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ON THE ANALYSIS OF RESIDUAL STRESSES BY RING CUTTING METHOD

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Abstract. The semidestructive methods of a residual stress analysis, i.e., the hole drilling and the ring cutting are very often used up today. Particularly the ring cutting method have been strenuously developed during the last fifteen years, (1-3). Differences, which occur between obtained results, are discussed. Studied methods of working up of holes and rings and stereoimage technique of the strain measurement are analyzed. An especial attention is devoted to the theoretical stress analysis in the central column after releasing of residual stresses

Key words: stress, strain, residual, state, analysis

Introduction

The ring cutting method is the semidestructive mode of a residual stress analysis, which was intensively studied during the last fifteen years. (1-3). The principal of this mode of determination of residual stresses lies in their releasing near a worked hole or inside a worked ring and in a measurement of induced strains. An evaluation of residual stresses from measured strains needs to introduce into the stress analysis some model, which must assume s a whole change of strain and stress states due to a drilling the hole or a cutting the ring. This point of view is important at a comparison of results from both methods. To obtain reasonable results, it is necessary to have in mind following assumptions in a process of a determination of residual stresses.

1/ Releasing of residual stresses must be the elastic process only and no further residual stresses may origin during it.
2/ Measurement of strains which origin due to the releasing of residual stresses must preserve the original character of the stress-strain state, which may differ by a constant multiple value only.
3/ Calculation of stresses must take into account the real state of stresses around the hole and in the column inside the ring.

The foregoing assumptions are mostly fulfilled approximately.

The working up of holes and rings

A working up procedure of a drilling the hole or a cutting the ring is strongly influenced by a tested material. Special high-speed drills are used for a hole drilling of standard metals. The working up of holes or rings into hard metals can be carried out carefully by electroerosive technology. Diamond tools, drills or drilling tubes, must be used for making a hole or a ring in

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a glass, ceramics or concrete. The laser beam cutting have been tested also. It gave good results with regard to a form, but with regard to the temperature influence, at a low power, hasn't been applicable. The non-elastic deformations around the hole or ring edge are possible to detect microscopically.

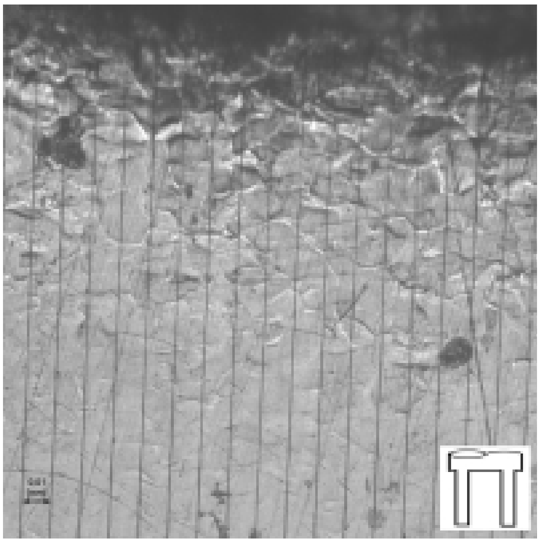


Fig. 1. The carbon steel specimen with the ring drilled by the diamond tube. On the edge of the ring the grain boudaries rise above.

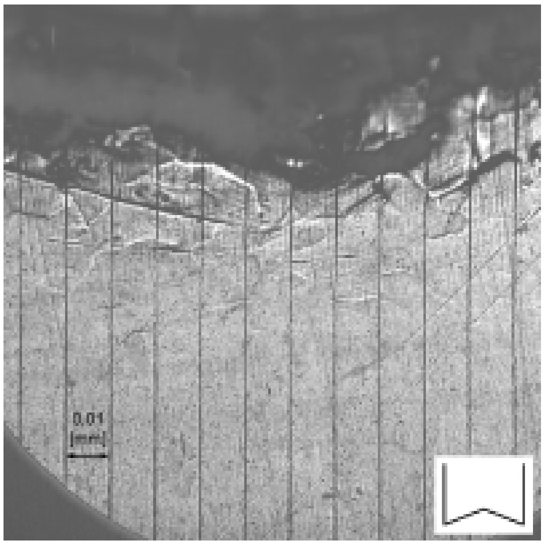


Fig. 2. The carbon steel specimen with the hole drilled by special drill with the tip showed in the right corner. On the edge of the hole the grain boudaries rise above

Analysis of microscopic images of the surface of the specimens tested by cyclic loading showed on the special kind of deformation near the edge of the fatigue cracks. The grain boundaries, which rise above the surface of the specimens due to the cyclic loading, were watched by optical microscope also near the edges of cuted specimens. Next two figures show the surface morphology near the edge of the ring drilled by diamond tube (Fig.1) and near the edge of the hole drilled by special drill (Fig.2) used for residual stress analysis.

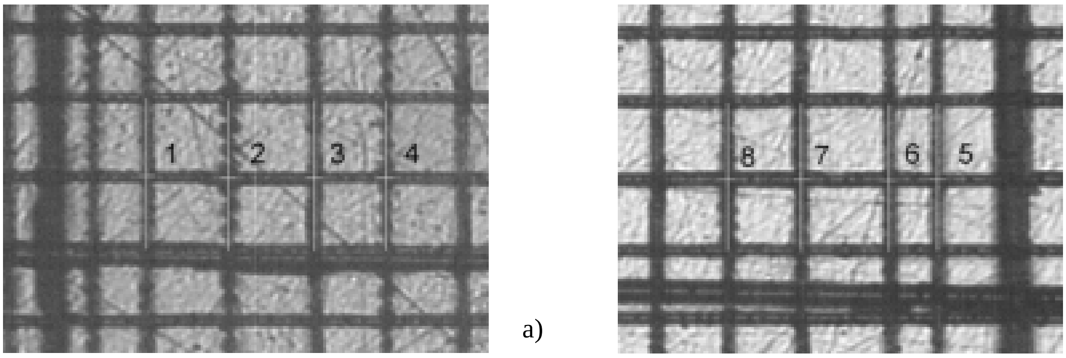
The strain measurements

The strain-gages rosette carries out the measurement of strains at the hole drilling method. The measured data express two-dimensional state of strains only and from them is impossible to do a deduction about the concentration of stresses around the hole. Also other techniques – interferometry were used also for a measurement of strains. Both methods have been used for strain measurement at the ring cutting method, but with a special arrangement (2,3). The stereoimage technique is used to this application by us and some problems arise with it to reach a high level of accuracy. This method needs to have on the specimen surface a very fine grid, which images taken before and after deformation serve to their comparation and computation of in plane strains.

The accuracy of a digital comparation of both images is limited by 1 pixel and this accuracy is possible to reach when both images have the same quality, i.e., they are practically identical. This requirement needs to form on a surface of the specimen enough hard and shiny layer into which a fine grid could be mechanically cut. The nickel layer was electrochemically deposited on the surface of tested steel specimens, which were processed by grinding and shot peening.

The size of a chip of CCD camera, in pixels, which is used for taking of measuring microscopic images is the parameter determining the accuracy of measurements of strains. The rate 1/d, where d is a lower size of the chip in pixels, is the maximal error, which can be reached. Our microscope ZEISS Neophot 21 is equipped by digital camera Praktica Scan

2000. Its images have the size 3600x4400 pixels and the theoretical accuracy of strain measurements is $\Delta\varepsilon = 1/4400 = 2,3.10^{-4}$.



a) b)

Fig. 3. The microscopic image of the grid on specimen surface, magn. 65x, record by Praktica Scan 2000, chip size 3600x4400. Image before – a) and after – b) a cutting the ring.

The analysis of stresses

If the hole drilling and the ring cutting semidestructive methods of residual stresses are compared, then two different resulting states of strains and stresses must be assumed. While at the edge of the hole in a tension strip is the stress state in polar coordinates expressed in the form.

$$\sigma^{h}_{r,x} = \frac{\sigma_x}{2}\left(1-\frac{a^2}{r^2}\right)+\frac{\sigma_x}{2}\left(1+\frac{3a^4}{r^4}-4\frac{a^2}{r^2}\right)\cos 2\varphi$$

$$\sigma^{h}_{\varphi,x} = \frac{\sigma_x}{2}\left(1+\frac{a^2}{r^2}\right)-\frac{\sigma_x}{2}\left(1+\frac{3a^4}{r^4}\right)\cos 2\varphi$$

The stress state of the circular plate – the circular region inside the ring, loaded by the one-dimensional tension is in polar coordinates express by the formulas

$$\sigma^{p}_{r,x} = \frac{\sigma_x}{6}\left[\left(2+5\frac{r^4}{a^4}\right)+\left(-2+15\frac{r^4}{a^4}\right)\cos 2\varphi\right]$$

$$\sigma^{p}_{\varphi,x} = \frac{\sigma_x}{6}\left(2+\frac{r^4}{a^4}\right)(1+\cos 2\varphi)$$

Conclusion

The stresses course around the hole edge and around the plate edge are different. The solutions show that stress states around the hole so around the ring are not homogenous with regard the angle φ. The stress concentrations, which there occur, are impossible to measure.

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