

**DUCTILE – BRITTLE TRANSITION
BEHAVIOUR OF
CIRCUMFERENTIAL WELD OF
REHEATER HEADER
DETERMINED BY SMALL PUNCH
TESTS**

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1. INTRODUCTION

- **Determination of actual mechanical properties (Tensile properties, Ductile Brittle Transition Temperature – DBTT and their changes during long-term service – important data for residual lifetime assessment of several industrial components.**
- **Welded equipments :**
 - **Parent material and/or weld metal application of standartized test procedure**
 - **HAZ (Heat Affected Zone) – narrow area - possibility of utilization of small test methods**
 - **Present paper - comparison of results of standartized tests and Small Bulge tests**

2. TESTING MATERIAL AND TESTING METHODS

- **Weld joint of Reheater header – tube \varnothing 324x46 mm from (low-alloy heat resisting steel of 0.5Cr-0.5Mo-0.3V base)**
- **service conditions 107.500 hours at 540°C**

TESTING METHODS

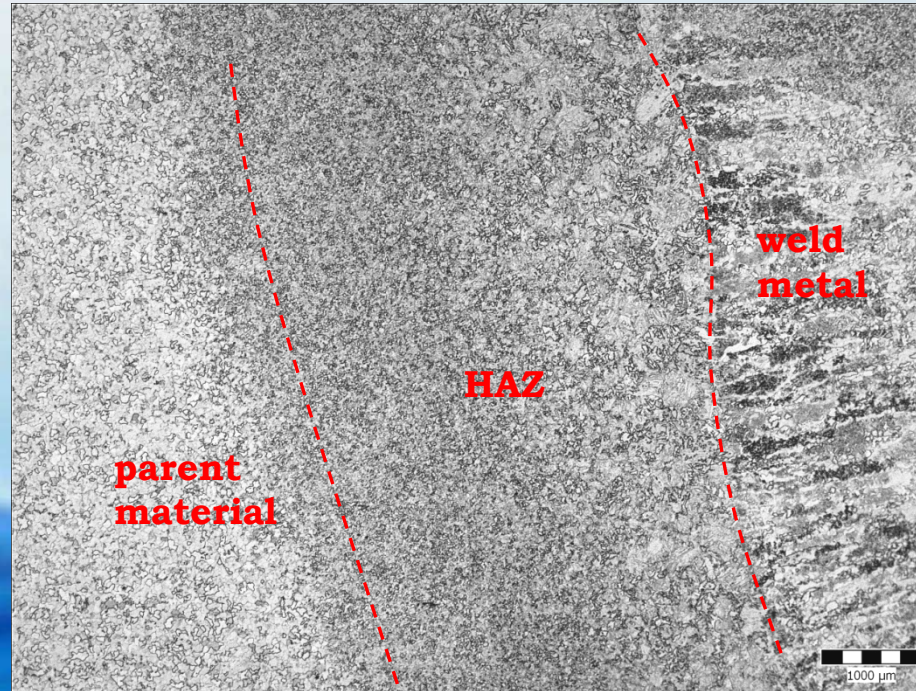
Standardized test

- **Tensile properties \varnothing 6 mm dia**
- **Impact toughness \varnothing 10x10x55 mm, V notch 2 mm**

-Small Penetrating Bulge Test

**test piece \varnothing 8 mm, hemispherical tip \varnothing 2 mm
crosshead speed 1 mm/min**

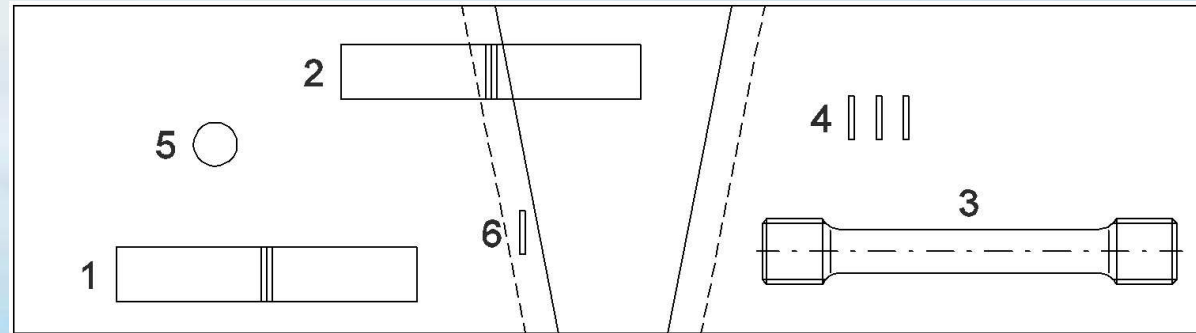
Hardness test HV 10



Macro-etching of the weld investigated

Measurement of HAZ width – 4.8 mm

Location and orientation of test specimens



Location of test specimen in the testing material

Orientation of test specimens

1; 3; 4; 5 - parent material

2; 6; - HAZ area

1; 2; 3; 5 - paralell to tube axis - L

4; 6 - perpendicular to tube axis - T

3. RESULTS AND DISCUSSION

a) Standardized tests - Tensile properties

Tab.I

| $R_{p,0,2}$ [MPa] | R_m [MPa] | A [%] | Z [%] |
|----------------------|----------------|----------|----------|
| 376 | 550 | 27 | 72 |

- Impact properties
FATT Temperature
+48°C – parent material
+10°C - HAZ

b) Small Punch Bulge tests

| Test specimen | h_0 [mm] | F_e [N] | F_m [N] | u_m [mm] |
|---------------|------------|-----------|-----------|------------|
| PM/1 | 0,500 | 164 | 1182 | 1,74 |
| PM/2 | 0,500 | 146 | 1187 | 1,74 |
| PM/3 | 0,500 | 143 | 1115 | 1,73 |
| HAZ/1 | 0,500 | 249 | 1311 | 1,70 |
| HAZ/2 | 0,500 | 258 | 1328 | 1,70 |
| HAZ/3 | 0,500 | 260 | 1382 | 1,72 |

Table II where h_0 specimen thickness
 F_e load at yield stress
 F_m maximum load
 u_m displacement at F_m

| Test method | Parent material | | HAZ | |
|-------------------|-----------------|-------------|-------------|-------------|
| | R_e [MPa] | R_m [MPa] | R_e [MPa] | R_m [MPa] |
| Standard. tests | 376 | 550 | | |
| SP Bulge tests | 366 | 553 | 560 | 659 |
| HV10 measurements | | 541 | | 648 |

Table III Comparison tests results obtained from standardized and SP Bulge tests and HV 10 measurement

- **Very good agreement among for standardized, SPB and HV10 tensile results**
- **Minor effect of orientation of tests specimens (isotropic of parent material, the same crack propagation for SPB and for standardized tensile test.**

Impact properties - SPBT

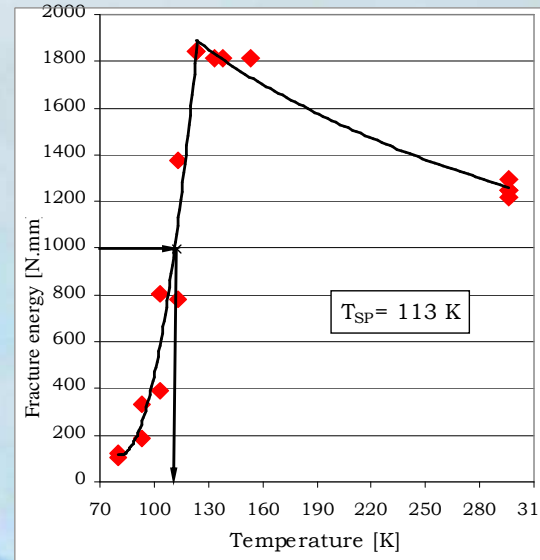
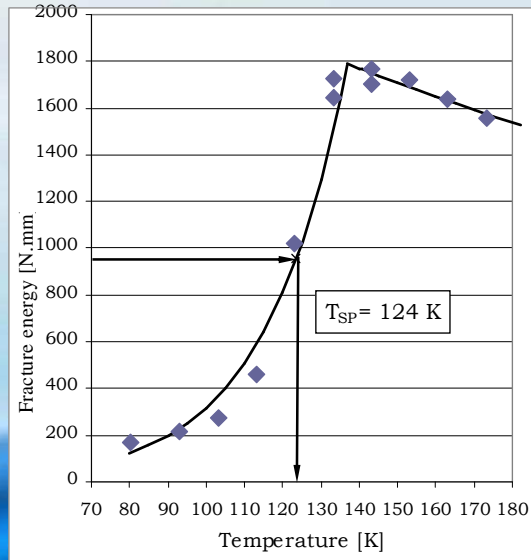
-Temperature dependence of fracture energy

-Temperature range - 193°C to - 110°C

Parent material T-L



Fig.4



Parent material L-T

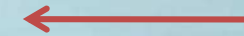


Fig.5

HAZ T-L

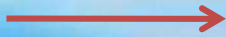
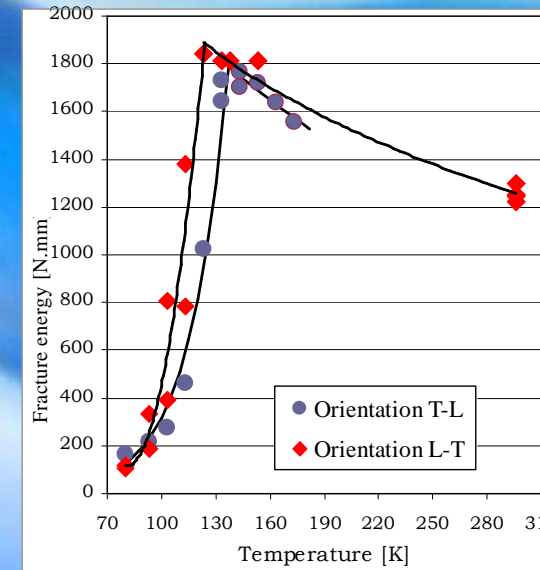
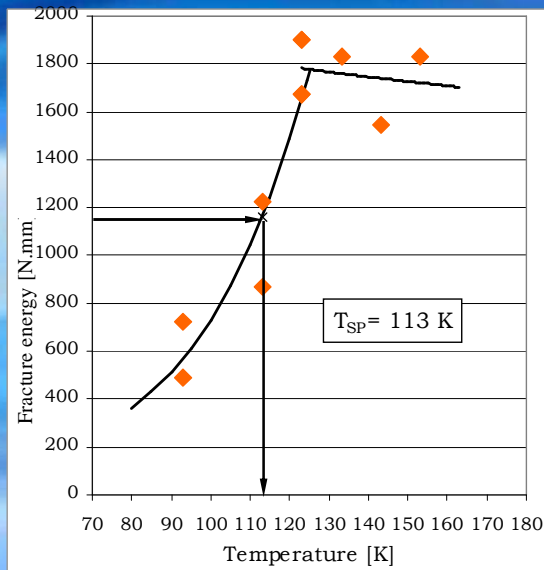


Fig.6



Parent material T-L



Fig.7

FATT and T_{SP} – Table IV

| Specimen taken from | Charpy orientation | FATT | SP disc orientation | T_{SP} | $\alpha = T_{SP}/FATT$ |
|---------------------|--------------------|------|---------------------|----------|------------------------|
| | | [K] | | [K] | [1] |
| parent material | T-L | 321 | L | 113 | 0,35 |
| parent material | L-T | - | T | 124 | - |
| HAZ | T-L | 283 | T | 113 | 0,40 |

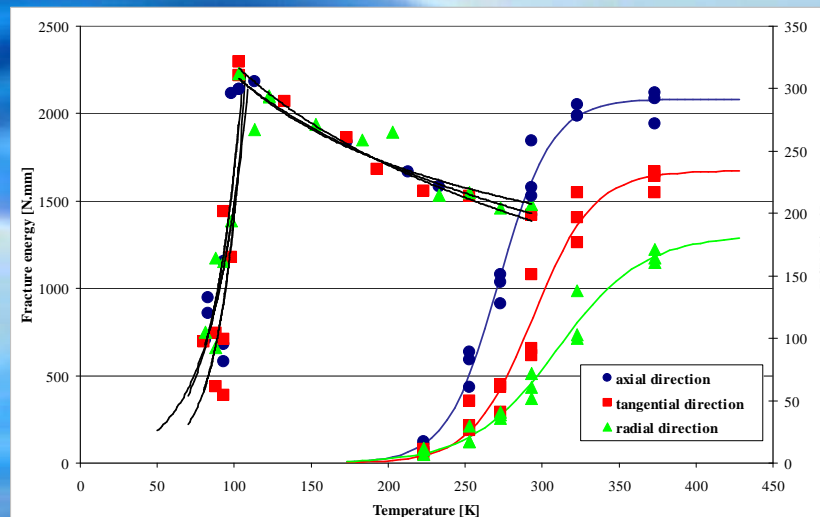
Table IV – Relation bw. FATT and T_{SP}

$$\alpha = T_{SP}/FATT$$

$\alpha = 0.35$ – parent material

$\alpha = 0.40$ - HAZ

Comparison of SPBT and Charpy impact toughness energy for CrMoV steel



Comparison of temperature dependence of fracture energy and Charpy notch toughness showing the difference in shift of transition temperatures T_{SP} and FATT according to the sample orientation

For CrMoV steel

- **Very significant differences among of standartized tests results of FATT for axial, tangential or radial direction**
- **A little significant differences between SPB tests results for determination T_{SP} – radial, tangential and axial orientation (the same for our results).**
- **Importance of future testing SPB in different orientation, correlation by modern modeling methods (finite elements, neural network).**

4. CONCLUSIONS

- **Very good agreement of standardized and SPBT tests determination of tensile properties for parent material and HAZ after long term service is proved. It is in good correlation with HV 10 tests.**
- **Charpy notch toughness depends on orientation of small disc specimens – attention for correct correlation SPBT and full size specimens.**