PERIODICA POLYTECHNICA SER. TRANS. ENG. VOL. 20, NO. 2, PP. 135–141 (1992)

FATIGUE TEST OF MATERIALS AND THEIR WELDED JOINTS USED IN VEHICLE MANUFACTURING

P. BERKE, F. GALAMBOSI and P. MICHELBERGER

Department of Transport Engineering Mechanics
Technical University of Budapest

Received: January 22 1991

Abstract

The Department of Mechanics at the Faculty of Transport Engineering of the BME took a considerable part in the research connected with vehicle manufacturing, and especially with the manufacturing of motor buses. During the past years, research was carried out into such materials, among others in [1], [2], which resulted in providing basic design data for both factories: GANZ-MÁVAG and Ikarusz.

Keywords: material testing, fatigue, welded joint.

Introduction

For the manufacturing of the structural parts of road and railway vehicles steels 37, 45, 52 are generally used as weld steel. Though, there is a trend to shift the utilisation ratio of the mentioned steels towards steels 52 allowing the possibility of the mass reduction obtainable in this way, nevertheless steels 37 are still used to a considerable extent as the structural material of the vehicles.

When the problem arises which is to be chosen from among the welding technologies when e. g. the arc-welding is to be selected to meet the purpose, then the CO_2 shielded arc-welding procedure is chosen due — among others — to its reasonable price and cheap feasibility.

It is a fact that — in certain respects — there are sufficient pieces of information about the properties of the steels mentioned, as e. g. in the case of [3], [4], [5], [6], but on the other hand, in some cases it seems to be suitable to complete the existing pieces of information with others available in the course of special examinations. As an example of it, the examination of deformation anisotropy of materials and their embrittlement due to the reduction in temperature can be mentioned.

Results of Examinations

With regard to the fact that our examination covers — among others — also the numerical determination of the characteristics of material 37 D, therefore analysis was performed for the detection of the chemical composition, texture and the slag composition. (The textural composition was ferrite-perlite, the grain size was found to be between values 0.012 ... 0.015 mm with uniform distribution. The values characteristic of the slag composition were under the 3rd grade, the average value of hardness was $HV_{10} = 153$).

The static characteristics — though in most cases these values are taken into consideration only for identification purposes, or dimensioning for static loads, respectively — were determined, and in particular, as a function of temperature for the sake of taking into consideration the process of embrittlement. The measurement results are shown in *Fig. 1.* Certain embrittlement could be observed due to the reduction in temperature; the values measured on the specimens worked out in deformation direction and in the direction perpendicular to it can be considered as identific.

In spite of the unreliable character of contraction — measurability, the value of the energy required to failure was also calculated, for the sake of orientation, namely from the tensile test results measured at test-temperatures of between 20 °C and −40 °C. On the basis of the data obtained for the specimens subject to tensile test at 20 °C, the average value of the energy required to failure was found to be 906 J/cm^3, its standard deviation was 94.5 J/cm^3, while the same values obtained from the tensile-test performed at a temperature of −40 °C were found to be 851 J/cm^3, and 124 J/cm^3, respectively.

The embrittlement can be expressed numerically — apart from the change in the energy required to failure — also by the Charpy impact test method applied to the examination of resistance to dynamic loads, with the remark added that this procedure can be considered very sensitive to the detection, of anisotropy caused by the deformation direction too. The values measured on the micro impact test specimens are shown in *Fig. 2.*

In the course of design, the notch sensitivity of materials should also be taken into consideration, which was examined by the variation of the corner radius of the notches in the Charpy impact test specimens (*Fig. 3*), especially with the development of notches with nose radii of $r = 1$ mm and $r = 0.25$ mm, and with a remainder cross-sectional area of 2×3 mm. However, with the cross-sections reduced to such an extent, the value of the specific impact energy, too, will be different, since the extent of plastic deformation developed in front of the crack nose will increase as compared to the remainder cross-section. The variation in the value of specific impact

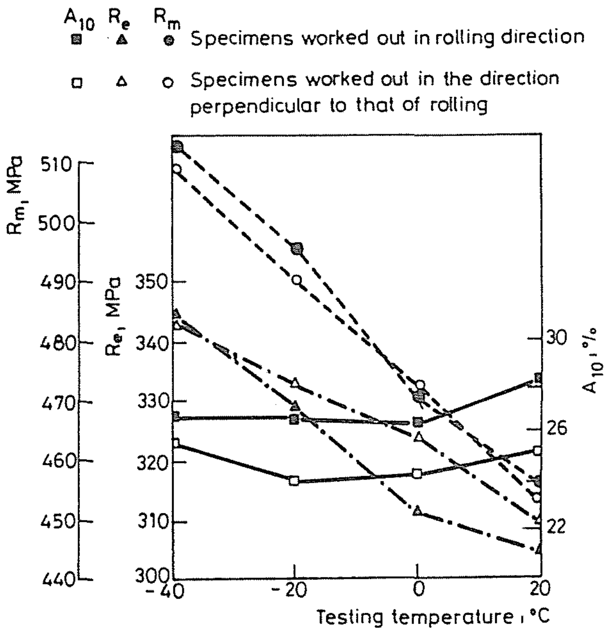

Fig. 1. Static material characteristics of specimens worked out of the basic material in deformation direction and perpendicular to it

energy involving the reduction of profile dimensions is decisively influenced by the reduction in the crack propagation energy besides the nearly constant crack initiating energy, consequently with a certain profile size, the value of the specific impact energy will not change decisively even in the case of notches with different nose radii, since the share of the crack propagation energy within the total amount of energy is considerably reduced. In this way, *Figs. 2* and *3* are not commeasurable. From the values shown in *Fig. 3,* it can be seen that the notch sensitivity of the tested material had not changed as a function of temperature.

In the case of fatigue tests, the temperature dependence of the load cycle numbers to failure with the given loads could not be followed due to the lack of experimental equipment, however, the effect of deformation direction was examined. The different load cycle numbers to failure associated with different asymmetry factors — 0.1; 0.4 — are shown in *Fig. 4.* The fatigue test results of the welded specimens are also plotted in *Fig. 4.*

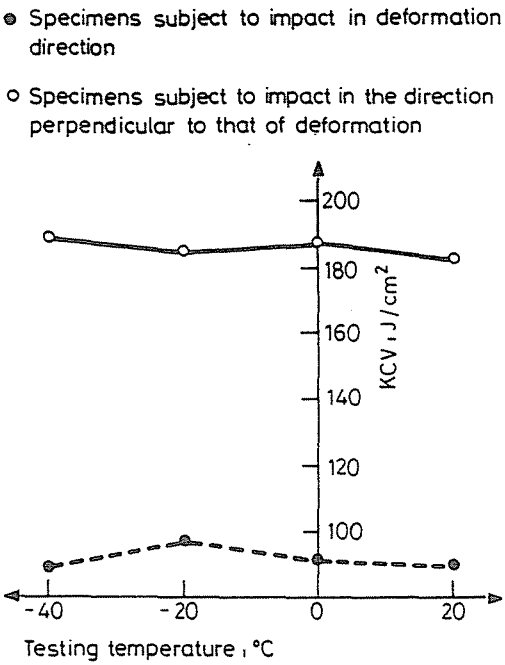

Fig. 2. Development of energy to failure in the case of specimens subject to impact test in deformation direction and perpendicular to it, respectively

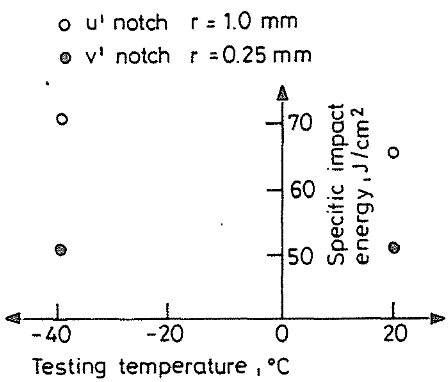

Fig. 3. Effect of chamfering the notch on the specific impact energy at different temperatures

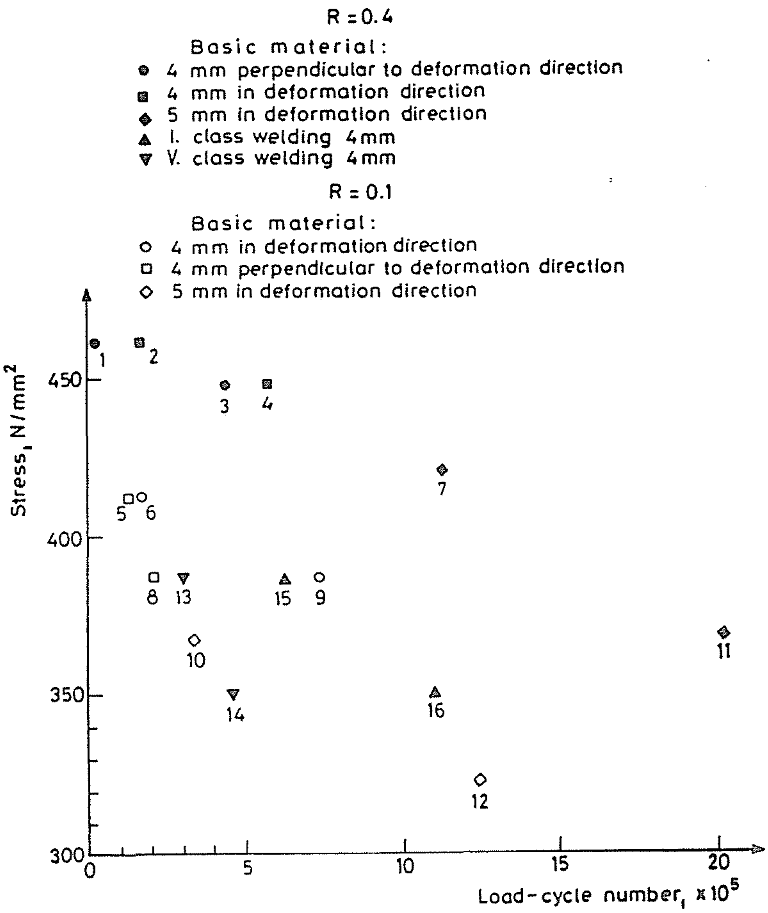

Fig. 4. Effect rolling direction on the load-cycle number to failure

With respect to the fact that the most frequent manufacturing technology used for building the structures of vehicles is the CO_2-shielded manual arc welding, therefore the specimens worked out with the help of this technology were also subject to examination. The tensile test results are shown in *Fig. 5.* (In this case, due to the neutralizing effect of the weld bead in deformation direction, the elaboration of specimens in the deformation direction and perpendicularly to it was not justified.)

Instead, it was examined at what distance from the weld bead, the deformation direction effect will occur again. As a method for doing this, the impact test was chosen performed on notched specimens worked out

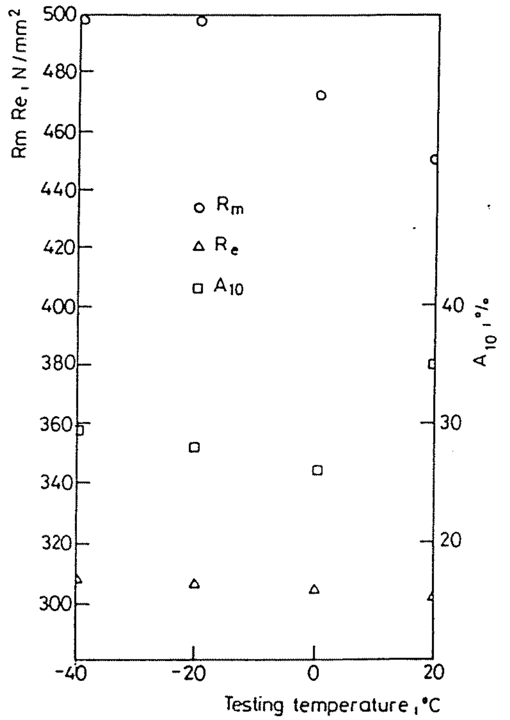

Fig. 5. Effect of rolling direction in the case of welded specimens

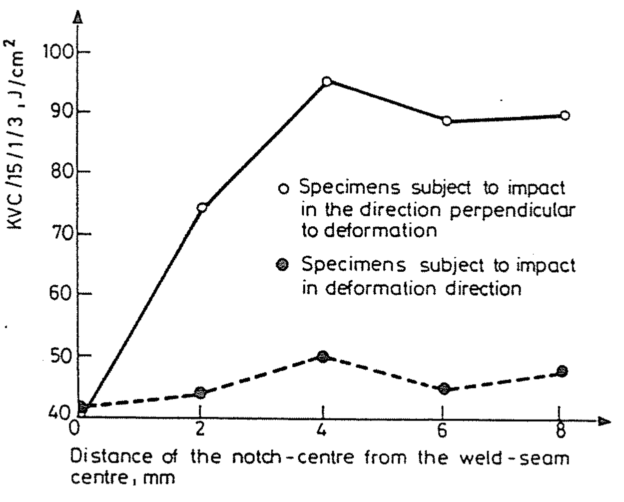

Fig. 6. Development of impack energy in the neighbourhood of welding seam

by steps of 2 mm starting from the weld seam. The results can be seen in *Fig. 6.* (The test temperature was −40 °C).

Summary

On the basis of experimental results

- it has not proved suitable that with structures subject to static load to pay a special attention to the differences in the properties due to anisotropy caused by deformation; the same can be stated in connection with the welded joints subject to static load, too.
- a considerable difference can be experienced in the case of dynamic loadability with the specimens worked out in the deformation direction and perpendicular to it; the deformation-direction effect can be observed in the close neighbourhood of the welded joints, too, therefore it became necessary to neutralize the negative effect of welding by applying a proper constructional layout.
- when fatigue loads are applied, it is advisable to reckon with the effect of deformation direction. With welded specimens, the negative effect of welding can also be neutralized by the proper constructional layout of the weld's neighbourhood.

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Address:

P. BERKE, F. GALAMBOSI and Pál MICHELBERGER
Department of Transport Engineering Mechanics
Technical University of Budapest
H–1521, Budapest