Ryszard ŻUCHOWSKI*, Jerzy LASKA**, Franciszek LESZKOWICZ***

Specific Strain Work as a Damage Measure in Power Plant Pipelines under Complex Stress

* Technical University of Wroclaw, Poland

** Research and Development Centre for Overhaul Management of Power Industry, Wroclaw, Poland

*** Power Plant "TURÓW", Poland

Keywords: specific strain work, pipelines, testing

ABSTRACT: An attempt was made to assess how much boiler pipes get worked-out after a period of service under creep conditions. The method of specific strain work was used to evaluate specimens cut out perpendicularly to the pipe axis. The sample direction follows then the maximum tensile stress direction and is perpendicular to those grain boudaries that are a primary site for structural defects being produced in the process. Comparative tests on specimens cut out along the two directions made it possible to state that this technique of sample preparation gives a better insight into the damage process and is better suited to safety regulations since the produced grooves can be easily weld-repaired.

Introduction

Materials used for pipelines in power industry are subject to creep and thermal cycling conditions during exploitation. Structural changes in material of structural members cause deterioration of physical properties and exhaustion of durability reserve. The aim of overhaul diagnostics is the determination of this durability reserve in nondestructive testing (NDT). Relationship between the results of NDT and the real durability reserve is determined during the destructive testing, especially in laboratories, and during testing pipelines at power plants, if it is needed or/and possible.

Material properties as well as damage of material are direction-sensitive. Material properties depend on the direction because nonmetallic inclusions are located primarily along the direction of maximum plastic strain and on the material texture due to plastic working that does not vanish even upon recrystallisation taking place during hot primary working operations or subsequent heat treatment. Damage of material depends on the direction because during work under the creep conditions structural defects structural defects are coalescing primarily within grain boundaries perpendicular to the maximum tensile stress direction and at the final stages of creep they give rise to the well-established sequence of damage features: isolated micropores, micropore chains, microcracks, macrocracks and final rupture.

Mechanical properties are the highest along the direction of maximum strain obtained during plastic working while the first signs of damage arise at the grain boundaries perpendicular to the direction of maximum tensile stress – these are the same directions. The maximum stresses in the power plant pipelines working under the creep conditions are the circumferential stresses.

The presented study was aimed at assessing the material damage using a specific strain work (obtained during a tension test) as a damage parameter [1]. Specific strain work (SSW) is one of the most sensitive measures of material deterioration, which was confirmed in the investigation of both exploited and failed pipelines [2–4]. Up to now all the SSW investigations were performed using specimens cut out along the direction of plastic deformation. Unfortunately, the conditions of power utility industry practically exclude the posibility of cutting through pipelines, such a method being regarded as both expensive and troublesome.

The proposed method of taking specimens from power pipelines requires that a special portable saw be used so that a sample can be cut out without cutting the pipe throughout and the removed volumes of material be replaced by a welding process suitable for a given steel grade. These requirements exclude thin-walled pipes for obvious resons. So far, the results can be compared within a given steel grade and pipe size, microstructure checks being a welcome supplement.

Specimens

Examinations were performed on specimens cut out from pipelines made of 13HFM steel (designation according to Polish Standard PN - 75/H - 84024) before exploitation as well as from pipelines after working for 220 000 hrs.

The designed life time was 100 000 hrs under the following conditions:

- temperature: 530^{0}C,
- pressure: 15 MPa,

Number of out-of-service periods: 766, and specifically:

- - up to 8 h: 142,
- - from 8 to 24 h: 396,
- - over 24 h: 228

The specimens of 5 mm diameter and 50 mm gauge length were cut out from pipelines with the external diameter of 324 mm and thickness 36 mm. Seven specimens were cut out in the direction parallel to the pipeline axis and the other seven – in the direction perpendicular to this axis (Fig. 1). The shape of these specimens was the same as the shape of specimens used in the earlier examinations [3,4] to be able to compare the results.

Results and analysis

For the pipes tested differences were found in ultimate tensile strength (UTS) and yield strength (YS) measured in the longitudinal and the transverse directions. The SSW values were also different for the two directions. In a new material the differences were smaller than 5 %, in a worked-out one they reached 10 %. The observed changes in UTS, YS and SSW prove that grain boundaries perpendicular to the maximum stress direction are a preferred site for structural defects.

The aforementioned quantities did not change considerably so we are in a position to state that material commonly regarded as no longer usable is still suitable for service. This finding is further enhanced by microscope examinations showing no clear damage features (Figs. 2, 3).

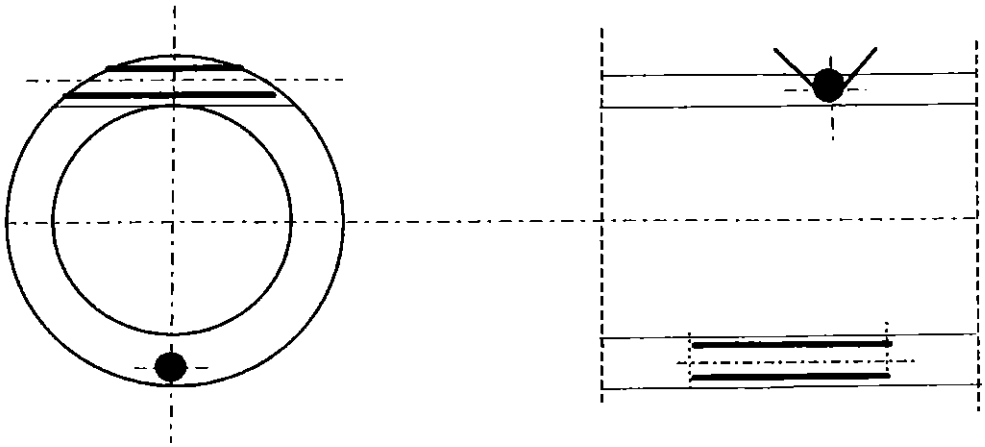

Fig. 1. The sites the specimens were cut out.

The presented investigation demonstrates that for moderately worked-out materials the mechanical tests and the SSW test are a better indicator of their condition than microstructural examination.

It is very likely that in a more worked-out material the difference in mechanical characteristics and SSW value between the longitudinal and the transverse directions will be larger.

Conclusions

The results obtained show that the specimens cut out in the direction perpendicular to the pipeline axis can be used for the SSW determination. It was also found that a significant difference exists between material damage obtained in specimens cut out in these two

perpendicular to the pipeline axis is higher than that evaluated for specimens cut out in the direction parallel to that axis. The obtained results were confirmed with the results obtained from metallurgical examination performed on the same specimes. The obtained results showed also that specific strain work can be used as a parameter of material damage in different directions. It allows to attempt determining damage parameters in the tensor form of the damage growth law.

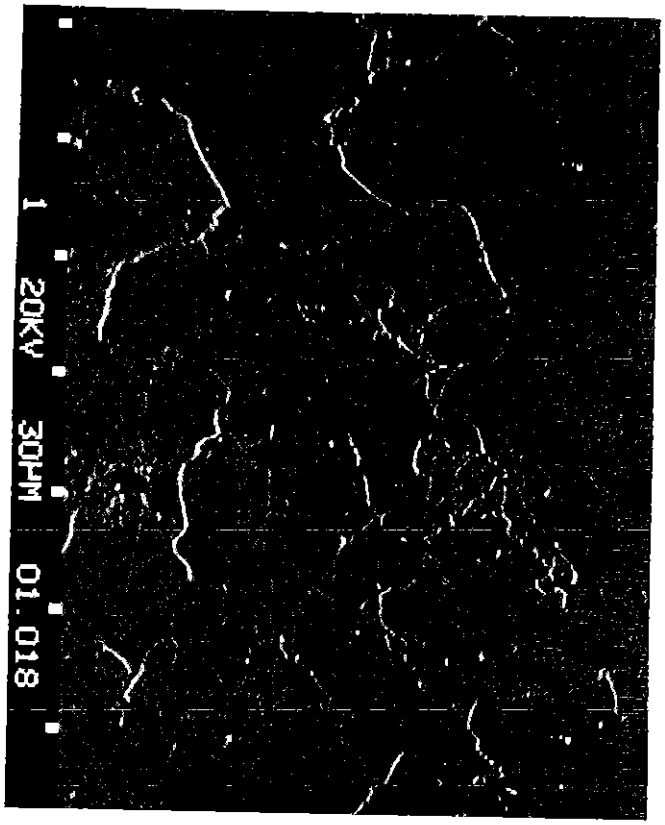

Fig. 2. Microstructure of a worked-out pipe at a longitudinal section (500 X).

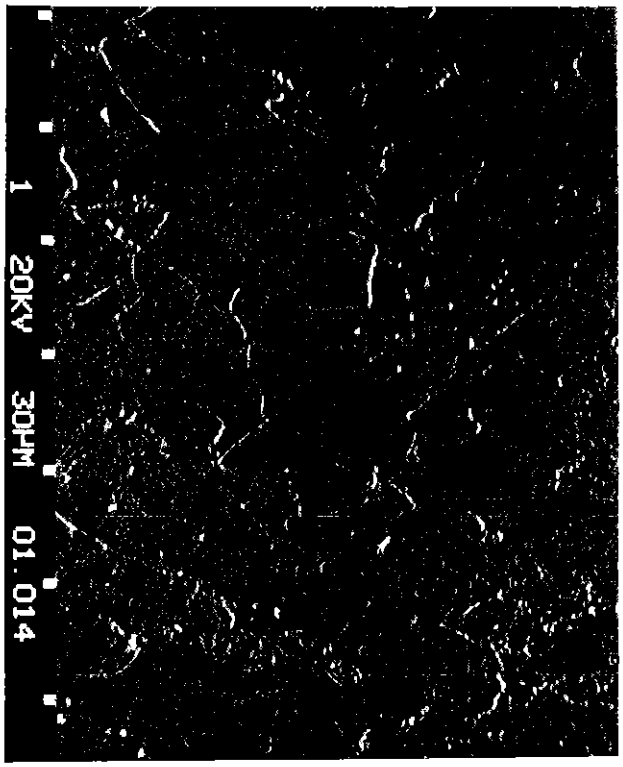

Fig. 3. Microstructure of a worked-out pipe at a transverse section (500 X).

References

1. ŻUCHOWSKI R., (1989), Specific strain work as both failure criterion and material damage measure, Res Mechanica,27, 309-322.

2. ŻUCHOWSKI R., (1992), The effect of damage on material conditions in boiler down-pipes, The Inter. Conf. on Pipeline Reliability, Calgary, Canada 1992, Gulf. Publ. Comp. Houston, London, Paris, Zurich, Tokyo ,V10.1 - V10.8.

3. LASKA J.,KORUSIEWICZ L., (1992), Residual life of 15HM steel and the specific strain work criterion (in Polish), 3rd Conf. on Repair Operations in Utility Industry, Bielsko-Bia³a, Zeszyty Naukowe WSI Opole, No 180.

4. LASKA J.,KORUSIEWICZ L, BESZTAK L., (1994), Evaluation of the damage extent in a re-superheated steam boundary made of 13HMF steel (in Polish), 8th Int. Symp. on Methods of Material and Product Characterization, Opole-Jesenik, Zeszyty Naukowe WSI Opole, No 208.