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♦ RESIsT ♦

Expert System for Fatigue Assessment and Optimization of Welded Elements

*(**Re**sidual **S**tress and **I**mprovement **T**reatments)*

Effect of Welding Residual Stresses and Improvement Treatments

In general, in modern standards and codes on fatigue design the presented data correspond to the fatigue strength of real welded joints including the effect of welding technology, type of welded element and welding residual stresses. Nevertheless, in many cases there is a need to consider the influence of welding residual stresses on the fatigue life of structural components in greater details. These cases include: the use of fatigue testing results of relatively small welded specimens without high tensile residual stresses, analysis of the effect of such factors as overloading, spectra loading, application of the improvement treatments etc.

The Expert System for Fatigue Assessment and Optimization of Welded Elements - **RESIsT** was developed to find the optimum way for fatigue life improvement of welded elements without the increase in metal consumption. Major attention was paid to developing the predictive model for analysis of the influence of the residual stresses and their redistribution under the effect of cyclic loading and improvement treatments on the fatigue life of welded elements.

The following important parameters of welded elements are analyzed with the goal to enhance the fatigue performance:

- preferred design of welded elements;
- material selection;
- weld processes;
- **welding residual stresses**;
- **application of the improvement treatments**;
- influence of possible repair technologies;
- realistic service conditions.

The **RESIsT** includes the possibility to assess through calculations the effect of residual stresses and improvement treatments application on the fatigue life of welded elements without having to perform time and labor consuming fatigue tests.

The program package enables to calculate the fatigue strength parameters of welded joints after application of heat-treatment, vibration treatment, overloading, ultrasonic peening and other improvement treatments. The mechanical properties of the used materials, the type of welded elements and stress concentrations, as well as the cyclic loading parameters are taken into account in an explicit form. A detailed analysis of the influence of residual stresses and their redistribution under the effect of cyclic loading in the zones of stress concentration is performed during fatigue assessment.

Computation of the effect of welding residual stresses and improvement treatments on the fatigue life of welded elements

Example 1. The significant increase in the fatigue strength of welded elements can be achieved by redistribution of high tensile **residual stresses**. The fatigue curves for the transverse loaded butt weld with different levels of the initial residual stresses at R=0 are shown on Figure 1. The fatigue curve of welded joint will be located between lines 1 and 2 in the case of partial removal of tensile residual stresses (line 3 and line 4). The decrease of the residual stresses from initial high level to 100 MPa causes in this case an increase of the limit stress range at $N=2\times10^6$ cycles from 100 MPa to 126 MPa. Introducing the compressive residual stresses in the weld toe zone can increase the fatigue strength of welded elements even more (line 5 and line 6 on Figure 1).

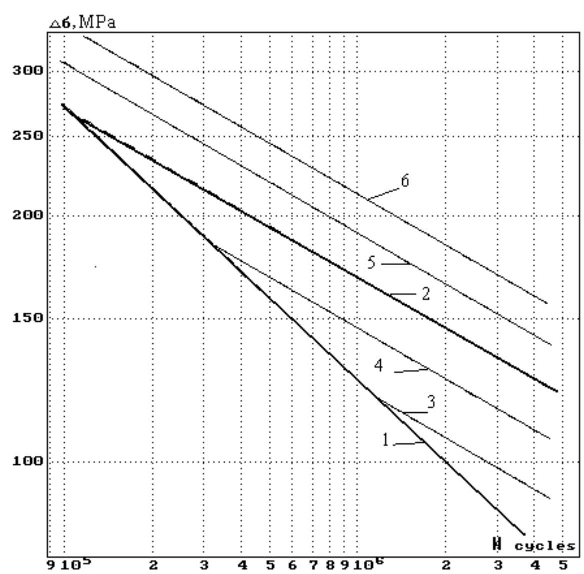

Figure 1. Fatigue curves of transverse loaded butt weld at R=0:
1 - with high tensile residual stresses;
2, 3 4, 5 and 6 - with residual stresses equal to 0 MPa, 200 MPa, 100 MPa, -100 MPa and -200 MPa

Example 2. The results of computation presented in Figure 2 show the effect of application of the **Ultrasonic Peening (UP)** for increasing the fatigue life of welded joints in steels of different strength. The data of fatigue testing of non-load-carrying fillet weld specimens in as-welded condition (with high tensile residual stresses) were used as initial fatigue data for calculating the effect of the **UP**.

Four types of steels were considered for fatigue analysis: Steel 1 - (σ_y = 270 MPa, σ_u = 410 MPa); Steel 2 - (σ_y = 370 MPa, σ_u = 470 MPa); Steel 3 - (σ_y = 615 MPa, σ_u = 747 MPa) and Steel 4 - (σ_y = 864 MPa, σ_u = 897 MPa). Line 1 on Figure 2 is the fatigue curve of considered welded joint for all types of steels in as-welded condition, determined experimentally. Lines 3, 5, 7 and 9 are the calculated fatigue curves of welded joint after application of **UP** for Steel 1, Steel 2, Steel 3 and Steel 4, respectively.

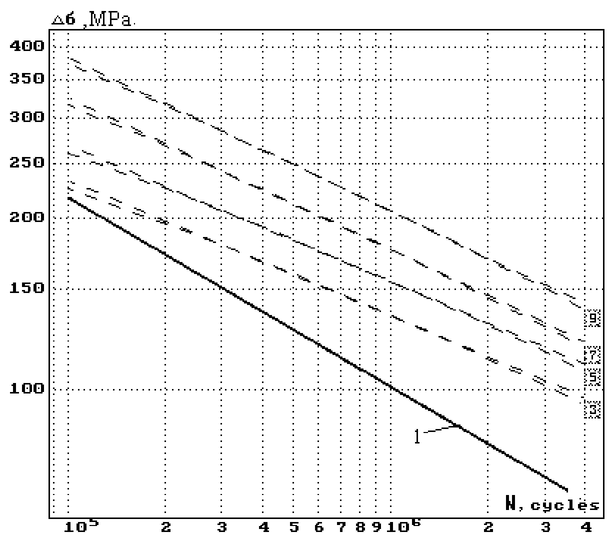

Figure 2. Fatigue curves of non-load-carrying fillet welded joint:
1 - in as-welded condition for all types of steels;
3, 5, 7 and 9 - after application of the UP for Steel 1, Steel 2, Steel 3, and Steel 4

As can be seen from Figure 2, the higher the mechanical properties of the material - the higher the fatigue strength of welded joints after application of the UP. The increase in the limit stress range at $N=2\times10^6$ cycles under the influence of UP for welded joint in Steel 1 is 42%, for Steel 2 - 64%, for Steel 3 - 83% and for Steel 4 - 112%. These results show a strong tendency of increasing the fatigue strength of welded elements after application of UP with the increase in mechanical properties of the material used. In case of high strength steel, application of UP caused a more than 2 times increase in the limit stress range and over 10 times increase in the fatigue life of the welded elements.

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