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IMPACT OF SCALE FACTOR ON CRACKING RESISTANCE OF THERMOSTRESSED AND OUTPUT REINFORCEMENT STEEL

R. Humenyuk[1]*, A. Wójcik*[2]*,*

[1]*Lviv National Agrarian University; e-mail: grv.lnau@gmail.com*
[2]*University of Agriculture in Krakow; e-mail: artur.wojcik@urk.edu.pl*

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Summary. The changes of cracking resistance $K_C=f(D)$ have been investigated for test cylinders with a circular crack made from thermo stressed and output reinforcement steel 25H2S and 35HS in the range of diameters (D = 6 ... 28 mm) and tested by the scheme of axial tension that appeared to be insignificant for thermo stressed and significant for output. It is established that the proportionality of values $K_C=K_{IC}$,for thermostressed test cylinders starts after testing D = 16mm (K_{IC} = 95.5, 74.4 $MPa\sqrt{m}$) and output (state of delivery) - D = 22mm (K_{IC} = 60.5; $MPa\sqrt{m}$ *46.5*), respectively, both for steel 25H2S and for 35HS. Method of axial tension of test cylinder with a circular crack is an effective tool to correctly determine the fundamental characteristics of crack (K_{IC}) for the studied steels and ranking the quality bar steel at the stage of entrance control.

Key words: reinforcement steel, test cylinder, temperature, cracking resistance.

ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

It is known that for professionals who are studying the strength of thermo stressed steel rebar, in order to determine its suitability for use in the construction industry conduct testing of a specific diameter of reinforcing rods in axial tension, according to GOST 12004-81 [1] and DSTU 3760-98. [2] By this they found out that the method of producing bar steel by blanking in beds in the conditions of heating or cold-working practice in powerful stamps also change its strength, which, undoubtedly, is important for practice, especially when it is subjected the electro thermal heating [3].

Let us try to analyze the state of the researches due to the influence of scale on static cracking resistance (K_{1c}) of structural steel, because there are many works dedicated to the study. In particular, the impact of test cylinder size on cyclical cracking resistance of heat-resistant steels was established [4] or influence of scale factor and residual stresses on welding and the growth rate of fatigue cracks was also investigated [5] or the effect of test cylinder size on the parameters of cracking resistance, which is determined on the basis of complete diagrams of destruction of smooth cylindrical samples was also proved [6]. It should be noted as a little influence of the scale factor on fragile strength of titanium alloys [7] or alloyed special steels [8].

However, the impact of the scale factor on K_{IC} of structural material in various types of prototypes is almost not studied except [9-14], where the authors measured the changes $K_{IC} = f(B)$ - by three-point scheme prismatic specimen deformation with side crack and $K_{IC} = f(D)$ – by the scheme of axial tension of test cylinder with ring crack accordingly to low-carbon and medium-carbon steels and titanium alloys.

The objective of the study is to investigate the effect of different diameter test cylinders made of thermo stressed (by electric heating) and output (state of delivery) reinforcing steel bars 25H2S and 35HS on the value of the fundamental static characteristics of cracking resistance K_{IC}, by which the brittle fracture resistance of these steels is established, ie their cracking resistance.

MAIN RESULTS OF THE RESEARCHES.

The effect of different diameters of test cylinders on static cracking resistance, ie $K_C=f(D)$ of thermo stressed and output reinforcing steel bars was the subject of our research. The material for the tests were reinforcing bars of diameters 8; 14; 18 and 24 mm for steels 25H2S and 35HS after electro-thermal strengthening during different times of heating: Ts = 3; 4; 5; 8 min. on an industrial installation [15] and reinforcing rods of diameters 8; 14; 18; 24 and 30 mm of this steel (state of delivery), respectively. It should be noted that the increase in heating time led to temperature variations along the length of rods of various diameters ranging from 320 to 410 ° C.

So, in order to study $K_C=f(D)$ of thermo stressed and output (state of delivery) reinforcing bars with a six-meter lengths, we mechanically cut at 1 m 18 party pieces for the manufacture of various diameters and lengths of test cylinders.

General dimensions on manufacturing a test cylinder with ring crack accordingly to recommendations [16] shown in Fig. 1.

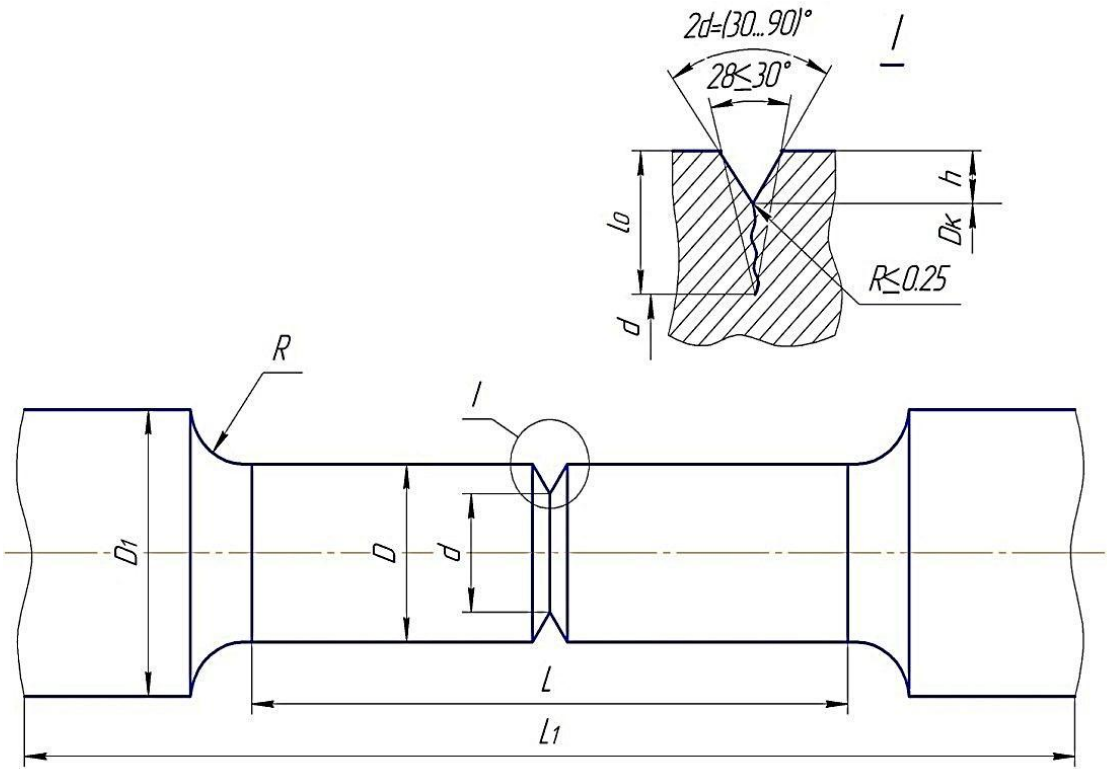

Fig. 1. A test cylinder for tension

$L = 5\,D$; $d = (0{,}6 - 0{,}7)\,D$; $L_1 \geq 8D$; $l_0 = 0{,}5\,(D - d) \geq 0{,}5$ *mm and* $l_0 \geq 3{,}7h\ tg\ a$; $D_k = D - 2h \approx 0{,}85\,D$. It is recommended for materials' research with bar diameter 10 ... 30 mm.

In all the parties' blanks (6 pcs. in each party), the size of test cylinders was: Ø 6; 12; 16; 22; 28 mm and ten-fold length of 60; 120; 160; 220; 280 mm, in which a ring concentrator was cut with notch acuity ρ≤0,2 mm and depth d_k / D = 0,7; firstly with threaded cutters with carbide plate mark T15K6 and then, with finishing grinding jeweller's saw with a vertical angle α = 60 °.

Modes of initiation of fatigue ring cracks of each diameter of test cylinder were kept by choice of bending efforts in the condition: $Q_b \leq 0{,}7\sigma^*$, where σ * - tension at the bottom of the ring concentrator at three-point bending in the middle length of the cylinder *L / 2* for the corresponding diameter, which was carried on a lathe machine, model 16K20 by the methodology [17]. The relative depth of the ring crack for different diameters of the test cylinders was calculated from the ratio: ε = d / D and is within 0.6 ... 0.65, and their testing scheme is shown in Fig. 2.

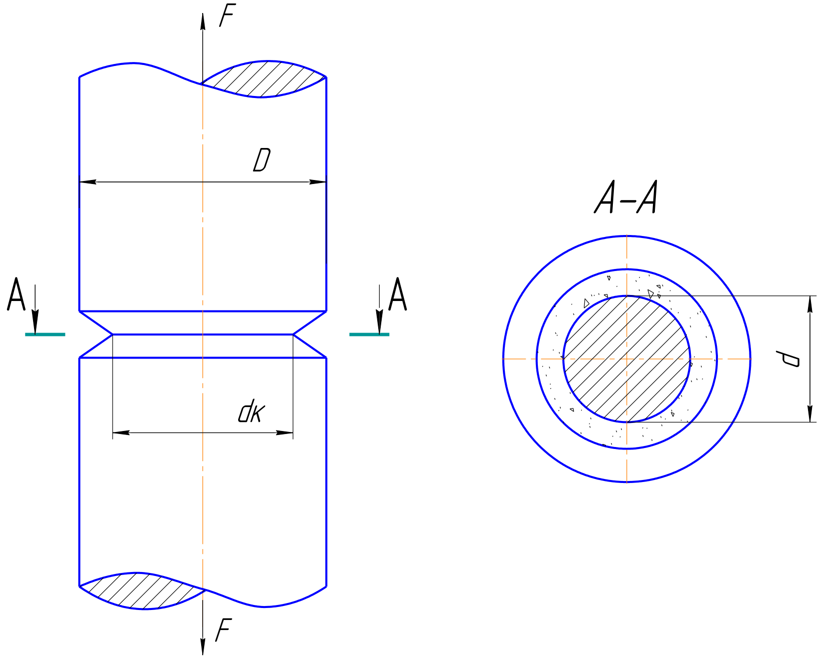

Fig. 2. Scheme of axial tension of a test cylinder with a ring crack

The experiments were performed on test machines R10 and R25, where, after their accuracy calibration, were recorded in the stretch charts for different diameters of samples in the coordinates: F – force, Ɛ - deformation. During stretching, the moving cross head of the machine made movement of 2 mm / min. For each sample, the diameter of destructive force $F = F^*$ was recorded and measured the values of d and D of the cylinder and using the formula [18] calculated the cracking resistance $K_C=f(D)$

$$K_{1C} = \frac{\mathrm{P}^*}{D\sqrt{D}} \cdot y, \qquad (1)$$

where: $y = \frac{0.7976\sqrt{1-\varepsilon}}{\varepsilon\sqrt{\varepsilon}\cdot\sqrt{1-0.8012\varepsilon}}$; $\varepsilon = \frac{d}{D}$.

Results of the obtained values of $K_C=f(D)$ are shown in Fig. 3 from which we can see, that curves 1 and 2 for thermo stressed (by electric tension) steels 25H2S and 35HS have smooth ups with access to the levels, starting from the diameter D = 16 mm; and curves 3; 4 for the output steels (state of delivery) with characteristic steep climbs with access to the levels, starting from the diameter D = 22 mm.

Thus, based on Fig. 3. for the small-diameter test cylinders, obtaining lower values of K_C may be explained by the overlapping of the net section of the test cylinder with a ring crack by the strips of plastic deformation in the plane of the closed circuit of the cylinder by the diameter d, (see. diagram in Fig. 4), that means, that the size of these strips is not compatible with d_{pl} diameter, and therefore do not satisfy the conditions of self-similarity of prefracture zone in its axial tension [19].

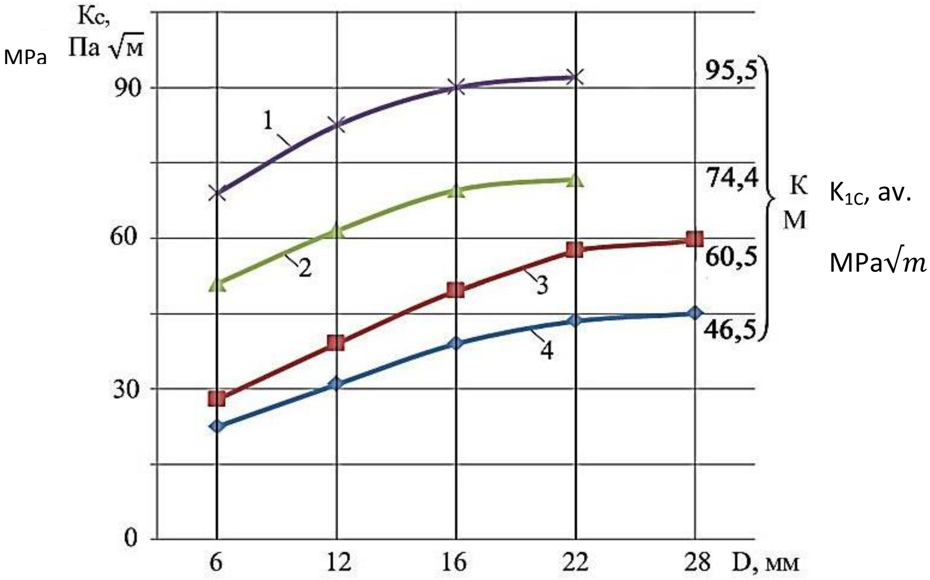

Fig. 3. Change of K_C of diameter D for test cylinders of ring crack of 25H2S and 35HS steel: 1; 2 - after electro thermal strengthening; 3; 4 - delivery condition respectively

When d_{cr} of cylinder diameter is greater than the size of the plastic strips, that is, there is no overlapping of their net-sectional diameter d_{pl}, thus, we satisfy the conditions of self-similarity of prefracture zone in its axial tension. (See. diagram in Fig. 4).

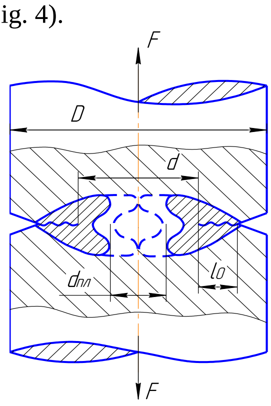

Fig. 4. Scheme to determine the length of the crack l_{cr} with correction Δl on plastic zone in front of the crack to correctly determine K_{IC}: d_{pl} - diameter covered with plastic zone (dotted line); D and d - outside diameter and the diameter of the sample of ring crack ($l_{cr} = D - d_{pl}$; $l_o = D - d$; $\Delta l = d - d_{pl}$).

In other words, the minimum diameter of the test cylinder is one in which the determined value of K_C will be compatible with K_C of the next larger diameter of test cylinder, having reached the value $K_C = K_{IC}$ of the horizontal line (Fig. 3), corresponding to a plane deformation condition. In this case, we received not the cracking resistance of a given diameter of test cylinder K_C, but the actual test material K_{IC} cracking resistance.

CONCLUSIONS

Due to impossible ring cracks circuit coming out on the free surface of the external diameter of the cylinder, the minimum outside diameter (D_{min}) of this sample will always be less than the minimum thickness (T_{min}) of beam or any other type of sample, and therefore the fair value of the fundamental characteristics of crack resistance - viscosity destruction (K_{IC}) of the material can be defined in less material consumption and using standard test equipment and test facilities and the proposed methodology of research.

For the studied thermo stressed steels 25H2S and 35HS the minimum diameters on the correct definition K_{IC} is diameter Ø 16 mm (see. 1 and 2 curves in Fig. 3), for which K_{IC} = 95.5; 74.4MPa√m, respectively. As for the studied steels 25H2S and 35HS in a state of delivery, then for the correct definition K_{IC} the minimum diameter of the cylinder is Ø 22mm (see. 3 and 4 curves in Fig. 3), for which K_{IC} = 60.5; 46.5MPa√m, respectively.

It should also be noted a significant increase in the values of $K_C=f(D)$ for steel 25H2S compared to $K_C=f(D)$ for steel 35HS consistent with data [20] for these steels.

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ВЛИЯНИЕ МАСШТАБНОГО ФАКТОРА НА ТРЕЩИНОСТОЙКОСТЬ ТЕРМОНАПРЯЖЁННЫХ И ВЫХОДНЫХ АРМАТУРНЫХ СТАЛЕЙ

Гуменюк Р., Вуйцик А.

Аннотация. Исследованы изменения трещиностойкости $K_C = f\ (D)$ для цилиндрических образцов с кольцевой трещиной, изготовленных из термонапряженных и выходных арматурных сталей 25Г2С и 35ГС в диапазоне диаметров (D = 6 ... 28мм) и испытанных по схеме осевого растяжения, которые оказались незначительными для термонапряженных и существенными для выходных. Установлено, что соразмерность значений $K_C = K_{1C}$, для термонапряженных цилиндрических образцов, начинается после испытаний D = 16мм (K_{IC} = 95,5; 74,4 МПа√м) и выходных (состояние поставки) - D = 22мм (K_{IC} = 60,5; 46,5 МПа√м) соответственно, как для стали 25Г2С так и 35ГС. Методика осевого растяжения цилиндрического образца с кольцевой трещиной является эффективным инструментом корректного определения фундаментальной характеристики трещиностойкости (K_{IC}) для исследуемых сталей и ранжирование качества прутковой арматуры на стадии входного контроля.