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Investigations of different improvement methods in the clamping area of reinforcing steels in uniaxial fatigue tests

Wissenschaftlicher Kurzbericht Nr. 67 (2022)

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Arbeitsgruppe 3: Stahl und Korrosion

1 Introduction

The fatigue strength of reinforcing steel is an indication of their resistance against dynamic loads, which is evaluated using the uniaxial fatigue test [1]. However, during the fatigue test, premature fractures often occur in the clamping area, which is deemed invalid according to the standard DIN EN ISO 15630-1 [2]. Within this study, two different improvement methods were investigated in order to reduce the invalid fractures.

2 Theoretical background

The fatigue test is usually performed on reinforcing steels that are not embedded in concrete. The concentration of notch stresses and the triaxial stress distribution is the fundamental cause of premature fractures from a microscopic perspective [3]. In reinforcing steels, the stresses are generally concentrated at the bottom of the rib due to the irregularity of the surface [4]. Jhamb [3] identified the ratio of the fillet radius r of the rib base to the rib height h (Figure 1) as a determinant of the stress concentration factor and the optimum fatigue strength is reached when the r/h ratio is equal to or greater than 1.25.

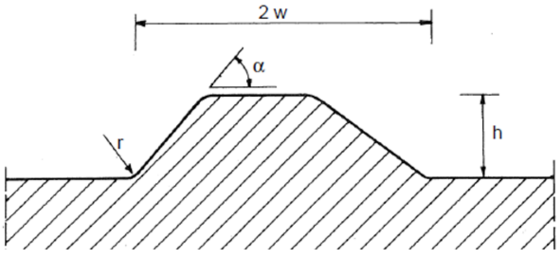

Figure 1: Representation of the rib geometry [5]

In previous studies, a few methods have been tried to reduce premature failures of reinforcing steels in fatigue tests. Jhamb [3], Weirich [5] and Heeke [6] have used the method of gluing reinforcing steels to the steel sleeves to improve their clamping area. Rocha [7] used shot peening to completely remove the ribs from the clamping area of the reinforcing steels. Eick [8] investigated the improvement of the clamping area by using sandblasting.

3 Methodology

Three different diameters of reinforcing steels were used: 12 mm, 16 mm and 20 mm. In total 120 samples were tested. The first improvement method was sandblasting. Sandblasting was done with the help of high-speed abrasives impacting the surface of the reinforcing steels. Through this process, the small notches on the surface can be removed, the fillet radius of the ribs is increased and the rib height decreases. The distance between the nozzle and the reinforcing steel surface and the blasting duration were considered to be the most effective factors for varying the sandblasting intensity [3]. The second improvement method was shot peening. The peening media was a mixture of S 230 and double-rounded steel wire grain with a diameter of 0.8 mm. Two parameters can be set by the machine: low or high rotation speed (“6V” and “8V”), which can directly affect the speed of the peening media; and the shot peening duration (“4x25 s” and “4x40 s”). To compare the surface of reinforcing steel before and after sandblasting or shot peening, a laser-based line scan (LLS) measuring system was used [9]. The data from the LLS measuring system can help to determine r and h. The rib height is the height from the rib bottom to the top of the rib. Therefore, the two rib valleys next to the rib top served as basis (Figure 2). The determination of the fillet radius can be done by inserting the fillet circle at the bottom of ribs. (Figure 3). Fatigue tests were used to compare whether there was an improvement in the clamping area before and after sandblasting or shot peening. In the tests, the maximum stress was 300 N/mm^2 and the stress range was 175 or 200 N/mm^2. The run out criterion was set to 2 million load cycles. The frequency of cyclic loads was between 85 and 100 Hz.

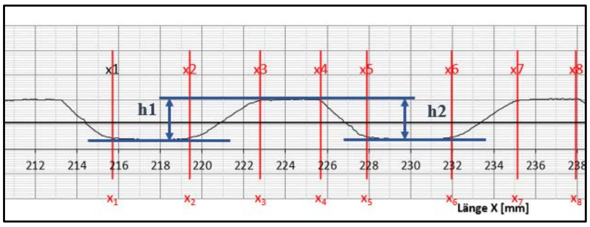

Figure 2: Determination of rib height

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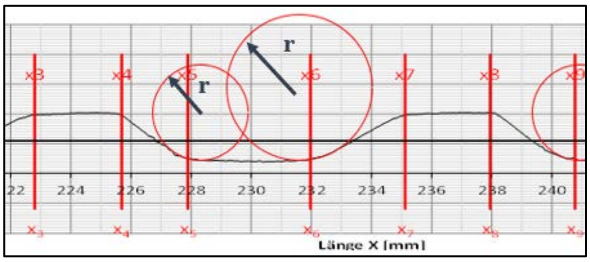

Figure 3: Determination of fillet radius of the rib

4 Results

The results show that the r/h ratio of all three diameters of reinforcing steels can reach 1.25 after sandblasting. Therefore, different sandblasting intensities are necessary (Table 1).

Table 1: Summary of the r/h ratio before and after sandblasting on the steep side of ribs

Diameter	Sandblasting parameter	r/h_before	r/h_after
12 mm	5 cm, 100 s	0.786	1.246
16 mm	5 cm, 120 s	0.882	1.252
20 mm	10 cm, 60 s	1.105	1.254

Eleven of 30 untreated reference specimens failed in the clamping area. In contrast, only one of the 30 sandblasted reinforcing steels failed within the clamping area during the fatigue test.

Figure 4 shows that the ribs on the surface of samples remain after shot peening. The results from the LLS measuring system show that shot peening has a positive effect on increasing the r/h ratio of ribs. The shot peening intensity, which was finally chosen for all three diameter reinforcing steels, was 8 V and 4x40 s. All 15 shot peened samples did not fracture in the clamping area in the fatigue test with a stress range of 200 N/mm^2.

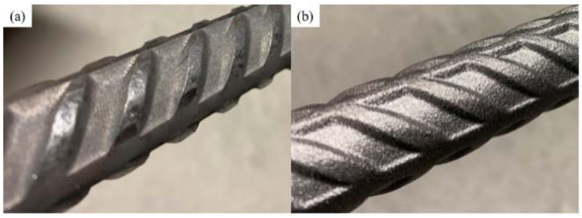

Figure 4: The surface of reinforcing steel before (a) and after (b) shot peening (Diameter 20 mm, Intensity “8 V and 4x40 s”)

5 Conclusion

Both sandblasting and shot peening have a positive effect on reducing premature fractures in the clamping area of reinforcing steels. After increasing the r/h ratio of the ribs to 1.25, the premature fractures in the clamping area of reinforcing steels were significantly reduced. Using shot peening invalid fractures in the clamping area were completely avoided.

6 Reference

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