THE EFFECT OF STRAIN RATE ON MASTER CURVE OF THE MARTENSITIC CHROMIUM STEEL

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Abstract

The effect of the strain rate on master curve of the martensitic chromium steel was examined. The tests were performed in both quasi-static and dynamic conditions. The pre-cracked Charpy V specimens were used in the test to allow to determinate Master Curve in dynamic conditions using instrumented standard Charpy pendulum. On the basis of the research, the effect of the strain rate on master curve was found. The increasing of strain rate from quasi-static to dynamic conditions in tested steel caused the significant decrease of K_{Jc} and consequently an increase of the reference temperature (T_0).

Keywords: Master Curve, Fracture Toughness, Martensitic chromium steel, Strain rate

1. INTRODUCTION

The Master Curve methodology is popular and commonly used method to determinate the transition behaviour of fracture toughness. The standard 1T specimens and specimens with reduced size can be applied to construct the curve showing the dependence of K_J on temperature of material [1-3]. On the basis of the master curve, the reference temperature (T_0) is received. The application of specimens with dimensions different than 1T standard specimen is complicated due to the necessity of conversion of the results to values equivalent to standard specimen. However, the miniaturization of specimen is sometimes recommended to minimize the amount of tested material. The literature data show increasing of the popularity of the application of miniaturized specimens in mechanical testing techniques (Tensile Test [4, 5], Fatigue Test, Fracture Toughness Test [6], Charpy Impact Test [7-18] and Small Punch Test [4,19]) allowing non-invasively testing of the construction.

The aim of the work was to examine the effect of strain rate on the Master Curve of martensitic chromium steel. The Master Curves determined in both quasi-static and dynamic conditions were compared. The pre-cracked Standard Charpy V specimens were used for possibility of determination of test in dynamic conditions using standard Charpy pendulum.

2. EXPERIMENTAL DETAILS

The Master Curve for X14CrMoVNbN101 martensitic chromium steel was determined in both quasi-static and dynamic conditions using pre-cracked Standard Charpy V specimens. **Figure 1** shows dimensions of the specimen. The samples were prepared by using Electrical Discharge Machining method, which facilitates precise machining of the materials [20, 22,23].

The specimens were pre-cracked using RUMUL resonant testing machine to crack length 5 mm and final stress intensity factor K = 16 $MPa \cdot m^{1/2}$. After pre-cracking operation, the side grooves with depth 1 mm were machined. The Master Curves were determined according to the ASTM E1921-97 standard [1]. The test in

quasi-static conditions was performed by three-point bending in various temperatures on Mayes electrical testing machine with 0,5 mm*min^{-1} crosshead speed. In the case of dynamic Master Curve evaluation, the test was conducted by using the instrumented Charpy pendulum WPM PSd with striking edge radius of 2 mm. The tests were supported by the Tensile Tests conducted on Mayes electrical testing machine.

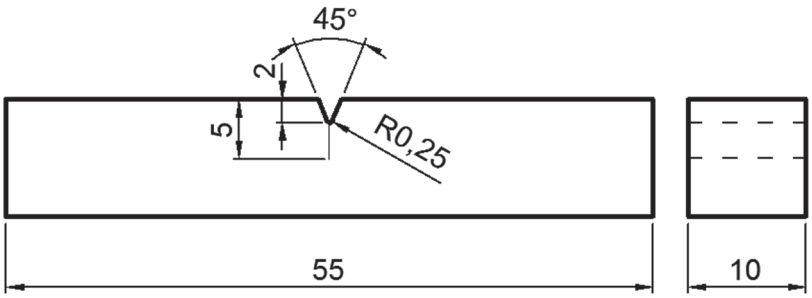

Figure 1 Dimensions of pre-cracked Standard Charpy V specimen [10,24]

3. RESULTS AND DISCUSSION

Figure 2 shows the results of the tensile test performed in the temperature range from -70 ºC to room temperature. The results were supplemented by regression line calculated using the least-squares method.

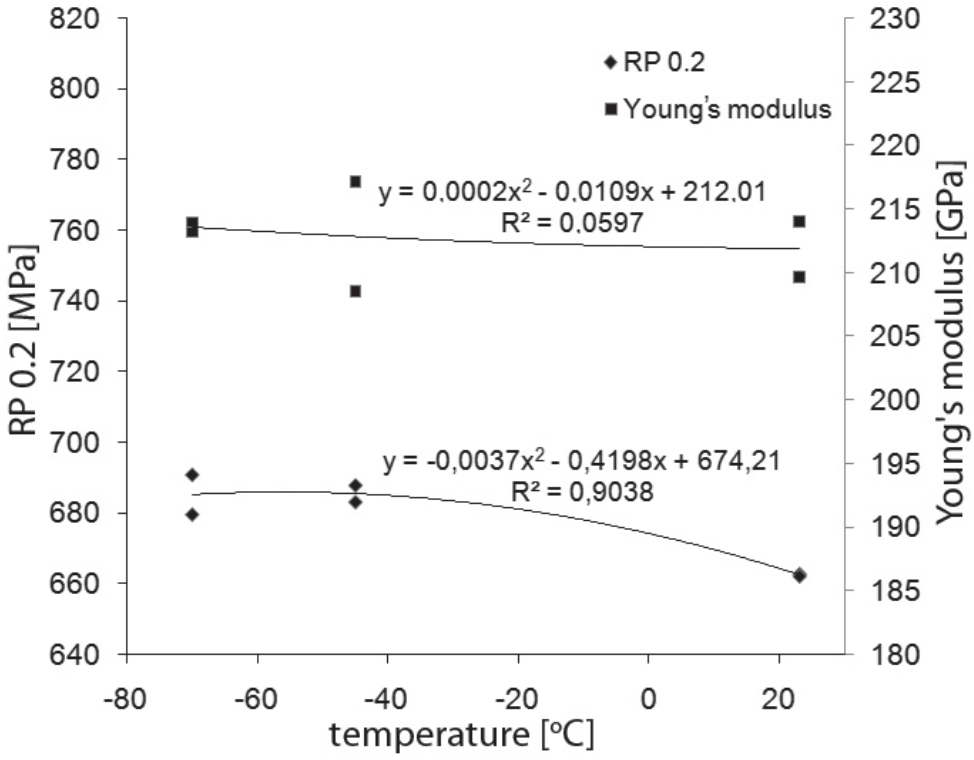

Figure 2 The results of the tensile tests of X14CrMoVNbN101 steel with the regression line

The K_{Jc} distribution in quasi-static conditions measured in the temperature range from -85 ºC to 20 ºC was shown in **Figure 3**. The graph contains the Master Curve (K_{Jc}) with the 1 %, 5 % and 95 % probability scatter bounds curves ($K_{Jc(0.01)}$, $K_{Jc(0.05)}$ and $K_{Jc(0.95)}$, respectively). On the basis of the Master Curve, it was found that the reference temperature (T_0) in tested steel in quasi-static conditions is equal to -75.7 ºC.

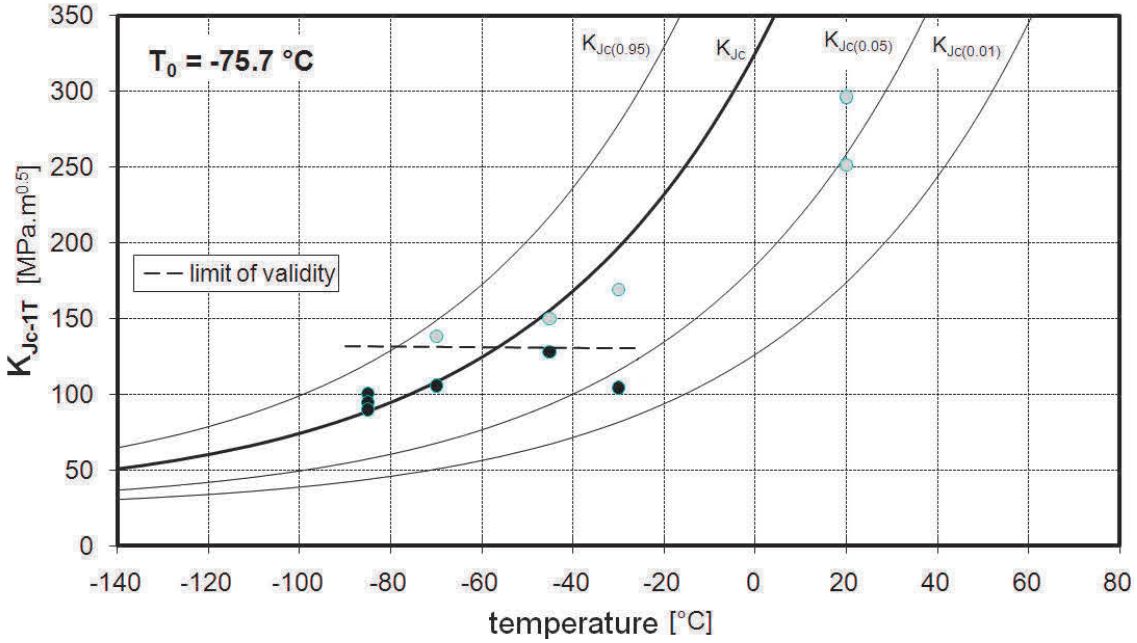

Figure 3 The Master Curve diagram in quasi-static conditions of the test

Figure 4 shows the distribution of K_{Jc} values in dynamic conditions in the temperature range from 0 ºC to 20 ºC including the Master Curve and the probability scatter bounds curves. The reference temperature (T_0) in dynamic conditions of the test was 10.8 ºC.

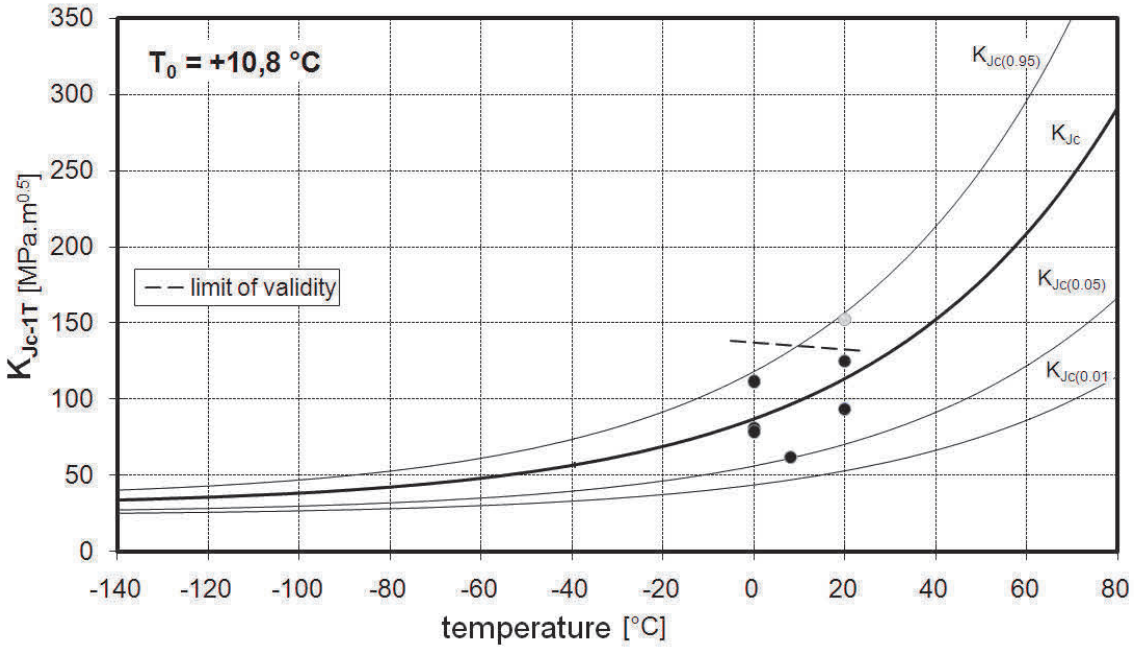

Figure 4 The Master Curve diagram in dynamic conditions of the test

The comparison of the Master Curve values determined in quasi-static and dynamic conditions is presented in **Figure 5**. From the figure, it is clear that increasing of the strain rate from quasi-static to dynamic conditions caused the significant decrease of K_{Jc} and consequently an increase of the reference temperature (T_0) from -75.7 ºC to 10.8 ºC. The results of the research showed significant decrease of the fracture properties of

examined steel in dynamic condition of the test. Low fracture properties limit the application of material in dynamically loaded structures at low temperatures.

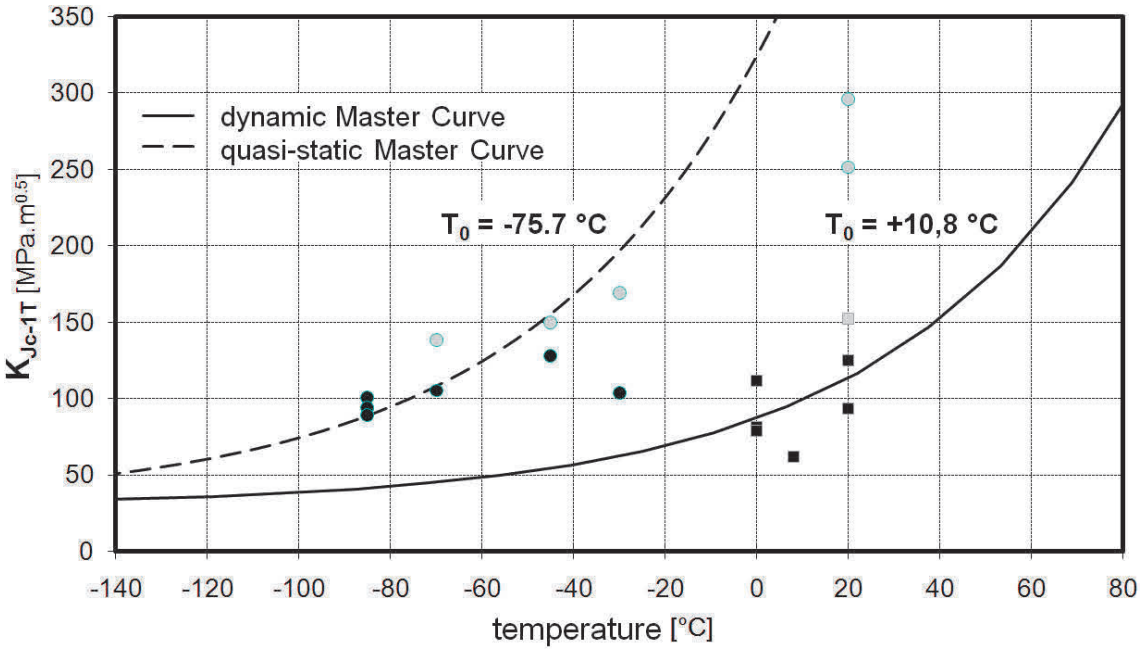

Figure 5 The comparison of the Master Curve for quasi-static and dynamic conditions

4. CONCLUSION

The effect of strain rate on master curve of the martensitic chromium steel was examined in the work.

The reference temperature (T_0) measured for quasi-static conditions of the test was equal to -75.7 ºC and it increased to 10.8 ºC when dynamic condition of test were applied.

The results of the research showed significant decrease of the fracture properties of examined steel in dynamic condition of the test. Low fracture properties limit the application of material in dynamically loaded structures at low temperatures.

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