THE USE OF THE RING-CRACK-SPECIMEN

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A special geometry for testing ductile materials is introduced. The basic idea is to use a rotationally symmetric geometry to avoid free surfaces. The rotationally symmetric geometry also allows experimental investigations under different triaxiality conditions. The triaxiality can be controlled by varying the inner radius or by appplying an internal pressure. These new features and properties of the specimen are described briefly.

INTRODUCTION

Experimental characterisation of ductile materials like construction steels causes some problems, the measured values are geometry dependant. The main reason for this phenomen seems to be the different amount of triaxiality resp. constraint along the crack-front inside of the common used specimen. Inside an ideal specimen there should be a constant amount of stress triaxiality, e.g. homogeneous plain strain conditions .

Only in the middle of a C(T)-specimen - as an example for a specimen with a cartesian geometry - there are plain strain conditions, while on the free surfaces nearely plain stress conditions can be found.
The plain strain conditions do occur because of the symmetry of the specimen. The free surfaces disturb homogenous conditions principally.

This is a well known problem, several attempts have been made to describe this phenomen, e.g. the so called dog-bone-model. And the problems have been tried to solve by engineering tricks like side grooves et cetera. They are all discussed in most of the monographs about fracture mechanics (1), (2) in general, and they are up to now actual topics in research.

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It is obviously the geometry of a specimen that causes the stress-strain-conditions and these stress-strain-conditions are the reason for the difference of the measured fracture parameters.

One way of measuring fracture mechanical properties is to avoid the -disturbing- free surfaces by using a rotationally symmetric geometry, and has been dicussed earlier (3). A rotationally symmetric specimen with a circumferential crack behaves like a cartesian specimen with infinit thickness.

GEOMETRY OF THE RING-CRACK-SPECIMEN

The geometry of the ring-crack-specimen, RR(T) (from the german "Ring-Riß-Probe", engl.: ring-rupture-specimen), is generally the same as the cross section of the C(T)-specimen. The cross section has just been rotated around a z-axis, as shown in Fig.1.

The main proportion of height to width, $\frac{h}{w} = 1.2$ has been kept. The main difference is just the way of applying the test-load to the specimen. Obviously there is no way to fix a bolt in a rotationally symmetric body as it is possible for the C(T) specimen.

Applying the test-load has been realised by a cylinder beeing fixed at the upper edge. Using a cylinder instead of a friction-free beared bolt causes a momentum beeing induced at the same edge. This moment must be taken into account, because it stresses the crack front additionally.

Let the inner radius r_i be varied and the dimensions of a and w be kept. Then the different positions of the test section will generate different ratios of σ_{rr} to $\sigma_{\varphi\varphi}$. This ratio is an important parameter, that can be used to subject the material certain stress-strain-conditions.

An important feature of the RR(T)-specimen is that the state of stress can be varied by another parameter. Applying a pressure at the inside of the specimen leads to an increase of the radial and tangential stresses, and thereby to a well defined increase of the stress-triaxiality.

Another feature is that mixed-mode experiments can also be performed. For mode I/III an additional torsional moment must be applied. That can be done on a usual multi-purpose test-machine. Even mode I/II/III experiments may be carried out - in certain limits, of course.

MECHANICAL AND FRACTURE MECHANICAL PROPERTIES

A family of specimen has been created for various values of the inner radius r_i. Fig. 2 shows the geometries for $r_i = 10,\ 20,\ 30,\ 40mm$.

The dimension of the specimen set is based on the C(T)50-specimen. For sizing the thickness d of the tension cylinder the diagram shown in Fig.3 has been used. The thickness d is strongly dependant on the ratio $\frac{a}{w}$. For the geometries shown in Fig. 3 the range is limited to $\frac{a}{w} = 0.4$, in order to design the whole family with the same thickness d (though the smaller specimen could have been sized with lower thicknesses).

The basic mechanical model for the test-geometry is, looking at the cross section, a rectangle with single force at the upper edge, see Fig. 4a, It has to be completed by superposing a moment at the same edge, as shown in Fig. 4b. The influence of the moment releaves the stresses at the crack tip to some extend.

The moments origin is the elastic clamp between specimen the tension cylinder. The design of this connection-point influences the height of the moment very much, therefore it should be designed as weak as possible. An other influence is, of course, the dimension of the tensile cylinder, its thickness, length and radius.

For the evaluation of the experiment it is necessary to know the moment as well as the force at every time of the experiment (4).

Measuring the moment during each experiment would be the exactest way. But an easier way is the calculation of a relationship between force and moment. Analytical shell theory gives an estimation but the geometrical conditions at the clamping-point are rather difficult.
Numerical calculations have shown, that the moment inside the cylinder near the clamping-point is so big, that it compensates tensile stresses at the outer surface and doubles it on the inner surface. And the shear force there is approximately one fifth of the testing force. To obtain more exact results for a relationship between force and moment numerical simulations become necessary.

Pressure on the inner surfaces at r_i raises the stress-triaxiality. The pressure raises the tangential stresses and lowers the radial stresses, but it has no influence on the crack driving normal stress.

Fig. 5 shows the stresses in our set of RR(T)-specimen for an internal pressure of $p_i = 100$ MPa. The greater the ratio $\frac{a}{w}$ and the larger the radius r_i is, the greater is the effect. For practical use of RR(T)-specimen it will cause less experimental efford to examine deeper cracked specimen or those with a big radius r_i.

CONCLUSION

The RR(T)-specimen is an adequate tool to describe ductile material behaviour under different amounts of stress-triaxiality. The advantages are a homogeneous loaded resp. constrained crack front and a wide range of applicable streess-triaxialities. These are features, that no cartesian specimen offers.

The differences lie in the experimental performance, for it causes much efford. Precracking ductile materials is difficult, especially because the precrack has to be concentrical to the specimens geometry. An other difficulty lies in handling high pressures.

The RR(T)-specimen is not a specimen for mass testing. It offers a possibility to investigate special problems and questions on the mechanisms of failure at different stress-strain-states.

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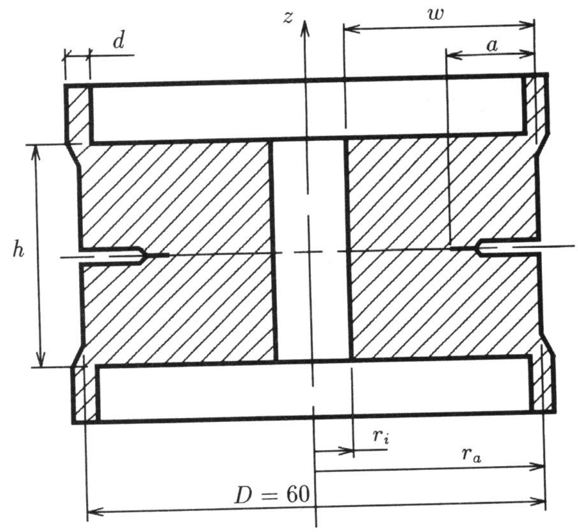


Figure 1.: Cross Section of the Ring-Crack-Specimen RR(T) 50/10

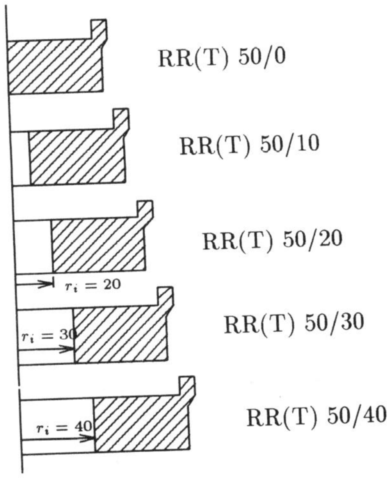
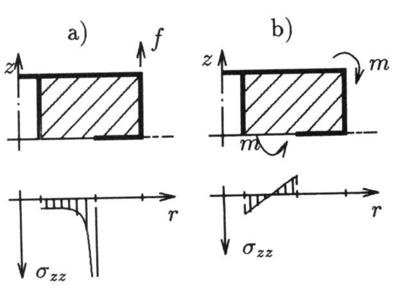


Figure 2.: Family of RR(T)-Specimen (upper right quarter)



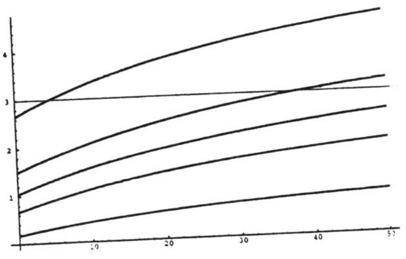
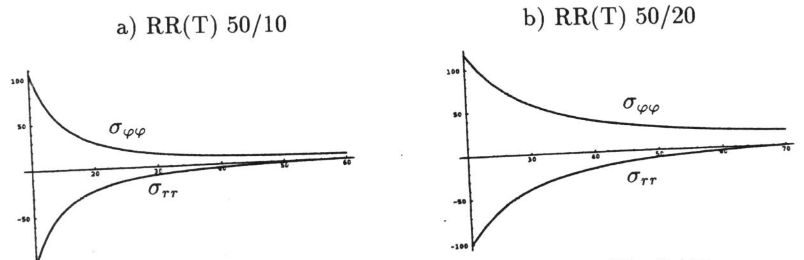


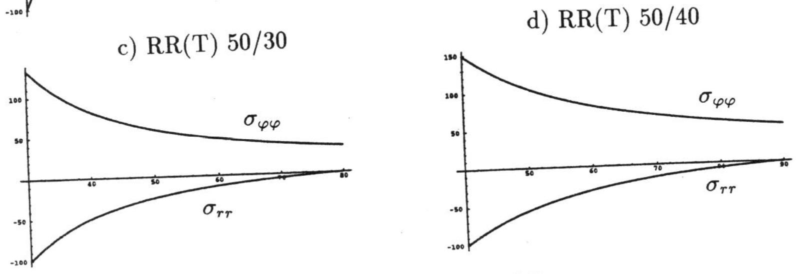
Figure 3.: Loads at the clamping point Figure 4.:

Required half Thickness of d over r_i



a) RR(T) 50/10

b) RR(T) 50/20



c) RR(T) 50/30

d) RR(T) 50/40

Figure 5.: Stresses caused by internal Pressure