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EXPERIMENTAL TECHNIQUES IN LOCAL APPROACH TO FRACTURE

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ABSTRACT
Local approach to fracture is introduced for solving complex problems (for example asymmetrical or anisotermal loading conditions), when global approach parameters can not confidently define and predict the behavior of materials under external load. By local approach, fracture process could be described in manner close to real material state during loading. That include application of appropriate experimental methods and convenient numerical simulations.
Application of numerical analysis and local approach parameters evaluation require reliable experimental results, following by appropriate measurements before, during and after testing.
Basic principles of local approach are presented, considering theoretical and numerical background. Specimens design and experimental testing procedure require special instrumentation. Newly designed cantilever device completed with clip-on-gauge and low temperature chamber for local approach to fracture parameters testing are presented in the paper. That is also the economical solution for testing in high temperature chamber and low temperature.
Keywords: Fracture mechanics, Local approach, High temperature, Low temperature

1. INTRODUCTION
The development of 14MoV6 3 steel (DIN) for highly loaded steam pipelines in late seventies offered significant benefits compared to the steels of previous generations [1, 2]. It was very popular for steam lines design and construction due to increased steam parameters (temperature up to 540°C and pressure as high 45 bar for service life of 100,000 operating hours), allowing reduced wall thickness of pipes.
Experimental analysis is performed in order to get more insight in 14MoV6 3 steel properties decrease when exposed to elevated temperature for long term, corresponding to design service life (117,000 service hours). The rate of properties decrease and their level after long-term exposure to service temperature is of importance for the evaluation of residual life and the decision about next service of damaged pipes.
ESIS document [3] establishes the procedure for the experimental determination of the parameters necessary for the application of the local approach to fracture. For this purpose we use notched tensile specimens. For experimental and numerical considerations, axisymetrical notched specimens including different notch radius were used. That specimen geometry enables relatively simple testing; as they are axisymetric, 2D numerical analysis could be performed without plane strain or plane stress assumption; by notch radius variation, different strain and stress states could be observed
The specimens, produced from samples taken from new and used of 14MoV6 3 steel have been simultaneously tested. Mechanical properties are evaluated by tensile and impact test. Resistance to

fracture has been determined by local approach and analyzed for ductile fracture properties, that is dominant in considered case.

2. CONTROL AND MEASUREMENT TECHNIQUES IN LOCAL APPROACH EXPERIMENTS

Application of numerical analysis and local approach parameters evaluation require reliable experimental results, followed by appropriate measurements before, during and after testing.

2.1. Measurement of notch tensile specimens geometry before testingext

To determine parameters of local approach of fracture mechanic, we use axysymetric notched tensile specimens, which are made with a radius of 2, 4 and 10 mm (Fig. 1).

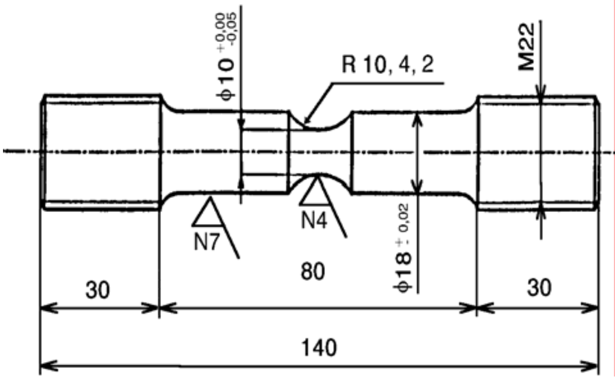


Figure 1. Notched tensile specimen

All dimension should be machined with a sufficient accuracy:

- minimum diameter ϕ: +0.00, -0.05 mm
- diameter of the outer section B: ±0.02 mm

The notch should be made by grindstone with the appropriate roughness at Ra=0,4µm. It is necessary to make precise dimensional control and roughness of specimens before testing. It is done because we make numerical simulation of these testing afterwards.

When we know that this specimen geometry is too complicated for measuring, it is then clear that we must use special measuring instruments. Because of specimens shape and notch geometry, special measuring instrument are required. Special measuring instruments for measurement of minimal diameter with 10^{-4} mm accuracy, exceed our accuracy demand, Fig. 2. This measuring is particularly important for testing in conditions of cleavage fracture, because when we calculate diametral contraction of the minimum section we deduct the diameters of minimal cross section at the beginning of the test and the one we measured after the rupture of the specimen. That means we have measured maximal diametral contraction. Maximal diametral contractions, at the test in condition of cleavage are small (3% to 30%) because we test at the temperature of liquid nitrogen, -196ºC. Any error or inaccuracy in measuring leads to unacceptable scatter of results.

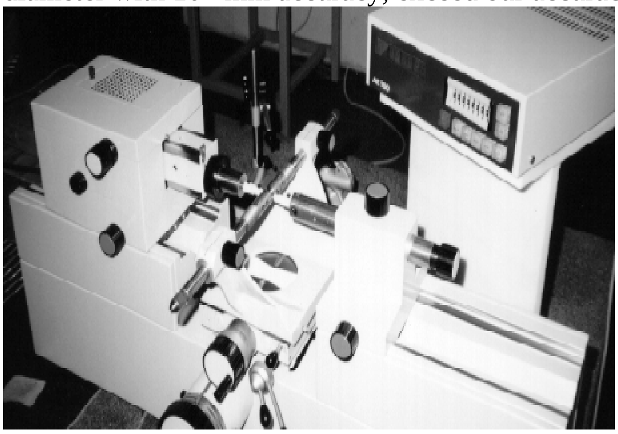


Figure 2. Instrument for measuring minimal diameter of specimen CARL ZEISS JENA

For specimens notch radius and notch roughness measurements, laser instrument for control of ball bearings inner ring is used, Fig. 3. The measurement report of initial dimensions of notch radius and roughness, measured by laser instrument, are given in Fig. 4. This measurement ensures a possibility

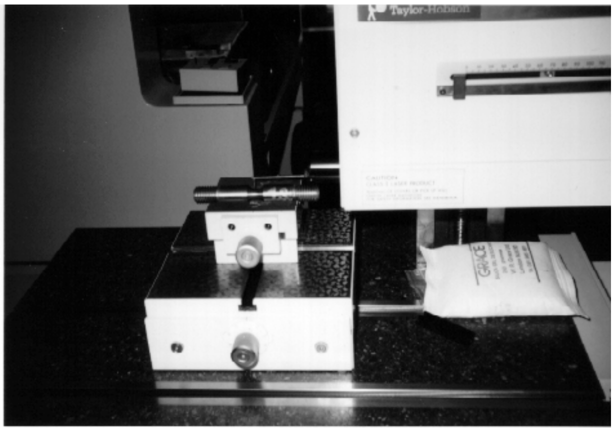


Figure 3. Laser instrument, TAILOR HOBSON, for control specimens notch radius and notch roughness measurements

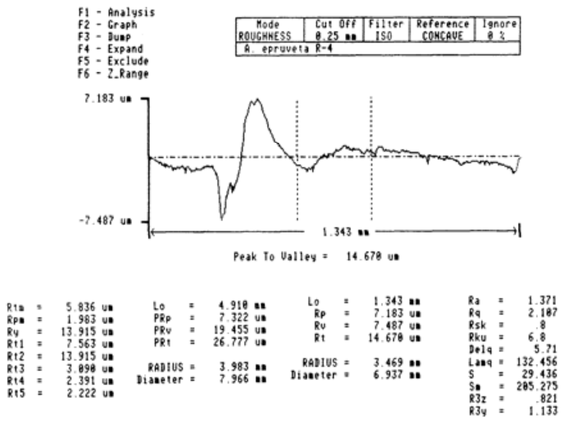


Figure 4. Measurement report of initial dimensions of notch radius and roughness measured by laser instrument

of unacceptable scatter of results which would be the consequence of unequal geometry of specimens and high roughness. In case the scatter of results is higher then 20%, testing must be repeated [3], because the methodology of local approach testing is based on the fact that fracture accurse due to deficiency in a volume containing enough carbides or inclusions[4]. That means that if we have low level of roughness the damage will not start from the surface of the specimen, but from the metallurgical deficiency.

2.2. Measurement and control during testing

The test temperature must be selected to obtain fully ductile fracture behaviour and cleavage fracture. Considering conditions of testing, high temperatures for ductile fracture and extremely low temperatures for cleavage fracture occurrence, there are some problems of specimen diametral contraction measurements. The change in diameter shall be measured with an accuracy of 0.1%. For testing at elevated temperatures, accessory for reliable measurement of specimens contraction by standard COD (crack opening displacement) extensometer is designed. At usage of accessory, extensometer is placed outside chamber, i.e. at room temperature, Fig. 5. Before testing, extensometer and accessory should be calibrated, Fig. 6.

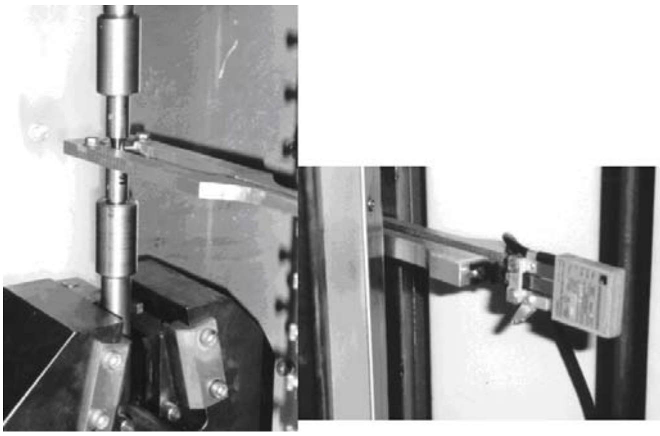


Figure 5. Testing equipment for high temperature testing, left inner part of chamber, right outer part of chamber

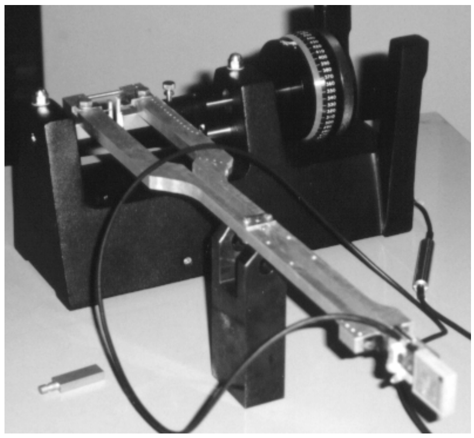
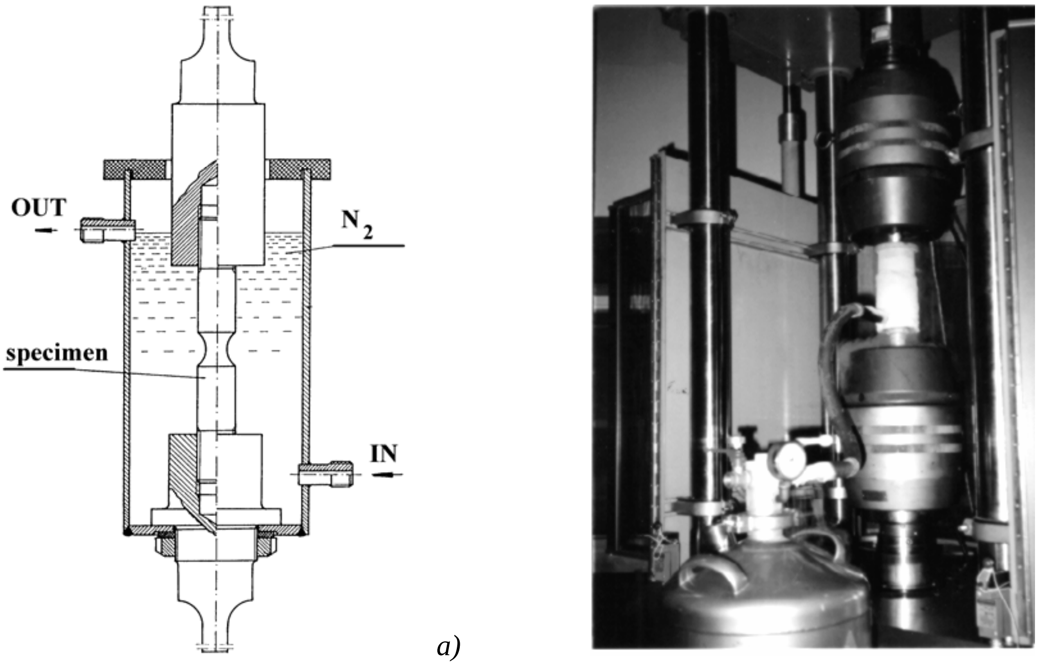


Figure 6. Calibration COD extensometer for measuring diametral contraction of the minimum section

The temperature must be controlled during the test, within ±2ºC in the notch area. For ductile fracture experiment was carried out in temperature chamber with an accuracy of ±1ºC. Measurement of cleavage temperature in critical specimen zone - notch zone, is possible by design and use of accessory for tensile testing, which ensure testing at proper low temperature.



a) b)

Figure 7. Testing equipment for cleavage fracture; a) drawing and b) picture

We designed the chamber, Fig. 7, for testing at the temperature of liquid nitrogen, -196ºC, and obtained better accuracy.

3. CONCLUSION

Determination of local approach parameters requires numerical analysis and experimental results, obtained by appropriate measurements before, during and after testing. Measuring equipment in bearings factory could accomplish demands of before testing measurements. For testing at elevated temperatures, at ductile fracture conditions, accessory for reliable measurement of specimens contraction by standard COD extensometer is designed. At aleavage fracture conditions, there are no possibilities of specimen contraction measurement during testing, so minimum diameter should be measured after testing by profile projector. Measurement of temperature in the notch zone, is enabled by design and use of accessory for tensile testing, which ensure testing at proper low temperature. In that way, reliably testing and measurements are enabled in laboratories that are not supported by modern and expensive equipment.

4. ACKNOWLEDGMENTS

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