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Application of technical diagnostic parameters for evaluation of serviceabilty forcible power plants high temperature pipelines

Zastosowanie parametrów diagnostyki technicznej do oceny zdolności do pracy wysoko-temperaturowych rurociągów elektrowni cieplnych

ABSTRACT

Technical diagnostic parameters that are used to assess operability of high temperature pipelines thermal power plants has concidered. It was found the sensitivity of these parameters to assess the metal degradation in the steam during a long operation. It has been propose the approaches to assess the residual life of steam pipelines, taking into account parameters that are structurally vulnerable to degradation of metal.

Keywords: *reliability, technical diagnosis, pipeline, structure, damage, serviceability*

STRESZCZENIE

Analizie poddano parametry diagnostyki technicznej stosowane w ocenie zdolności do pracy wysokotemperaturowych rurociągów elektrowni cieplnych. Określono przydatność tych parametrów do oceny stanu degradacji metali stosowanych w wysokotemperaturowych rurociągach, w warunkach długotrwałego, eksploatacyjnego oddziaływania pary wysokotemperaturowej. Zaproponowano sposób oceny tzw. resztkowego czasu eksploatacji parociągów, oparty o parametry diagnostyki technicznej pozwalające na określenie tzw. strukturalnej podatności na uszkodzenia, prowadzące do degradacji metalu wskutek oddziaływania wysokotemperaturowej pary technologicznej.

Słowa kluczowe: *niezawodność, diagnostyka techniczna, rurociąg, struktura, zniszczenie materiału, zdolność do eksploatacji*

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1. Introduction

The resource of high temperature pipelines forcible power plants (FPP) depends on the temperature-power parameters operation and amounts to (75 ... 300) · 10^3 hours. Up for the present time, the most of FPP steam pipelines fulfilled certain period. So, it is important the assessment of metal state and determine the possibility of their further exploitation. High-power plants pipelines made ftom heat-resistant steels (12Cr1MoV and 15Cr1Mo1V), which should ensure their reliable operation at high temperature-power conditions (T=545°C, p=10...22 MPa) for a determined period [1, 2].

Operating experience and damage of pipelines indicate that bends the least reliable of their constituents.

This is due to a structurally-technological features production and dynamic changes in the structure and properties, the operational impact on the geometric dimensions, redistribution of stresses etc. Accordingly park resource bends of steam pipelines amounts to 75.0 ... 87.5% of direct resource of pipes and welds.

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2. Materials and experimental procedure

It has been investigated the bends of steam pipelines of fresh pair made from the heat-resistant steel 12Cr1MoV (Tab. 1, 2) after different periods of operation. For laboratory testing specimens has selected as well as from the bends, rejected in the results of flaw detection and the bends with the worst characteristics of permanent deformation creep ovality, hardness or microdamage.

Samples of steam pipelines damaged metal has investigated on static tensile and bending impact at ambient and operating temperatures.

Tab. 1. The chemical composition of steel 12Cr1MoV
Tab. 1. Skład chemiczny stali 12Cr1MoV

C	Si	Mn	Cr	Ni
0.10 ÷ 0.15	0.17 ÷ 0.37	0.40 ÷ 0.70	0.90 ÷ 1.20	≤ 0.25

Mo	V	Cu	S	P
0.25 ÷ 0.35	0.15 ÷ 0.30	≤ 0.20	≤ 0.025	≤ 0.025

Tab. 2. The mechanical properties of steel 12Cr1MoV
Tab. 2. Właściwości mechaniczne stali 12Cr1MoV

Yield Strength, MPa	Tensile Strength, MPa	Elongation, %	Reduction, %	Impact Strength, MJ/m²
≥ 274	441 ÷ 637	≥ 19	≥ 50	≥ 0,5

3. Results and discussion

3.1 Stress analysis in the steam pipelines

Working stresses due to the pressure of the environment has arise in steam pipelines. They are stretching and called as arising. The tension caused by the weight of construction, thermal movements are interchangeable and can be characterized bending and twisting, changing their size, and sometimes a sign arising first during starting and stopping. These stresses caused by external loads, referred to as equivalent. The reliable operation bends of steam pipelines provided by compliance with the conditions under which, the total value of work stress - reduced and equivalent does not exceed allowable values for this steel grade and temperature operating environment.

3.2 Technical diagnostics parameters

To assess the state of of steam pipelines flaw detection using different methods (visual-optical, magnetic, ultrasonic). These methods reliably detect unacceptable defects (mainly makrosize), but they are not sensitive to changes in metal degradation during prolonged use.

Is revealed that most of the parameters used in the assessment of energy for steam pipelines (and metal bends particular), are macroscopic or integral. Among them acceptable levels of mechanical characteristics and hardness, deformation permanent and creep speed, ovality.

During the observations of steam pipelines metal has found that in the process of long operation changes the microstructure, characterized by the collapse of the main solid solution, the allocation of excess phases and their coagulation, redistribution and accumulation of mikrodamage [3, 4]. Changes in the structure are accompanied by changes in the mechanical properties of the metal. Due to [3], the ratio is less scatter values than the ultimate tensile strength at operating temperature. This predefined by that pipes are stronger at room temperature, and the stronger by operating temperature too. Ultimate tensile strength at operating temperature decreases during prolonged operation regardless of the initial of strength. However, strengthened in the initial state softening pipes faster.

According to the test results, the ratio for steel 12Cr1MoV in the initial state is typically 1.28 ...1.65. During operation it increases, indicating a softening of metal. Analysis of mechanical testing metal samples of steam pipelines that had a different value of permanent deformation was found that metal of steam pipeline with high residual deformation and unsatisfactory structure ratio is higher and amounts to 1.60 ... 1.78. For pipes damaged due to creep, it was more than 1.75 [3] (Fig. 1.).

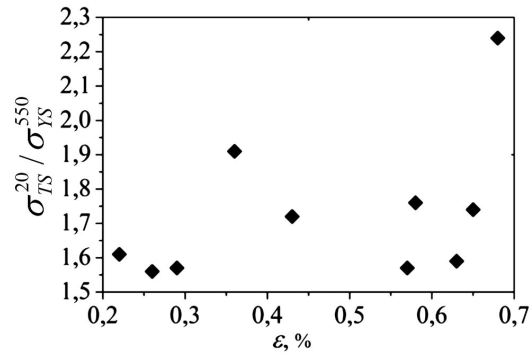

Fig. 1. Dependence $\sigma^{20}_{TS} / \sigma^{550}_{YS}$ of value of residual deformation of pipe-line
Rys. 1. Zależność $\sigma^{20}_{TS} / \sigma^{550}_{YS}$ od wartości pozostałego odkształcenia rurociągu

Great importance for predicting the operability of steam pipelines has a score of resistance to brittle fracture of material. It is traced the cases of anisotropy of metal bends impact toughness with existing crack defects. In this case the impact strength of samples transverse orientation was an order of magnitude smaller than the impact strength of samples longitudinal orientation. Clearly expressed anisotropy at room temperature indicates the presence of submicroscopic and microscopic pores. In this case the impact strength in transverse samples significantly reduced, while at the longitudinal changes slightly. It is related to nucleation and the location of microdefects [5, 7].

As a result of prolonged use of steam pipelines metal the impact toughness at room temperature usually decreases (Fig. 2a) due to aging, a shift transition of brittleness temperature to the area of positive temperatures even higher than room, as well as the development of microdamage and steel hydrogenation [6-8]. At the same time by the operating temperature it changes a little (Fig. 2b). So after a long operating time resistance to brittle fracture is higher than at room temperature (Fig. 2.). We should not discard the impact of heating and shutter steel at 560 ÷ 565°C before testing when metal has adsorbs the residual (mobile) hydrogen. The positive effect of holding in vacuum at elevated temperatures associated with degassing of metal traced previously [8, 9].

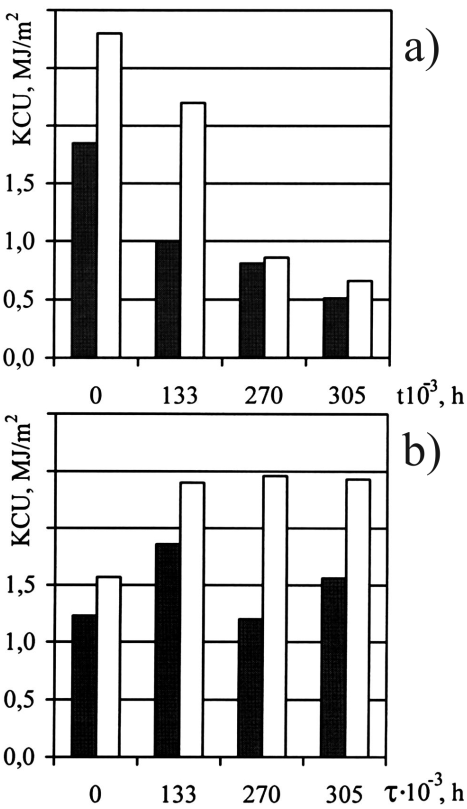

Fig. 2. Histograms of impact toughness KCU at room (a) and service(b) temperature of 12Cr1MoV steel during its exploitation in pipeline: dark columns – transversal speciments, light – longitudinal (metal of direct bend sections was tested).
Rys. 2. Histogramy udarności KCU w tenperaturze pokojowej (a) i eksploatacji (b) stali 12Cr1MoV podczas jej pracy w rurociągu: ciemne kolumny - próbki poprzeczne, jasne - próbki podłużne (materiał pobrany bezpośrednio z próbek zginanych)

It has been investigated bend, which up to damage has worked of 285786 hours and has moved through 1142 shootdown. In order to clarify the status of the damaged metal bending and degree of degradation of mechanical properties, microstructure and assessment of different sites microdamage metal bend we cut and studied their part. Ovality ring sample - "reel" was 4.1%. For laboratory research sample has conditionally divided into three sections (I - stretched, II - neutral, III - compressed).

According to the results of tests on static tensile strength (σ_{TS}, σ_{YS}) and plastic (δ_5, ψ) metal properties all areas has tested due to the requirements for the supply of technical requirements. The lowest strength (σ_{TS}) metal fixed in a neutral area. Characteristics of the material of this section is fairly homogeneous. However, for the ultimate tensile strength area has increases in the direction from the outer to the inner surface of the bend, and from the compressed – to the contrary.

Impact toughness, which is characteristic of the material resistance to brittle fracture, metal top of the stretched area is critically low amounts to 0,26 MJ/m^2, even taking into account the allowable decrease after prolonged operation (1.5 MJ/m^2) is unsatisfactory. At the same time impact toughness metal all other tested areas is satisfactory and increases the thickness of the wall from the outer to the inner surface.

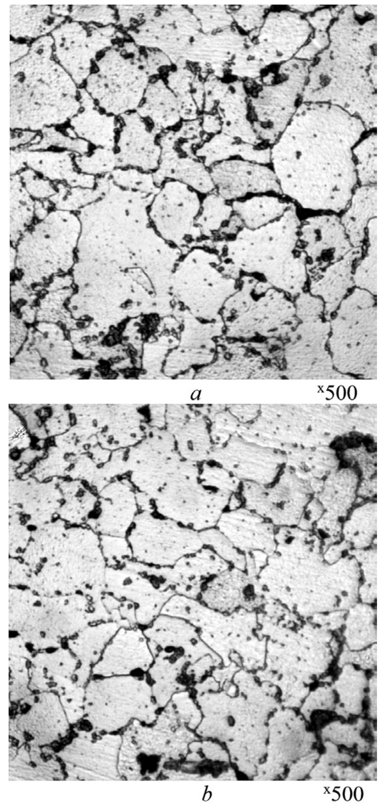

Fig. 3. Microstructure of metal different from zones stretched bending area: - closer to the outer surface; b - closer to the inner surface
Rys. 3. Mikrostruktura materiału w różnych strefach giętej próbki: (a) bliżej powierzchni zewnętrznej; (b) bliżej powierzchni wewnętrznej

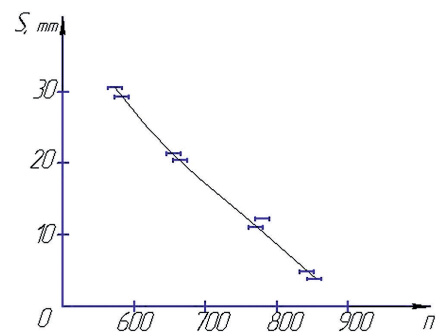

Fig. 4. Distribution of microdamage (n) on the thickness of the bend (S) (counting starts from the outer to the inner surface)
Rys. 4. Rozkład mikropęknięć (n) na grubości próbki giętej (S) (zliczanie rozpoczęto od zewnętrznej do wewnętrznej powierzchni)

Metallographic investigations were performed on the entire section (thickness) bend. Besides magistral cracks in the stretched area of bending cracks has found that generally oriented parallel to macrocrack. Microcracks has distributed in grain boundaries, they traced to ~ 2/3 of wall thickness of the outer surface. Outside of crack microstructure of metal is ferrite-carbide unsatisfactory and shows complete degradation of the metal during the prolonged use. In assessing microdamage determined amount (density) of pores creep in high temperature steam pipeline bending thickness of the samples (Fig.3).

The top of the sample (closer to the outer surface) (Fig. 3a) has demonstrated the number of pores per 1 mm^2 ~

600, and in the bottom of (closer to the inner surface) (Fig. 3b) - ~ 500.

Results of investigation has show that in all the areas of cross-section bending microdamage micropores the creep has observed throughout the thickness of the bend. In the stretched section of bending microdamage gradually decreases in the direction from the outer to the inner surface.

4. Conclusion

Thus, the criteria by which we must for the first determine the suitability of of steam pipelines to further work is accumulated during operation the microdamage (as absolute size, orientation micropores and their density), the total residual deformation speed of creep, which is integrally reproduce changes in the metal during the operation.

Metallographic control method of microdamage bends should be used with the analysis of the actual stress distribution, which allows to identify the local area with a maximum level of microdamage.

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