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The Fatigue Strength of Steel and Butt Welds in Definite Working Conditions

La limite de fatigue d'acier et de soudages bout à bout dans des conditions déterminées de service

Die Dauerfestigkeit von Stahl und Stumpfschweissungen unter festbegrenzten Betriebsbedingungen

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Introduction

In design of civil engineering structures such as bridges, crane beams etc., which are working under dynamic loading the fatigue strength is taken into account. The fatigue strength is usually taken from standard tests which are performed under conditions characterized by the testing equipment and not by the real dynamic loading of the structure.

To consider the real working conditions it was decided to take into account the cessations in the loadings. At the same time, by keeping up to fracture the investigated specimens in constant temperature, the influence of cooling is considered.

Description of Tests

The investigations were performed on specimens made of steel St 37 S with chemical composition: 0,11% C; 0,49% Mn; 0,04% Si; 0,032% P; 0,02% S, and average mechanical characteristics $R_e = 31{,}25\,\mathrm{kG/mm^2}$, $R_m = 52{,}95\,\mathrm{kG/mm^2}$, $a = 25{,}85\%$, $c = 38{,}63\%$. The shape and dimensions of the specimens were taken according to the instruction of Schenck-Pulsometer (Fig. 1).

In investigation specimens with 100 and 120 $\mathrm{mm^2}$ cross-sectional areas were used. The specimens were cut from plates of 10 mm thickness. The

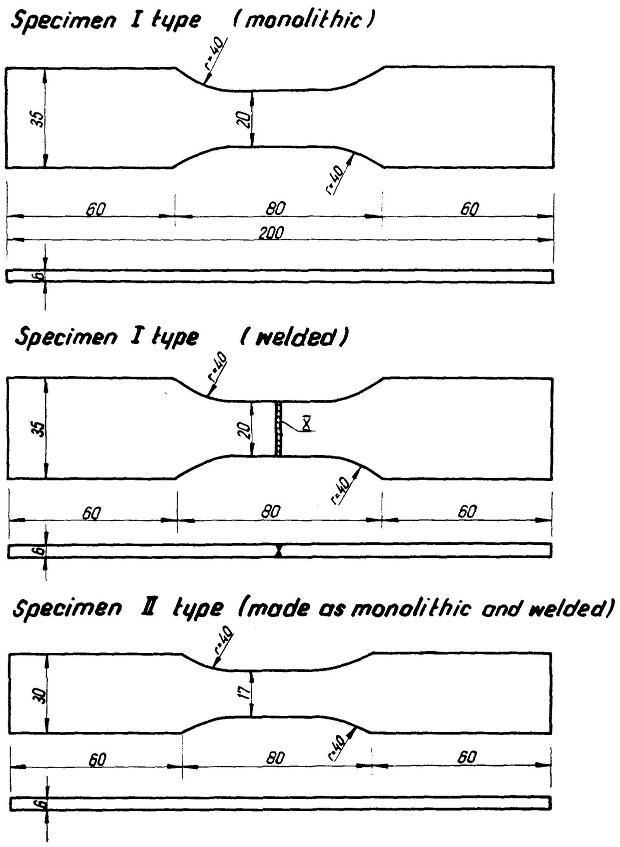

Fig. 1.

thickness of the part at which measurements were taken, was reduced to 6 mm within the accuracy of $\pm 0{,}05$ mm. The grinding was undertaken by a disk-type grinding wheel with intensive cooling by an adequate emulsion. Finally all the specimens were polished.

The butt welds were made by hand with the electrode EP 52-28. With the help of X-ray tests only specimens with defectless welds were chosen. In several cases the fatigue fractures showed minor defects (such as gas cavities, slag inclusions). The results from such tests were neglected in the analysis.

In spite of a very careful manufacturing the discrepancies from the theoretical values in the cross sectional areas were up to $\pm 1{,}5\%$, which was taken into account in the determination of the loading.

Three hundred fifty specimens were prepared (175 monolithic, 175 welded) and 336 were considered in the analysis.

The investigations under tensile pulsations with frequency 960 cycles/min were performed on a hydraulic testing machine manufactured by the Losenhausen Company. The investigations under tensile-compression pulsations with frequency 3000 cycles/min were performed on a resonance testing machine manufactured by Schenck of Darmstadt.

The temperature was measured with an accuracy of $\pm 1\%$ with the help of a special equipment made in the G.D.R.

In the investigations 5 minute cessations were applied at 15 minutes intervals. In the case of cooling the temperature was kept nearly at 18° C degrees.

The Results of Investigations

The results of investigations in the case of coefficient of uniformity of load $\kappa = 1{,}25 \left(\kappa = \frac{\sigma_m}{\sigma_a}\right)$ are given in Table I.

Table I

Types of specimens	Loading cessations	Z_{rj} kG/mm²	Standard deviation kG/mm²	R_r kG/mm²	Comparison of results*)
monolithic	without	33,50	±2,47877	52,95	100
welded	without	30,09	±1,60032	—	89,82
monolithic	with	34,31	±0,34275	52,95	102,44
welded	with	30,53	±1,67600	—	91,14

*) As 100% the strength Z_{rj} of monolithic specimens, equal to 33,50 kG/mm², is taken.

The table shows that the influence of cessations is advantageous, but very small. The increase in fatigue strength is 2,4% for monolithic and 1,5% for welded specimens. The influence of cooling was not considered because the increase of temperature was insignificant.

The results in the case of coefficients of uniformity of load $\kappa = 0$ are given in Table II.

Table II

Types of specimens	Loading cessations	Z_{rc} kG/mm²	Standard deviation kG/mm²	R_r kG/mm²	Comparison of results*)
monolithic	without	16,22	±0,63906	52,95	100
welded	without	15,06	±1,21669	—	92,88
monolithic	without and cooling	18,50	±0,69356	52,95	114,12
welded	without and cooling	17,42	±1,17644	—	107,46
monolithic	with	18,33	±1,01880	52,95	113,04
welded	with	16,97	±1,09279	—	104,66

*) As 100% the strength Z_{rc} of monolythic specimens, equal to 16,22 kG/mm², is taken.

In this case the introduction of cessations led to an increase of the fatigue strength equal to 13% for monolithic and 12,7% for welded specimens. The influence of cooling is of the same order and corresponds to 14,1% for monolithic and 15,7% for welded specimens.

The influence of the change of the velocity of loading (frequency) in the two cases was not considered.

In Fig. 2 and 3 the Wöhler diagrams are given the coefficients of uniformity of loading $\kappa = 1{,}25$ and $\kappa = 0$.

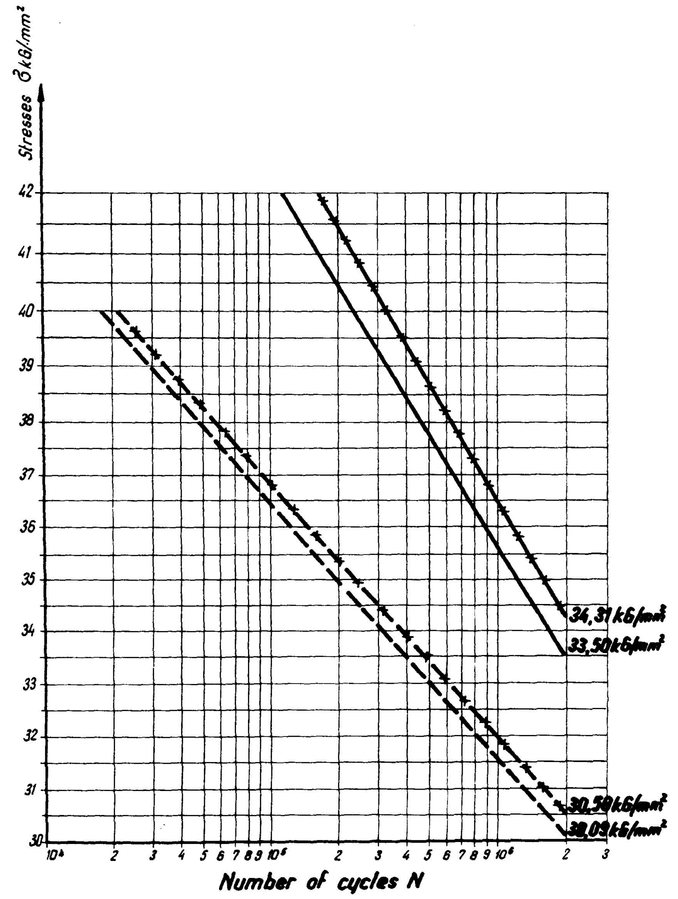

Fig. 2. Wöhler's diagrams for the coefficient $\kappa = 1{,}25$.

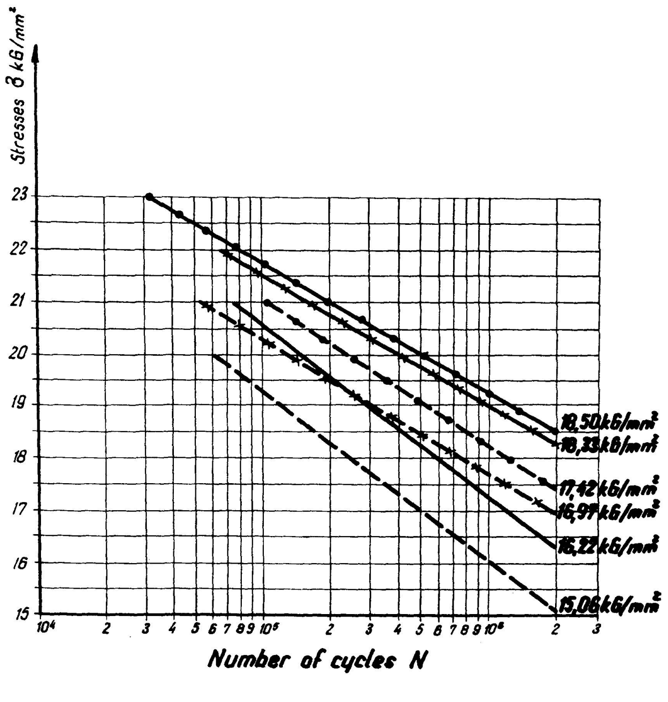

Fig. 3. Wöhler's diagrams for the coefficient $\kappa = 0$.

Conclusions

1. The results of standard fatigue tests do not correspond adequatly to the working conditions of civil engineering structures in view of the cessations in loading, and large surfaces which help to keep the structure at the ambient temperature.
2. The application of cessations in loadings increases the fatigue strength of steel and butt welds. For the same kind of steel the amount of increase depends upon the coefficient of uniformity of loading and the time of cessations.
3. The problem should be considered for other types of structural steels.
4. Based on further tests an adequate safety factor should be defined which takes into account the cessations in loading along with different factors such as shape, quality of manufacturing and material.

Summary

The paper presents the experimental results of the strength of butt welds subjected to cyclic loads corresponding to the working conditions of bridge structures.

The problem was discussed on the basis of research performed at the Chair of Steel Structures at the Technical University of Gdansk on specimens made of steel St 37 S.

Résumé

Ce travail traite les résultats expérimentaux de la résistance de soudages par rapprochement soumis à des charges cycliques correspondant aux conditions de service des constructions de ponts.

Le problème a été discuté sur la base de recherches entreprises à la chaire des constructions en acier de l'Université technique de Gdansk sur des spécimens en acier St 37 S.

Zusammenfassung

Die Arbeit vermittelt die experimentellen Ergebnisse der Festigkeit von Stumpfschweissungen gegenüber zyklischer Belastung entsprechend den Betriebsbedingungen von Brückenbauten.

Das Problem wurde auf der Basis von Untersuchungen beim Lehrstuhl für Stahlbau an der Technischen Universität Gdansk an Stahlproben St 37 S diskutiert.

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