The Stresses in the Progress of Crack in Tubular Specimens

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If the plasticity of a material is limited by reducing the temperature, a crack once initiated can progress under diminished stress. This could be shown for a two-axial stress; at internal pressure tests on tubular specimens with conical transitions, stress at the end of the crack was essentially lower than the stress for the beginning. In the first series of tests 1), all stresses were related to the dimensions of specimens before the beginning of test; but it is necessary to consider the true stresses related to the actual dimensions.

In tests on tubular specimens (fig. 1), internal pressure and axial load were increased proportionally, axial- to tangential stress relation being 1 : 1 up to ultimate strength.

If the octahedral stresses (v. Mises) are calculated from axial load and internal pressure for the ultimate strength regarding the dimensions before the test, fig. 2, curves in the midth, an increment of stresses results from +20 to -100 °C for two steels, the third one having somewhat lower values for -100 °C than for -70 °C. It makes no difference, that at room temperature the two steels St 37-2 and St 37-2 semi-killed have axial cracks, but the St 37-3 has circular cracks; at lower temperatures the three steels have more or less branched cracks running into the cone, fig. 1 .

For the steel St 37-3, a decrease of axial load and hydraulic pressure was always measured from ultimate strength up to the fracture. Having great ductility for all investigated temperatures, fig. 2, lower curves, the octahedral stresses for the fracture point are more than double, 2,1- up to 2,9-times, compared with the ones for the ultimate strength, fig. 2, upper curves. But for the two steels St 37-2, there was no change of load or hydraulic pressure from ultimate strength up to fracture, the crack being very fast. Even though higher load and hydraulic pressure must be regarded in the calculation, these two steels had a smaller rise of stress up to the fracture caused by the lower deformation. Therefore the octahedral stresses are only 1,5- up to 2,0-fold and 1,35-up to 1,6-fold of that for ultimate stress.

The cases of circular cracks, simple axial cracks and branched axial cracks must be differentiated, if deformations and breaking stresses, octahedral or in the three directions, are to be evaluated. All the specimens of the three steels have got a distinct bulging in the middle, cylindrical part, combined with a significant reduction of wall thickness, fig. 2, lower curves. The deformations decrease from the midst to the end of the cylindrical part and diminish still more in the conical transition parts. As axial loads and hydraulic pressure remain equal, stresses decrease.

Steel St 37-3 having cylindrical cracks at room temperature, there is no distinct change of stresses, because deformation is equal. But for the two specimens investigated at -50 and -100 °C, stresses at the end of the crack were calculated down to 330 N/mm^2 as against 1100 and 1200 N/mm^2 at the beginning of crack, the cracks and therefore stresses being often not symmetrical (fig. 3).

Three specimens of the steel St 37-2 were tested at deep temperature and had branched cracks, fig. 3 . In the cylindrical part, from fork to fork, stresses change only by the amount of 100 N/mm^2 ; then they fall considerably and when the cracks join, stresses are smaller than the half of that in beginning of crack.

In fig. 4 , the results for the steel St 37-2 are shown. The stresses at the beginning of crack rise by about 100 N/mm^2 with decreasing

temperature. For the stress at the end of the crack, there is a continual diminishing towards lower temperatures. At -100 °C, the stresses at the one end of the crack are only 270 N/mm^2, compared with 810 N/mm^2 in the midst of the bulge; for the other end 400 N/mm^2 being calculated. The fine dotted lines in fig. 4 are the stresses for the transition from cylindrical to the conical part of the specimens.

For the semikilled steel St 37-2 the results were not so clear, because the greatest deformations were unequal in parallel tests. In this "scatter range" unequal deformations have caused the breaking of specimens. Therefore, the highest stresses in the bulge and also at the ends of crack differ much; the lowest values at -50 ° are 233 N/mm^2 compared with 784 in the midst of bulge; for -100 °C crack arrests at 382 N/mm^2, stress in the midst of bulge being nearly the same.

The path of the crack is to be considered, and also whether the same external loads, axial loads and hydraulic pressures, may be taken into account for the stress calculation all over the length of crack. If fragments of the specimens are put together, the broken conical ends suit well to the middle parts, if the elements opposite to the axial crack are joined. The branch in the middle part has opened only after the conical end has torn off. Therefore the following steps are to be supposed:

1) The middle part bulges.

2) An additional deformation happens, and the middle part breaks parallel to the axes.

3) The hydraulic pressure begins to fall, wherefore the relation between axial and tangential stress is varied. The crack changes its direction and branches.

4) The branched crack joins to a circular crack. It is not impossible, that the axial loads do not decrease as fast as the crack progress; then stresses could increase again over the rest of the circular crack.

5) The middle part is bent according to the width of the fissure; for this bending only a little rest of the hydraulic pressure is necessary.

The registration of axial load and hydraulic pressure with the oscillograph resulted only, that all events were very fast; the accepted sequence could not be confirmed until now.

In the midst of bulging, considerable deformations have been measured on all specimens, also at low temperatures. The specimens with a branching of crack have in spite of that only a short ductile fissure; rest of the axial crack and the branching crack being crystalline, although these stresses are only a half or a third of the stresses at crack beginning. It is not to be supposed, that the change in the relation of axial and tangential stresses can cause such a change of the breaking strength of material. It is more probable, that the first part of breaking causes elastic waves - the specimen is a stressed spring, which is decharged in breaking and oscillates - and that these waves cause considerable additional stresses. The existence of such waves is to be assumed from the regular look of the fragments. Such waves could be demonstrated in cylindrical tension specimens, surpassing the yield point and causing plastical deformations 2). Corresponding measurements at the internal pressure specimens are being prepared. -

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1) Krisch, A.: Arch. Eisenhüttenwes. 43 (1972) S. 431/37.

2) Krisch, A., u. U. Gramberg: Arch. Eisenhüttenwes. 42 (1971) S. 671/77.

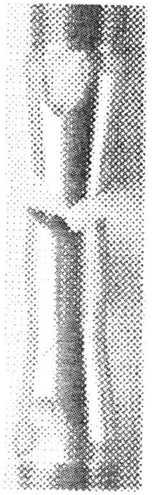

Fig 1 Specimen with conical ends for internal pressure tests
Steel St 37-2 ; -100 °C

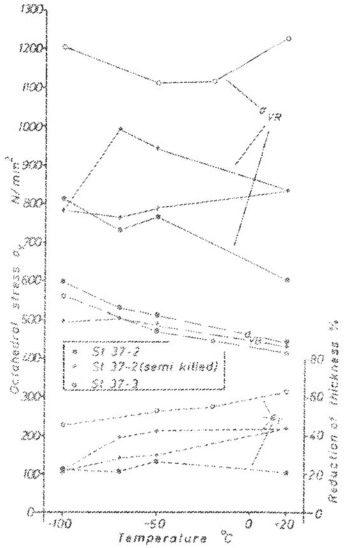

Fig 2 Rupture strength σ_{vR}, ultimate strength σ_{vB} and reduction of thickness $-\varepsilon_r$ in internal pressure tests

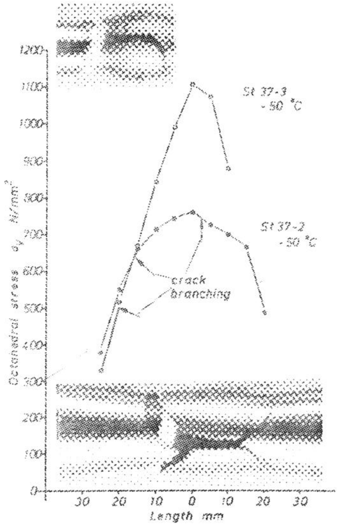

Fig.3 Stresses over the length of the crack

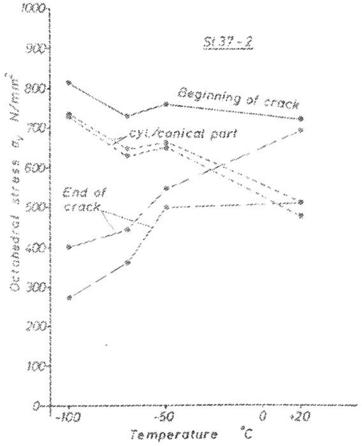

Fig. 4 Stresses in the beginning and the end of crack