COMPARISON OF MECHANICAL PROPERTIES OF OLD STEEL FROM TRUSS CRANE RUNWAY WITH S235 AND S355 GRADES

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Abstract. *The nowadays the using of S235 J2 and S355 J2 steel grades in civil engineering to design structures elements of cranes, bridges, building structures or simple engineering parts allows material and economical savings meeting the strict construction requirements. The aim of this contribution was to determine the mechanical, fatigue and strength properties of the old steel from steel truss crane runway in Vítkovice Company. The second task was the comparison of obtain data from old steel with properties of standard used S235 and mild steel S355 and to make recommendations based on the results which steel grade can replace existing damaged elements made from old steel.*

Keywords

Old steel; Steel tests; Fatigue; Change in mechanical properties; Change in strength properties; Long service.

1. Introduction

The piece of knowledge of the operational durability of old steel elements is essential for assessing their condition and remaining service life. Mild steel (iron containing a small percentage of carbon, strong and tough but not readily tempered), also known as plain-carbon steel and low-carbon steel, is now the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. Mild steel contains approximately 0.05–0.25% carbon [1] making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and easy to form.

Properties of steel S235 [2] and S355 are published with many references [3-8].

The aim of this contribution was to determine the mechanical, fatigue and strength properties of the old steel from a steel truss crane runway in Vítkovice Company. The crane runway has been in service according to the obtained knowledge for more than 80 years. The second task was the comparison of obtain data from old steel with properties of standard used S235 and mild steel S355 and to make recommendations based on the results which steel grade can replace existing damaged elements made from old steel.

2. Materials

Mild steel is a ductile material; its typical constitutive behavior is characterized by an initial linear response until the yield strength followed by a second nonlinear phase of reduced stiffness, see Fig. 1:.

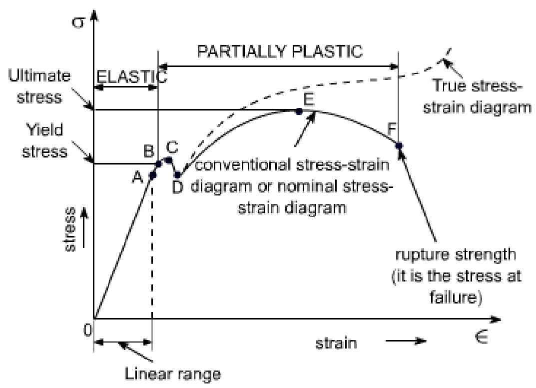

Fig. 1: Sketch of engineering stress- strain curves for steel see e.g. in [9].

Three kinds of steel grades were tested, the chemical compositions [10] of S235 J2 and S355 J2 steel grades are mentioned in Table 1. The third kind of material is steel extracted from an old crane structure. The structure is in process of renovation. The chemical composition of old steel was not this time detected.

Tab.1: Chemical composition in percentage by weight (wt. %) of S235 and S355 steel grades used for comparison of selected properties.

	Steel grade	
	S235 J2	**S355 J2**
C (max. %)	0.12	0.2
Mn (max. %)	0.84	1.6
Si (max.%)	0.22	0.55
P (max. %)	0.021	0.035
S (max. %)	0.002	0.035
N (max. %)	0.004	0.012
Cu (max. %)	0.03	0.55
CEV (max. %)	0.28	0.47

The specimens were cut out from 20-mm thick S235 J2 and S355 J2 steel sheets. The cross section was selected to be perpendicular to the rolling direction. The round bar specimens were manufactured for tensile test [9]. The geometry and dimensions of the specimens are shown in Fig. 2: Static tests were performed on Zwick/Roell machine with maximal capacity of 50 kN.

In total, 9 tests were performed under laboratory conditions, 3 specimens of each material configurations: S235 J2, S355 J2 and old steel from crane.

The fatigue endurance limit is determined from the *S–N* curve whereby the stress range, corresponding to a lifetime of 10^7 cycles is usually considered to be a safe reference that not being surpassed ensures non-failure during the whole service lifetime of the component. The testing procedure consists in applying cyclic loading with predefined stress range to determine the number of cycles to failure as described, e.g. in Eurocode 3 standard [10-12], part 1-9 for the stress ratio R=0.1. The specimen geometry used for the fatigue steel tests is shown in Fig.3.

In total, 42 tests were performed under laboratory conditions, 14 specimens of each material configurations: S235 J2, S355 J2 and old steel from crane.

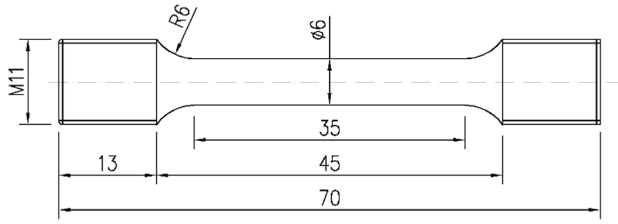

Fig. 2: Specimen geometry for mechanical property tests -dimension in [mm].

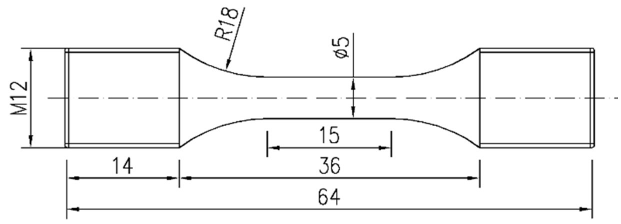

Fig. 3: Geometry and dimension of the specimen used for *S–N* measurement- dimension in [mm].

3. Results

Metallographic examinations were made to determine the homogeneity of the material structure. They were carried out on the specimens made of old steel, S 235 J2 and S 355 J2 steels in directions perpendicular to the rolling direction.

In the initial state, all steels (S 235 J2 and S 355 J2) showed a ferritic-pearlitic structure with average grain size of 15-25 µm, however, in S 235 J2 steel, the ferritic structure prevails, see Fig. 6

The test results were subjected to proper measurement in Zwick/Roell machine. The example of report for old materials is shown in Fig. 4:

Completed data with standard deviation for three steel grades are shown in Tab.2: The results indicate that the material meets the Eurocode requirements [11].

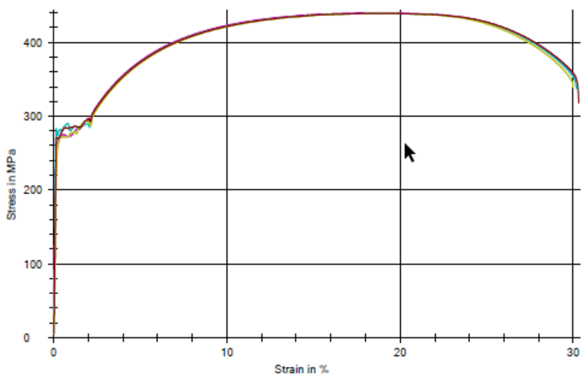

Fig. 4: Typical output of stress-strain curve from Zwick/Roell machine. Example is for old steel.

According to the evaluated parameters, it is recommended for practical applications in software for civil engineering structural analysis under static load [12][13].

The data could be used as basic input parameters for advance probabilistic prediction of residual life or used as input parameters for the sensitivity analysis in the calculation of civil engineering steel structures under fatigue loads like in [14][15][16].

Tab.2: Mechanical and strength properties with standard deviation of three kinds steels (Old one, S235 and S355).

Steel	Old steel	S 235 J2	S 355 J2
Young's modulus [GPa]	206.30 ±6.2	208.20 ±4.1	205.40 ±7.4
Yield stress [MPa]	271.20 ±2.46	276.87 ±0.31	381.94 ±6.22
UTS [MPa]	439.28 ±0.49	423.86 ±1.49	554.41 ±1.62
Elongation at break[%]	18.49 ±0.23	21.99 ±0.22	34.22 ±1.54
Poisson's ratio [-]	0.3	0.3	0.3

Generally, the materials used for manufacture of these structural elements contain defects and flaws [17], which have effect on durability, i.e. remaining service life [18][19][20]. Therefore, it is important to know the fatigue properties of the steels used in complex design analysis among them the old steel and S235 and S355 steel grades, traditionally used in construction.

In this part of the paper, the fatigue properties (Wöhler's field) of the studied steel grades are analyzed.

The results obtained are compared with the customary Basquin's formula [21] for the Wöhler-curves as straight lines in a double-logarithmic scale.

$$\sigma = AN^B, \quad (1)$$

where the parameters A and B denote the independent term and slope, respectively, of the resulting straight line in double logarithmic scale.

The scatter of the test results at the same level of loading is a characteristic inherent to the fatigue phenomenon due to several factors, such as material defects during the process of extrusion and machining process of specimens etc.

The results of the experimental program performed at stress ratio R=0.1. In 0, the amplitude stress σ_a versus number of cycles for studied steels are shown.

In the 0, there are comparisons of all measured data. It is apparent mainly the influence of the steel grade quality (stress amplitude of S235 is smaller than for S355 for the same number of cycles). From the graph it is possible to read the decrease of the fatigue life of old steel specimens by almost one order compared to samples S235 with similar value of yield stress (271 MPa versus 276 MPa).

4. Conclusions

An analysis of all the presented material properties shows that the tested old steel has now shown similar mechanical, strength and fatigue properties like S235.

The presented investigations should be considered as exploratory. It would be essential to compare the effect of the cyclic loads generated by passing vehicles on the mechanical and strength properties of the structural steel for various structure elements.

Therefore, it would be worthwhile to carry out such tests when opportunities (etc. demolitions) arise so that the dependence between the changes in the properties of the steel and the operating stress could be unequivocally established.

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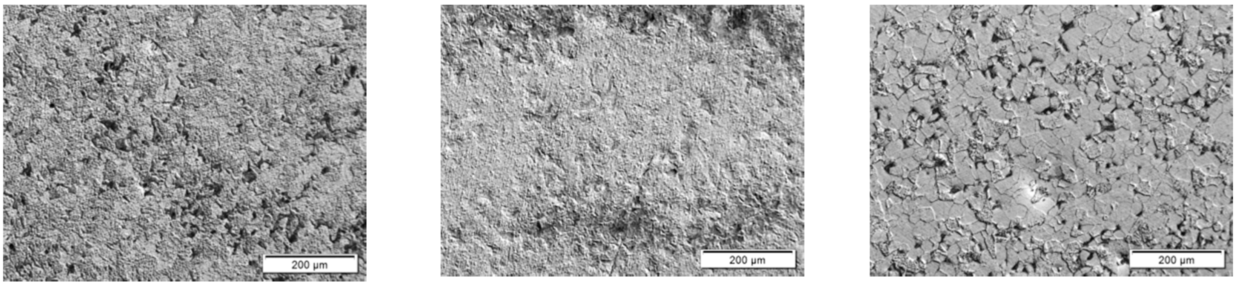

a) S235 J2 b) S355 J2 c) Old crane steel

Fig. 5 Structure of the S235 J2, S355 J2 and the old crane steel etched with 2% Nital, light optical microscope.

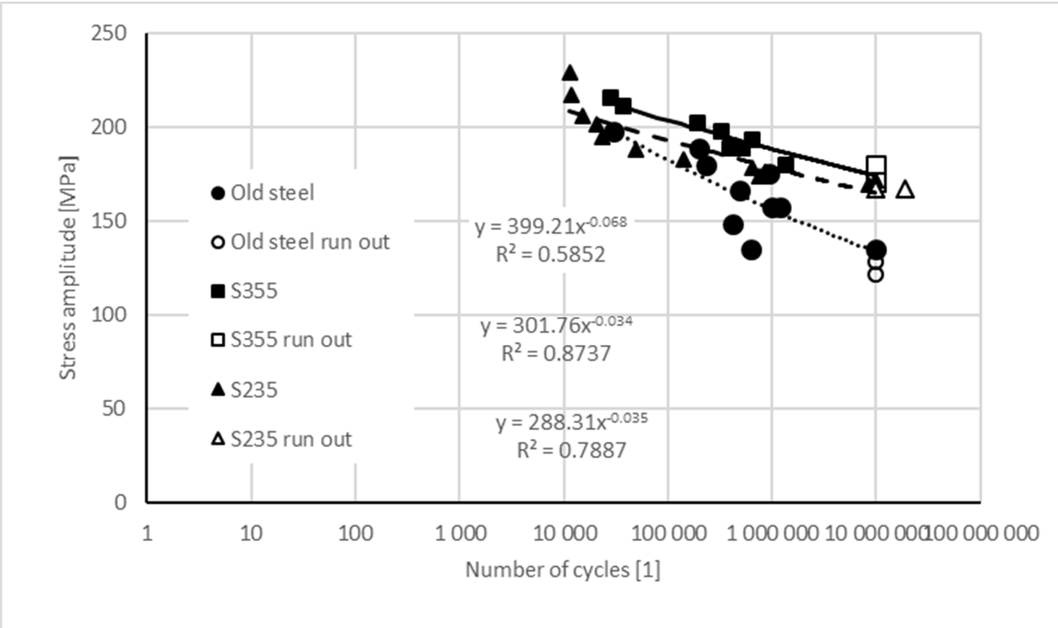

Fig. 6 Experimental results of the S-N field for and description of fatigue strength using Basquin formula [21].

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