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The Influence of Edge Surface Finishing on the Fatigue Life of Low Carbon Steel Sheet

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تأثير نعومة سطح الحافة على عمر الكلال للصلب الصفائحي منخفض الكربون

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تحسين عمر الكلال للصلب الصفائحي SAE 1005 بواسطة التجليخ عالي الدقة والتلميع قد تم بحثه. النماذج المستوية حُمّلت دورياً بواسطة جهاز الكلال الانحنائي المستوى بنفس قيم الإجهادات المتوسطة والمتناوبة. حيث أدت عملية التجليخ إلى تحريك منحنى الإجهاد - العمر لجهة اليمين، وحسّنت من مقاومة الكلال للصلب قيد الدراسة.

تم الحصول على أفضل نتيجة في مقاومة الكلال من خلال عملية التلميع حيث ارتفع عمر الكلال بنسبة 150% عن نظيره للنماذج غير الملمعة.

Abstract: *The improvement of fatigue life of SAE 1005 steel sheet by high precision grinding and polishing has been investigated. The flat speciments were cyclically loaded by a plane bending fatigue testing machine, with similar levels of mean and alternating stresses. The relation between edge surface roughness and fatigue life has been studied. Grinding process gives a movement of S-N curve to the right, and improves the fatigue strength of the steel under study. The best improvement in fatigue resistance is obtained by polishing, where the fatigue life has been increased by 150% of the fatigue life of specimens prepared from the as-received steel sheet. The fatigue life is considered as the number of cycles to cause failure.*

INTRODUCTION

Fatigue failure had been considered an important problem that can produce sudden fracture of components and machine members, and causes financial and personal disasters. Therefore, the improvement of fatigue resistance of materials has taken a considerable importance (Weibull, 1961).[1]

The term "surface" , as used here, has the connection of a layer of finite depth, usually small compared with the thickness of the fatigue test sample. Each of the numerous surface treatments establishes a characteristic state of residual stress in subsurface layer. From a somewhat simplified viewpoint, the capacity of this stressed layer to affect the fatigue life of the part depends on the sign of the residual stress, and the fact that the applied tensile stress will be maximum on the surface, decreasing toward the centre.

The residual stress is always algebraically subtracted from the tensile strength of the material in arriving at an allowable fatigue strength, thus the benefit of residual compression is related to its minus sign.[2]

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In addition to the compressive residual stresses caused by grinding and polishing, there is a removing of surface irregularities, partially or completely. Some previous researchers[2,3,4&5] have studied the influence of surface finishing on the fatigue life of materials by means of surface roughness. In the present work, the edge roughness was the considerable point in fatigue results comparison.

Similar investigations were made by Lai & Nee[6] on the improved fatigue life of holed flat specimens made from medium carbon steel, using reaming, ballizing, and emery polishing processes. Polishing is, generally, found to give the longest fatigue life, while ballizing generates the shortest life.

EXPERIMENTAL TECHNIQUE

The material used in the present study was SAE 1005, a low carbon steel sheet that has wide applications in the industries, because of its suitable mechanical properties, which is used in manufacturing of 35–75 litres water boilers in one of the indudstrial factories. A typical chemical composition is 0.056 percent, C, 0.1 percent, Si, 0.236 percent, Mn, 0.007 percent P, and 0.009 percent S. The microstructure of the mentioned steel is viewed where the planes of figure and rolling are perpendicular to each other (Fig. 1).

Ninety rectangular specimens (170x29 mm) were cut from a single stock of 2 mm steel sheet in ordinary climate conditions, i.e., temperature of 25°c and humidityh of 30%. Difference in surface finish of

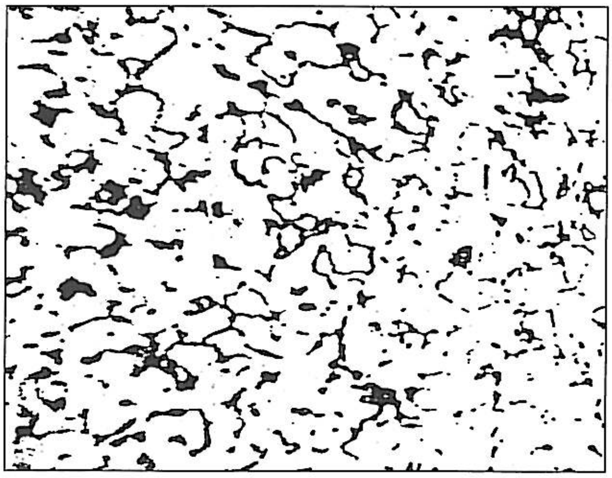

Fig. 1. The microstructure of SAE 1005 steel sheet. 2% nitric acid diluted in alcohol (x200).

speciments edges was achieved by grinding machine and elc. polisher. For each specimen tested by fatigue machine, the surface roughness of each edge was measured, where calculations involved the centre line average (Ra), average roughness depth (Rz), and maximum roughness depth (Rmax). Figure 2 represents the indication of one of the roughness tests which were carried out.

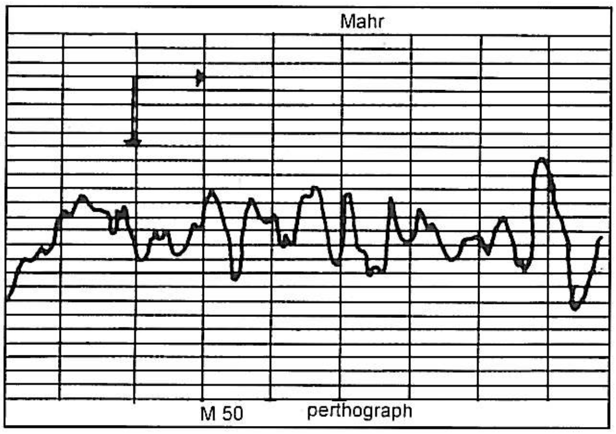

Fig. 2. Sample of roughness measurement indication.

RESULTS AND DISCUSSSION

The influence of edge surface roughness on the fatigue life of the steel under study is shown (Fig. 3).

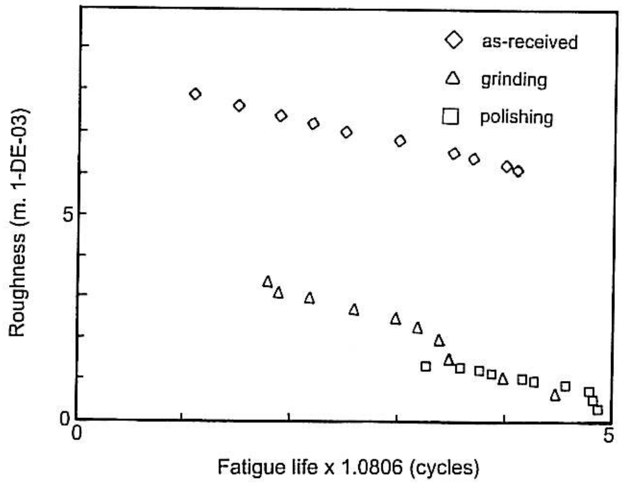

Fig. 3. Sample of roughness measurement indication.

The range of roughness of the polished specimens is between 0.5–1.5 μm and for the grinded specimens is about 0.8-3.5 μm, while the edge roughness of the as-received (unfinished) specimens is about 6.5–8.1 μm. There is an obvious effect of the surface roughness on the fatigue life where there is an adverse relation between roughness and fatigue life. There is a small difference in fatigue life between the as-received and ground specimens, because of very close surface finish, so that the crack initiates after small difference of cyhcles life of the two types. In the present study, the polishing process gives a larger effect on the fatigue life than its effect in Lai & Nee's study.

In the present work, the fatigue life increased by polishing at a fatigue percentage approaching 150%, while that of the above mentioned investigators is about 120% of fatigue life of the as-recived specimens.

Figure 4 shows the effect of high-precision grinding and polishing processes on the S-N curve of the steel under study. In case of grinding, the curve is shifted to the right with higher magnitudes of fatigue strengths of the tested specimens under the same conditions. While in case of the tested specimens under the same conditions. While in case of the polished specimens there is an emphasis in shifting and fatigue strength improvement.

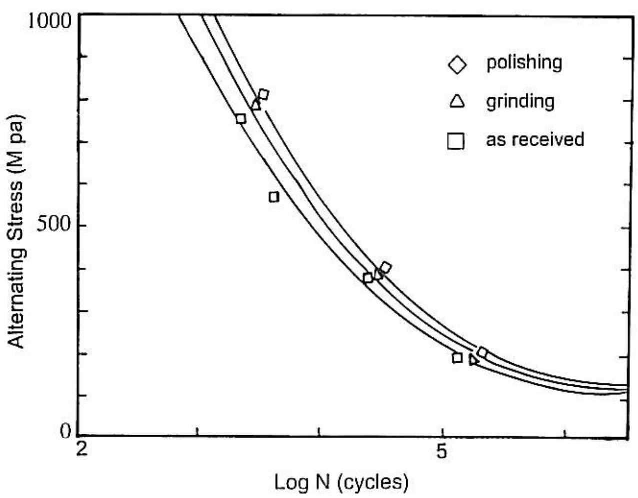

Fig. 4. The effect of grinding and polishing on the S-N curve.

Fatigue crack initiation has been superintended, for the fatigue tests which experienced by the plane bending fatigue testing machine. For the as-received specimens, the crack initiates after 30–50 percent of the number of cycles of crack initiation of the grinded specimens, and it initiated after 20–35 percent of that of polished specimens. The diversity of the obove notes of crack initiation is due to the removing of edge surface irregularities (which act as stress raisers) by surface finishing processes, where fatigue crack initiates at the surface and propagates at core region.[7]

CONCLUSIONS

1- The lowest values of edge surface roughness could be obtained in case of polished specimens, which had been approached 0.5 μm.
2- Polishing process improves the fatigue of SAE 1005 steel sheet by 150 percent of the as-received specimens fatigue life.
3- The S-N curve of the grinded specimens has been shifted to the right, and fatigue strength increased. These effects have appeared obviously in case of polished specimens.
4- The fatigue crack of the as-received specimens was initiated after 30–50 percent of the number of cycles of crack initation of the grinded specimens, while it initiated after 20–35 percent of the polished specimens crack initiation.

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