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The Evaluation of Actual Material Properties of Low Alloy CrMoV Steel from the Results of Small Punch Tests

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Abstract

The Small Punch (SP) test technique is used for the evaluation of actual tensile, fracture and creep characteristics of materials exposed for a long period in operating plant components in order to provide data needed for plant life and integrity assessment.
In the present paper the results of SP tests in the temperature range from -193°C to +20°C, carried out in two laboratories on low alloy steel of type 14MoV6-3 in as received state and after long term operation at 540°C were compared. SP transition temperatures T_{SP} determined from the temperature dependences of the fracture energy were correlated with the FATT temperatures obtained using standardized Charpy V notch test specimens.

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Keywords: SP test, load displacement curve, SP transition temperature T_{SP}, SP fracture energy E^{SP}, FATT, empirical correlation

1. Introduction

Both European Code of Practice [1] and Chinese Code of Practice [2, 3] give a guidance on the procedure to be followed when carrying out Small Punch tests aimed at evaluation of tensile and fracture behavior of materials exposed in operating plant components in order to provide data needed for plant life and integrity assessment. In 2012 the solution of bilateral project, focused on the comparison of Codes of Practice for determination of mechanical properties by SP tests between EU and China, was initiated in the frame of Czech-Chinese Scientific and Technological Cooperation. The participants of the project were MATERIAL & METALLURGICAL RESEARCH Ltd. (MMR), Ostrava, Czech Rep. and School of Mechanical Engineering, East China University of Science and Technology, Shanghai, China (SME). On the basis of common experimental programme realized in both laboratories the database of results of standardized tensile and impact tests and the SP tests results in the temperature

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range -193°C - +20°C were obtained. The objective of the common experimental programme realized on low alloy steel of type 14MoV6-3 in as received state and after long term exposition at 540°C was inter alia:

1) to compare the results obtained by standardized impact tests,
2) to compare the empirical correlations for determination of FATT from the results of SP tests
3) to compare results of SP tests obtained for the Super heater outlet header (SH) exposed for 90 000 hours at 540°C and outlet steam piping exposed for 151062 hours at 540°C (CH).

2. Testing material

A pipe ø 457 x 28 mm in as received state, Super heater outlet header (SH) ø 521x 36 mm exposed for 90 000 hours at 540°C and Output steam piping ø 324 x 48 mm exposed for 151062 hours at 540°C made of low alloy steel of type 14MoV6-3 were used as the testing materials. Chemical composition of the testing materials is shown in Table 1.

Table 1 Control chemical analysis

	C	Mn	Si	S	P	Cr	Mo	Ni	V	Al	N
AS	0,12	0,57	0,19	0,005	0,009	0,57	0,52	0,08	0,32	0,020	0,013
SH	0,14	0,64	0,29	0,009	0,013	0,51	0,59	0,17	0,33	0,005	0,010
CH	0,13	0,58	0,26	0,016	0,014	0,68	0,43	0,17	0,31	0,028	0,009

Note) AS- tube in as received state, SH-Super heater outlet header, CH-outlet steam piping

Metallurgical quality of the testing materials has been expressed by BRUSCATO factor X= (10.P+5.Sb +4.Sn+As)/100 and J factor J = (Si + Mn) x (P + Sn) x 10^4 (see Table 2).

Table 2 Metallurgical quality of the testing materials

Pipe ø457x28 mm in as received state	X = 12,0 ppm	J = 114
Super heater outlet header (SH)	X = 26,4 ppm	J = 223
Output steam piping (CH)	X = 17,8 ppm	J = 160

Segments of the size 405 x 70 mm, cut from the pipe in as received state, were heat treated by 7 different regimes (HT) (see tab. 3) to obtain significantly different yield stresses, tensile strengths and FATT.

Table 3 Selected regimes of heat treatment of testing segments

HT1	940°C/1 hour/water + 720°C/2 hours/air
HT2	940°C/1 hour/furnace +720°C/2 hours/air
HT3	940°C/ 1 hour/oil + 720°C/2 hours/air
HT4	940°C/1 hour/air + 720°C/2 hours/air
HT5	940°C/1 hour/water + 700°C/2 hours/air
HT6	940°C/1 hour/air + 740°C/2 hours/air
HT7	940°C/1 hour/oil + 740°C/2 hours 40 min./air

Charpy V notch test specimens oriented in T-L direction and semi- products of SP disc specimens 8 mm and 10 mm in diameter and 0.65 mm in thickness oriented in R-L direction were manufactured for both laboratories in mechanical workshop of MATERIAL & METALLURGICAL RESEARCH Ltd (MMR).

3. Results of impact tests

Impact tests were carried out in both laboratories at the same temperatures for each test material under investigation. The percentage of shear fracture %SF were was expressed in MMR in the form