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PLANE STRESS AND PLANE STRAIN IN SIDE-GROOVED CCT-SPECIMENS

Kees van Kranenburg[(1) (*)], Ton Riemslag[(1)], Saskia Benedictus-de Vries[(3)], Jan Zuidema[(1)] and Fred Veer[(2)]

[(1)] Laboratory of Materials Science, Delft University of Technology
[(2)] Faculty of Architecture, Delft University of Technology
[(3)] Netherlands Institute for Metals Research

ABSTRACT

To model the behavior of plasticity induced crack closure it is in the first place necessary to measure this behavior and then to manipulate and simulate this behavior.
The possibility of keeping a CCT specimen in plane strain during a CA experiment by implementing side-grooves has been investigated. If crack closure is caused by early contact of the crack flanks, a shift in the da/dN versus ΔK graph at different R-values in relation to tests without side grooves is expected. Putting side-grooves over the full width of the specimen did not result in an effect on the crack growth rate. However, side-grooves suppresses the development of shear lips. A series of experiments on specimens with varying length of side grooves shows that the development of shear lips is suppressed over the length of the side groove. After the side groove the shear lips develops quickly until full shear is achieved.

KEYWORDS

Crack closure, plane stress, plane strain, side-grooves

INTRODUCTION

Crack closure, caused by contact of the crack surfaces before zero load is reached is one of the causes of crack growth retardation. To model crack closure it is necessary to be able to measure it. A first step to measure crack closure is conducting tests on specimens where as much as possible closure is prevented. This can be achieved in a situation where plane strain dominates over plane stress. It is possible to create a dominant plain strain situation by:

- using thick specimens; in this case there is little plane stress related to plane strain.
- Introducing side-grooves that prevent deformation in the flanks and thus diminish the plane stress portion. This leads to a plane strain situation.

Schematically:

In the scheme in figure 1 a shift to the right of the Fatigue Crack Growth Rate Curves for decreasing R-values is observed. This shift is generally accepted as a result of crack closure. The closure effect is caused by plastic deformation and thus maximum in the plane stress flanks of the specimen. Except in very thin specimens both plane strain and plane stress are present.

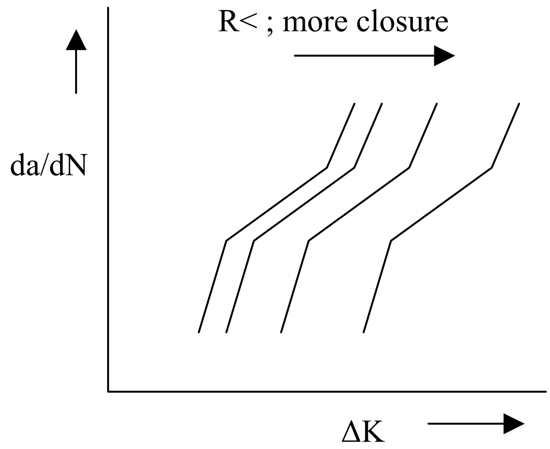


Figure 1: Different R's

Side-grooves:
By introducing side-grooves in CCT - specimens a predominantly plane strain situation is created because deformation in the flanks is prevented. This means that plasticity induced closure is avoided. In the da/dN-ΔK scheme a shift of the curves would be expected to the left, as shown in figure 2, in the direction of high R-values with a relatively low closure level.

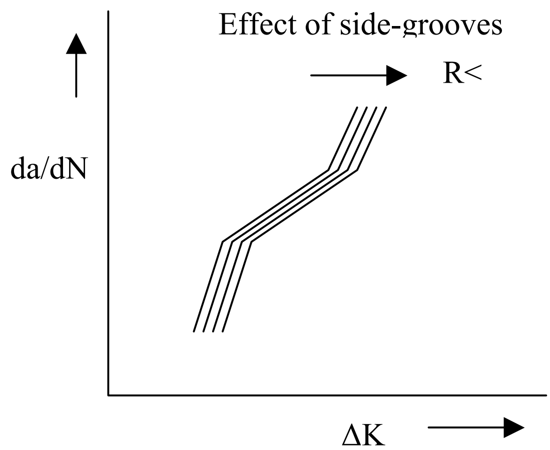


Figure 2: Scheme R's with side-grooves

EXPERIMENTAL DETAILS

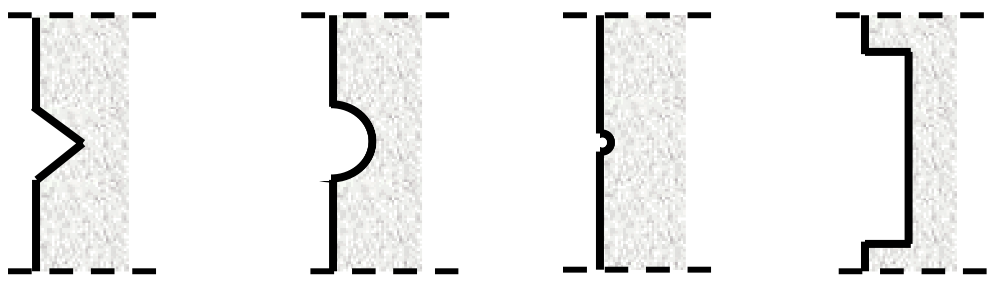
Experiments have been conducted on AA5083. The material data is in table I

TABLE I
MATERIAL DATA (wt%) AA 5083 H-321

AA	Al	Fe	Si	Cr	Mg	Ti	Cu	Mn	Zn	other
5083	94.1	0.22	0.26	0.1	4.5	0.03	0.09	0.65	0.06	<0.05

Below an overview of the different geometry's that have been used :

Geometry's: (normal thickness 8 mm)



A B C D

A: Sharp groove, effective cross-section plate 6 mm
B: *Rounded groove* with a depth of 1 mm.
C: *Very small scratch*, 0.1 mm
D: *Reference*: milled back till 6 mm

The cracklength has been measured using the pulsed direct current potential drop technique. First, the different geometry's were calibrated using this technique. Subsequently the specimens are fatigued to failure by CA tests in laboratory air for different load ratios at a frequency of 10 Hz. For specific load data see Table II.
Initially the side grooves were created by milling on the full width of the specimens.
With geometry C more experiments are done with scratches along the full width, in the crack growth direction; scratches on one side and on the other side with a varying lengths of 0, 20 and 30 mm.
Data is analyzed using the procedures given in ASTM 647 [1]

TABLE II
LOADS

R	P-max	Freq (Hz)
0.7	83.5	10
0.5	35	10
0.1	35	10

RESULTS

First place the effect of the difference in geometry's A-D has to be analyzed. Figure 3 shows a da/dN-ΔK plot for different geometry's at a load ratio of 0.5. The two extremes: right in the graph is the result of geometry D; on the left the result of geometry B. The difference in geometry has only a marginal effect on the da/dN-ΔK results. For all the different geometry's tunneling occurs. In geometry B the crack front at the flanks lags behind to the rest resulting in a convex crack front. For a sharp groove this effect is opposite, a concave crack front is obtained. In none of the specimens with side grooves shear lips are formed.[2]

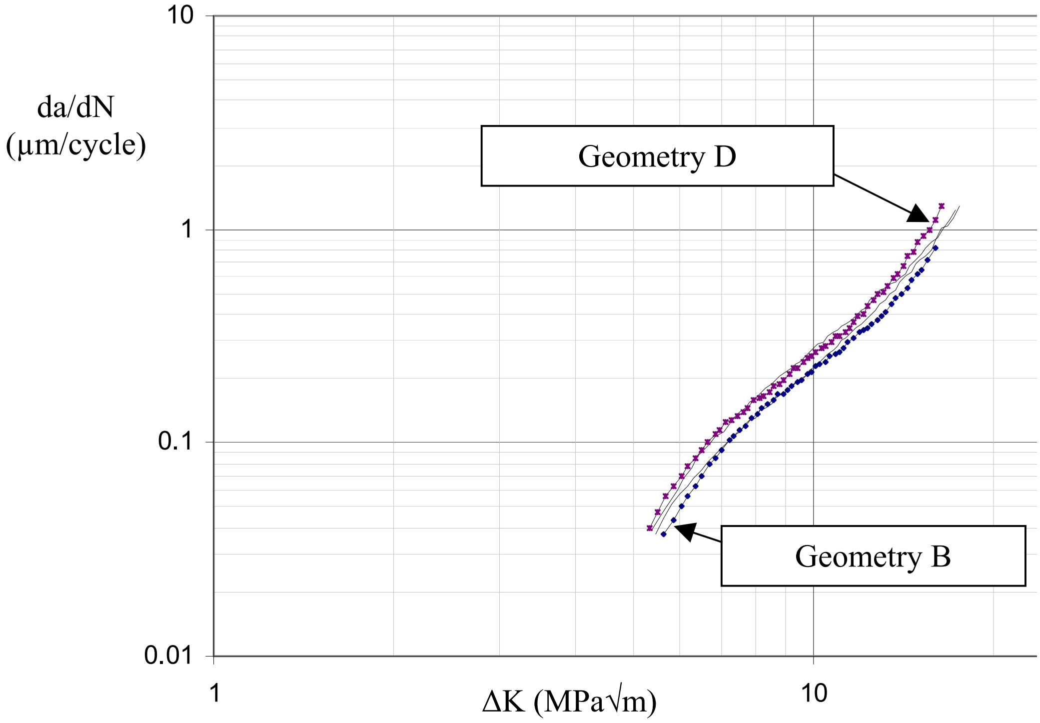


Figure 3: R=0.5 with different geometry's.

A. Hascariantono [3] found that in AA 5084 material the crack growth rates for R=0.5 and 0.7 are the same, suggesting the absence of crack closure. In figure 4 the results of tests at these load ratios *with* and *without* side-grooves are compared.

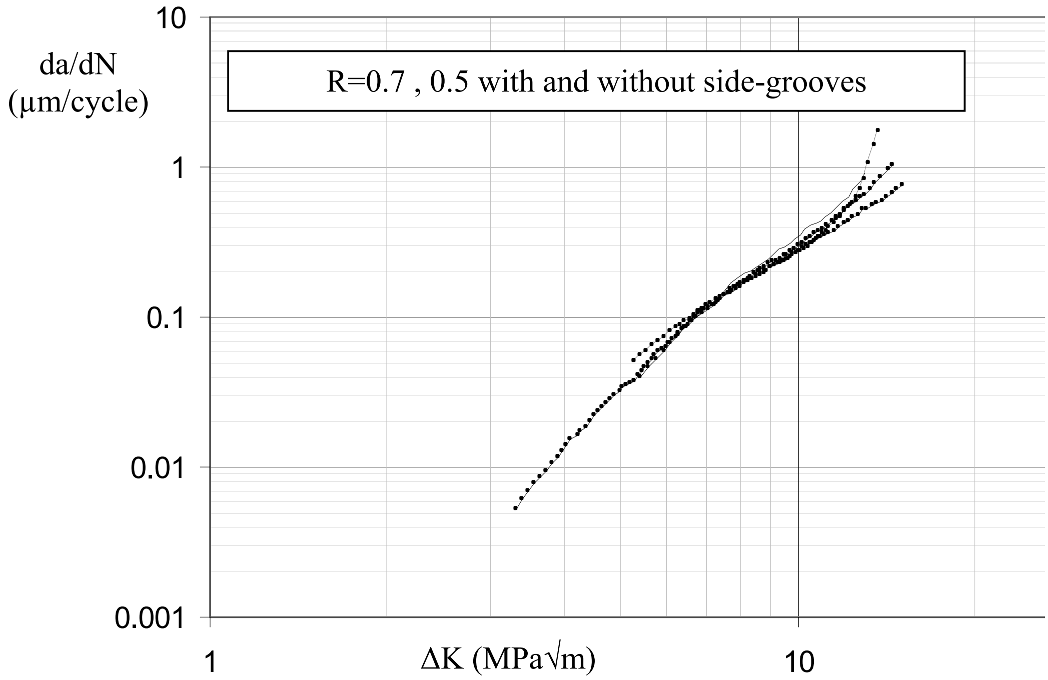


Figure 4 : R-values, no closure, without closure, with and without side-grooves

The results in figure 4 for different R-values and different geometry's show that there is no significant effect on the crack growth rate.
Finally the results at R=0.5, 0.7 (no closure) and R=0.1 (with closure) [1] are compared to R=0.1 *with* side grooves.

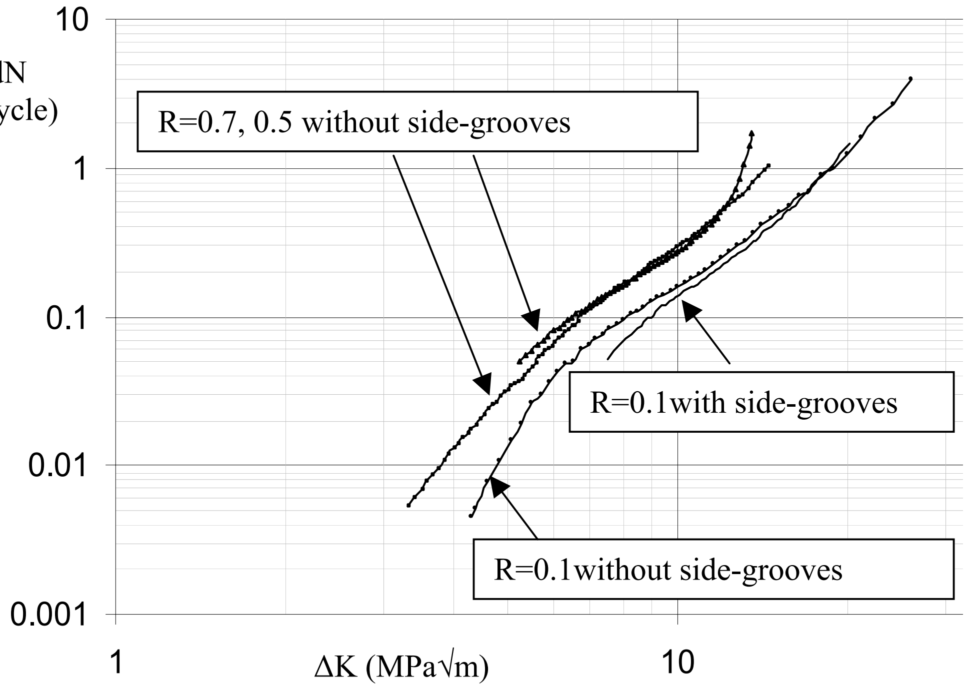


Figure 5: R's with and without side-grooves

The crack growth rates between specimens with and without side-grooves, even for R=0.1 show no significant differences. Thus introducing sidegrooves does not have the effect that we had in mind, namely changing the crack closure situation.

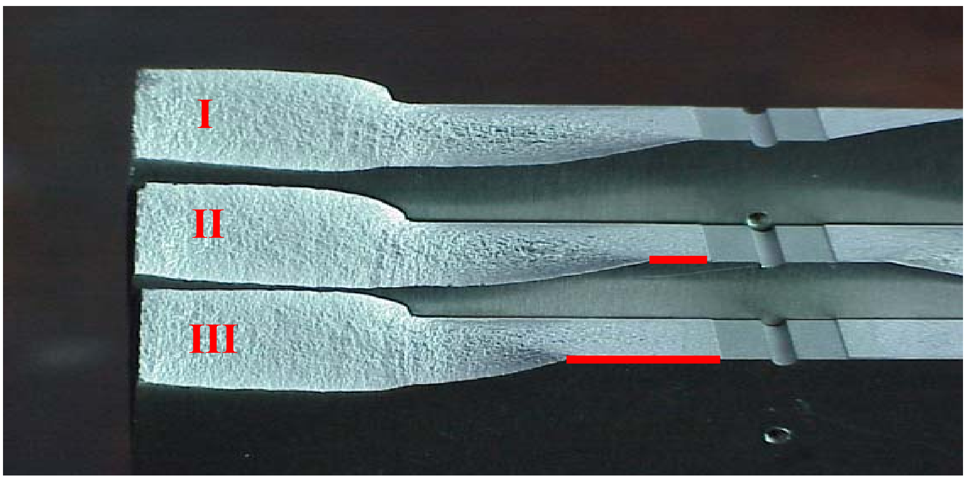


Figure 6: Geometry C with side grooves of varying length.

Figure 6 shows the results of three specimens of geometry C. They have been fatigued at a load ratio of 0.1 using a maximum load of P_{max}=95 kN. At one side the sidegroove is put on the full width, on the other side only partly.
At specimen I there is only one scratch on one side; on specimens II and III there are also scratches on the other side with a total length of 20 and 30 mm respectively. At specimen I shear lips develop immediately at one side. The other side remains smooth and follows the scratch, because sidegrooves prevent the development of shear lips. The *longer* the side groove gets (II and III), the faster the shear lip develops. At specimen III the shear lip grows in a relatively *very short* distance to full width. Despite the difference in the specimens, de crack growth rates are equal for all specimens.

CONCLUSIONS AND DISCUSSION

- For the results of the different side grooves no measurable difference in crack growth is observed in relation to the situations without sidegrooves. So the closure effect is not abolished.
- Different geometry's influence tunneling: a sharp side groove supports initiation of the crack in the flanks.
- Side grooves prevent the development of shear lips. Because there is only a marginal difference in crack growth rate with or without shear lips, the development of shear lips might not affect the crack growth rate.
- Side grooves force the crack in a certain direction. This is best seen with the rounded groove (geometry B). The crack tries repeatedly to grow *out* of the groove, but is redirected by the groove.

REFERENCES

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