Tests with Uncracked Specimen

Before moving on to the main fatigue experiments, a few tests are done on an uncracked specimen without creating an initial crack on it. This can be thought as a calibration test for the upcoming fatigue tests with cracked specimen. It is the *finite width correction factor*, denoted with β, in the equation of stress intensity factor (Eq. 1) that we are trying to find as a result of these tests.

$$\Delta K = \beta S_{max}(1 - R)\sqrt{\pi a} \tag{1}$$

where S_{max} is the maximum fatigue stress applied in terms of MPa, R is the stress ratio, a is the crack length in terms of milimeters and ΔK is the stress intensity factor in terms of MPa$\sqrt{mm}$.

Using the stress intensity, we evaluate effective stress intensity factor in terms of MPa$\sqrt{m}$ as in Equation 2.

$$\Delta K_{\text{eff}} = (0.55 + 0.33R + 0.12R^2)\Delta K/\sqrt{1000} \tag{2}$$

When $\beta = 1$, or absent from the equation, the stress intensity factor is evaluated for an infinite width specimen. For a very small crack, the specimen plate is effectively an infinite plate and the value of β is very close to 1. As the crack grows, the finite width of the plate is felt more and the value of β increases accordingly.

There are very good approximations in the literature for β, such as Feddersen's [1] (Eq. 3) but they are not for a cruciform geometry as the ones we are using. Secondly, they do not account for the biaxiality that is present in our experiments.

$$\beta = \sqrt{\sec \frac{\pi a}{W}} \tag{3}$$

β can, more precisely, be found as the ratio of the area under the $P - \delta$ curve, i.e. the external work done on the system, in the finite width case to that of approximately infinite case. (See Equation 4)

$$\beta = \frac{W}{W_0} \tag{4}$$

The uncracked specimen we are using in these test will provide us the work for the infinite width, W_0. As we compare it with the work in the fatigue experiments, W, we will have the most accurate β values for the calculation of

Table 1: Loads applied in the tests with uncracked specimen. The numbers indicate the test numbers, e.g. 1 is the 1$^{\text{st}}$ test.

Transverse / Perpendicular load	uniaxial (no rig)	$P_T = 0$	$P_T = 10$ kN	$P_T = 15$ kN	$P_T = 20$ kN	$P_T = 25$ kN
$P_{max} = 30$ kN	1	2	3	4	5	6

stress intensity factor. It is important to note here that the β we are aiming to find will not only account for the finite geometry but also for the biaxiality loading condition in our case.

Six tests have been performed, as shown in Table 1, each of them accounting for a different biaxial condition. In each test, a load of $P_{max} = 30$ kN is applied 3 times with the test machine. Three cycles do not decrease the fatigue life of our specimen considerably. Hence, the specimen will be reusable throughout these uncracked tests and also for a single fatigue test in the future. Running the same test 3 times is considered to be sufficient to ensure the behavior of the specimen.

Note that 30 kN is a sufficient maximum load for the $P-\delta$ curve to be drawn up to, since it covers the range we are working in the fatigue experiments, namely 15 kN and 22 kN maximum load with 0.1 stress ratio.

Table 1 is read as follows. In the 1$^{\text{st}}$ test, there will not be any rig or torsion bar present in the system. Hence, the only load is the one applied by the machine in the axial direction up to 30 kN. It will let us see the uniaxial elastic behaviour of the specimen. The rig and bar system is raised, hung by the ropes and clamped to the system in the 2$^{\text{nd}}$ test. The torsion bar is not pretensioned. By this, we mean that the torsion nut is tightened just enough to restrict the movement of the bar, which also results in a couple of kN of tension, but not specifically torqued to pretension value. In this test, biaxiality just enters into the equation, possibly restricting the elastic elongation of the specimen in the vertical direction as the machine applies an increasing force up to 30 kN.

In the 3$^{\text{rd}}$, 4$^{\text{th}}$, 5$^{\text{th}}$ and 6$^{\text{th}}$ tests, without changing the setup, we only torque the bar to the pretension levels we desire in the transverse direction, as indicated in Table 1. This is the point where we are using our calibration curve for the first time. The value measured by the strain gauges are read while the bar is torqued. When the strain reading corresponds to the desired load level according to the

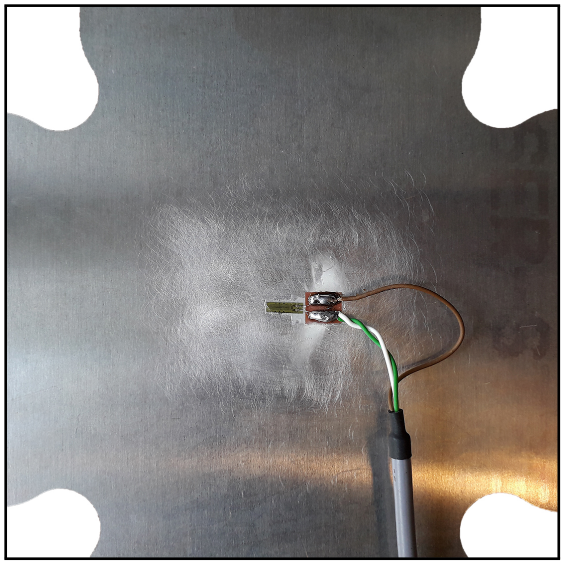

Figure 1: Strain gauge on the specimen, measuring the transverse strain on the central region

calibration curve, it means the pretensioning is done.

In the tests with uncracked specimen, different than the following fatigue tests with a crack in the centre, we are able to make use of yet another strain gauge which is placed on the center of the specimen. (Fig. 1) The readings of this strain gauge will let us measure how much the pretension elongates the specimen in the transverse direction, and how much of this elongation is contracted due to the machine load in the direction perpendicular to it.

Bibliography

[1] Jaap Schijve. *Fatigue of Structures and Materials*. second. Springer, 2001.