{12}) is made with an authorized ultrasonic head according to due procedure of WIT method quality system.

b) HB hardness

The Brinell scale is used, however hardness measurements are executed only with portable equipment. The modern measurement systems, electronic (low-energetic) are not discussed in the WIT document, as they are not useful for WIT method. For WIT method requirements hardness measurements are executed with modernized Poldy's method according to an established procedure which is also included into the general procedure of WIT method quality assurance system. Energetic background of the measured element has no influence on Poldy's method measurement result. Poldy's method allows to take a large imprint at the tested element, which penetrates the structure deeply.

4. Results analysis

The measured WIT and HB values are analyzed. The analysis result states whether the examined material is or is not susceptible to brittleness cracks. The measured WIT value is compared with its critical value. The quotient is named: WIT criterion (or brittleness criterion):

$$A^{L}_{12HB} = \frac{\alpha^{L}_{12}}{\alpha^{L}_{12HB}} \leq 1,$$

where: α^{L}_{12} is the measured WIT value, and α^{L}_{12HB} is its critical value dependent on hardness, granted that steel grain size is below 30 μm (the WIT method 2nd assumption). Therefore, it is possible to claim what follows:

a) $A^{L}_{12HB} \leq 1$

If a measured WIT value (α^{L}_{12}) is lower or equal to critical value (α^{L}_{12HB}) it means that the tested material is fine-grained (the 2nd assumption) and it does not reveal structure defects relevant to operation safety. After that one needs to decide whether the expected WIT value (α^{L}_{12}.) and hardness (HB) come within the particular steel ranges. That is how it is decided whether the particular steel meets the declared producer's standards. Later, we choose mechanical properties in accordance with measured values (from particular steel WIT diagram): firstly HB, then α^{L}_{12} modification.

b) $A^{L}_{12HB} > 1$

Statement, material not accomplishes WIT criterion is not a statement disqualify tested material. Different structure conditions, such as overheating, grain size above 30 μm, carbides on grains borders, twin grains in austenitic steels, inter granular corrosion, fatigue effects etc. influence the WIT value. There are also high WIT values caused by ultrasonic wave dispersion on damaged reflector (inner) surfaces of the tested objects. It is material-independent reasons. The measured WIT and HB parameters are often too simple tools to recognize different phenomena negatively affecting the structure and the measurement process itself.

If the $A^{L}_{12HB} > 1$, the WIT method states undefined steel condition and complementary tests to define the possible dangers are recommended. In practice, they usually include reflector (inner) surfaces investigation or structure replication. Rarely is a sample collected in order to perform transmission electron microscope investigation.

All above taken into account, the WIT method is named *positive method,* as defines only the proper conditions of an examined material, and for the undefined steel condition the complementary tests are always recommended. The experiments show so far only 5% of WIT results come within the undefined condition calling for the complementary tests.

Border-values

Mechanical properties set with the WIT method are of border values, which means the really properties of a material coming from invasive method testing should be higher than the border-values. Statistically, they come within + 10% of the WIT border-values.

WIT legal basis

WIT method is certified by Office of Technical Inspection in Poland (1993) and the Quality Assurance Policy (according to ISO/IEC 17025) has been issued. The first act including general guidelines for WIT Method usage was published in 1994 [2] by the Ministry of Industry and Trade. There are three license holders of WIT method except for our company (ZBM WITEX S.A). The method has been used to examine over 30 thousand installations and their parts. Many reasons of damages and dangerous structure conditions have been identified.

REFERENCES

[1] *Directive 97/23/EC* of the European Parliament and of the Council of 29 May 1997 on the approximation of the laws of the Member States concerning pressure equipment.

[2] WIT Method. General Guidelines Uses. Ministry of Industry and Trade, 1994.