REALISTIC DEFECTS AS SOURCES FOR INITIATION OF FRACTURE - MECHANICAL BEHAVIOUR - AVAILABLE FRACTURE CRITERIA

H. Kordisch and E. Sommer
Fraunhofer-Institut für Werkstoffmechanik
Rosastr. 9, D-7800 Freiburg, West Germany

INTRODUCTION

Failures of structures are caused by unfavourable coincidences of applied loads, material properties and defects. Depending on the type of defect, the margin of safety achieved for a given material and a certain loading condition is quite different.

For brittle fracture, a lower bound estimate is mostly based on a fracture mechanics approach. The difference in the calculated and realistically tolerated load bearing capacity of a structure will be the more pronounced the less the failure causing defect is crack-like. But even when the location and the form of the defect would be well-known, for instance by means of nondestructive test methods, in most cases, an exact prediction of the failure load could not be given.

When ductile material behaviour prevails, the local plastic deformation in the crack or defect surrounding reduces these differences. For instance, is the growth of the slip-line field with increasing load nearly the same for a crack and a defect of an equivalent size in the same structure? At increasing ductility, the tolerated load of a structure is less affected by the presence of cracks or crack-like defects.

In Figure 1, this behaviour is summarized; under the simplifying assumption of a structure containing a crack or a defect of the same size, the failure stress is plotted for increasing ductility. This ductility depends upon intrinsic material properties as well as the temperature and strain rate as external parameters. In order to minimize the gap between the applicability of fracture mechanics methods and realistic material response, two extreme cases will be considered:

1. In the case of brittle fracture, the experimental scatter in the strength of glass will be interpreted.

2. For extremely ductile behaviour, the stress-strain-field of a specimen with a crack and a circular defect of the same size will be compared.

DEFECTS IN MATERIALS WITH BRITTLE BEHAVIOUR

For the case of brittle fracture, glass will be considered as a typical model material. In general, the fracture of glass starts from defects of the specimen surface. The defects can be caused by normal handling of the specimens or can be artificially introduced. It is known that the scatter of the strength of glass \( \sigma_c \) severely will be affected by the geometry, location, and size of such defects. In order to investigate the influence of typical defect forms on the bending strength of glass in [1], careful experiments on glass rods have been carried out. As a main result, a variation of the bending strength by a factor of 15 is reported, whereas a "crack initiation constant" defined as \( K' = \sigma_c a_i^{3/2} \), with \( a_i \) as microscopically measured crack initiation length, varies only by a factor of 2.

In the following section, a failure stress prediction based on various defect configurations will be compared with these experimental findings. The considered configurations are (a = depth of the defect, W = thickness parameter of the specimen, \( \sigma \) = applied nominal stress, \( K \) = stress intensity factor, \( K_{IC} \) = fracture toughness):

- long surface crack caused by a scratch

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K_I = 1.1 \sigma \sqrt{\pi a} f(a/W) \leq K_{IC}
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