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DIFFRACTION DIAGNOSTICS OF SURFACE RESIDUAL STRESS DISTRIBUTION ON GUIDE GIBS

DIFRAKČNÍ DIAGNOSTIKA DISTRIBUCE ZBYTKOVÝCH NAPĚTÍ NA POVRCHU VODICÍCH LIŠT

Abstract

The goal of the contribution is to present a comparative X-ray diffraction analysis of the state of surface residual stresses on guide gibs for machine tools. Results of measurements on three types of samples from the steel 11 375.0 prepared by milling, grinding, and scraping are presented. Macroscopic residual stresses were determined by using one-tilt X-ray diffraction technique without any reference substance. An imaging plate was utilised for detection of diffracted CrKα radiation. Residual stresses were measured at 14 places lying on a grid covering the machined surface. Three kinds of measurements with different irradiated areas and their orientation were performed. It was found that the individual machined surfaces could be characterised by qualitatively different states of microscopic residual stresses. By analysing the chosen grids of the measured places it was proved that in all the cases under investigation the fields of surface stresses were inhomogeneous. The degree of inhomogeneity was assessed with respect to experimental inaccuracy.

Abstrakt

Předmětem příspěvku bude srovnávací difrakční tenzometrická analýza stavu povrchové zbytkové napjatosti tvarových lišt pro obráběcí stroje. Jsou prezentovány výsledky získané z měření na třech typech vzorků z oceli 11 375.0 připravených frézováním, broušením a zaškrabáváním. K rentgenografickému určení makroskopických zbytkových napětí byla zvolena metoda jedné expozice bez referenční látky s detekcí difraktovaného záření na paměťové fólii. Na zkoumaném povrchu byla zvolena síť 14 měřených bodů. Byly realizovány tři typy měření s různou velikostí a orientací ozářené oblasti, které ukazují, že jednotlivé zkoumané povrchy se charakterem zbytkových makroskopických napětí kvalitativně liší. Na základě proměřování zvolené sítě míst lze rovněž soudit, že pole povrchových zbytkových napětí je u všech vzorků nehomogenní. Míra homogenity zkoumaných povrchů je posuzována s ohledem na experimentální chybu měření.

1 INTRODUCTION

Residual stresses (RS) are one of the most important attributes of surface layers. They are formed in bodies of random composition as a result of the acting of external forces, thermal fields, phase transformations, etc., either directly or indirectly, as a result of inhomogeneous deformation,

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e.g., during the already mentioned surface finishing of machine parts and structures. If the residual stresses are known, it will be possible to predict operational reliability of mechanical parts and to choose such surface treatment that would result in creating a compressive pre-stressed layer acting as a barrier to prevent crack propagation into the material. Therefore, analysing residual stresses as part of material diagnostics is of the same importance as classic material testing methods, such as determining strength, impact hardness, hardness, resistance to abrasion and corrosion, etc.

X-ray diffraction methods represent a well developed tool for investigation of residual stress fields in metallic materials and engineering ceramics [1]. Due to the limitations of X-ray penetration depth, the X-ray diffraction technique can be used only for surface layers few micrometers in thickness. In the case of conventional X-ray diffraction equipment, investigation of stress depth profiles is performed in combination with electrochemical etching [2].

2 EXPERIMENTAL

2.1 Samples under investigation

Three types (*A*, *B*, *C*) of samples from the steel 11 375.0 without any heat treatment were measured. Semiproducts were cut by using an acetylene jig-burner. After that, final function surfaces of dimensions 160 × 51 mm^2 (Fig. 1) were prepared by milling (*A*), grinding (*B*), and scraping (*C*).

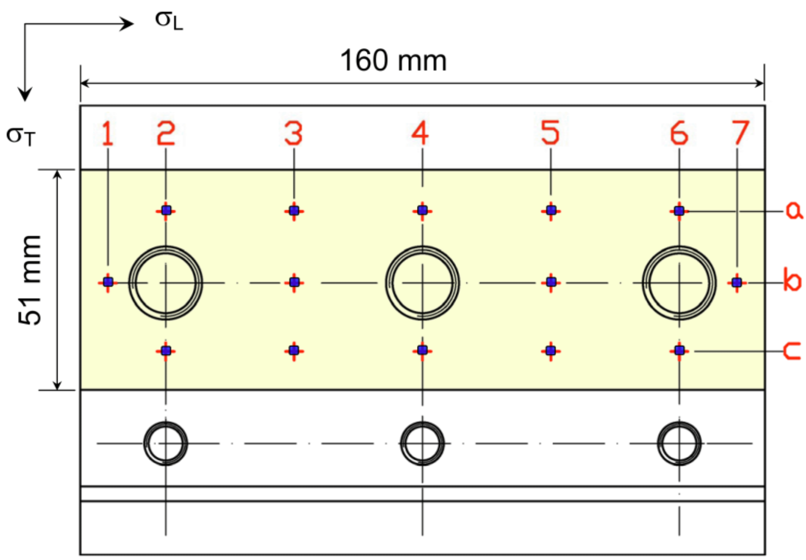

Fig. 1 Scheme of the measured surface 160 × 51 mm^2 on samples with marked directions of stress determination $\boldsymbol{\sigma_L}$, $\boldsymbol{\sigma_T}$ and the grid of measured points. The figure illustrates the irradiated area in the case of ***static measurement***.

2.2 Experimental arrangement

The incident *CrKα* beam directed by a cylindrical collimator of 1.7 mm in diameter impinged the sample surface at an angle of ψ_0 = 45° in the longitudinal and transversal direction, in which the surface components $\boldsymbol{\sigma_L}$, $\boldsymbol{\sigma_T}$ were analyzed. The record of the *{211} α-Fe* diffraction line intensity curve was obtained from a position sensitive detector based on imaging plates. The X-ray elastic constant $\frac{1}{2}s_2 = 5.76 \cdot 10^{-6}\ N^{-1}m^2$ was used in residual stress calculations [1].

Residual stresses were measured at 14 places lying on a grid covering the machined surface (Fig. 1). Since the used arrangement does not allow enlarging the irradiated area substantially, all the measured values have local character. In order to study inhomogeneities of surface stresses, the samples were placed on a table enabling a sample translation ± 5 mm around the grid points (Fig. 1) during exposition. Three kinds of measurements with different irradiated areas and their orientation were performed, i.e., ***static measurement*** – without any sample movement, ***L-measurement*** and ***T-measurement*** – with translation ± 5 mm in the $\boldsymbol{\sigma_L}$ and $\boldsymbol{\sigma_T}$ direction around the grid points respectively.

3 RESULTS

Back reflection patterns taken from all the three investigated samples before the stress measurements proved that the polycrystalline surface real structure is fine-grained and isotropic. The following Figs. 2 – 4 illustrate distributions of obtained residual stresses on the three studied surfaces *A*, *B,* and *C* when ***static measurement*** was applied.

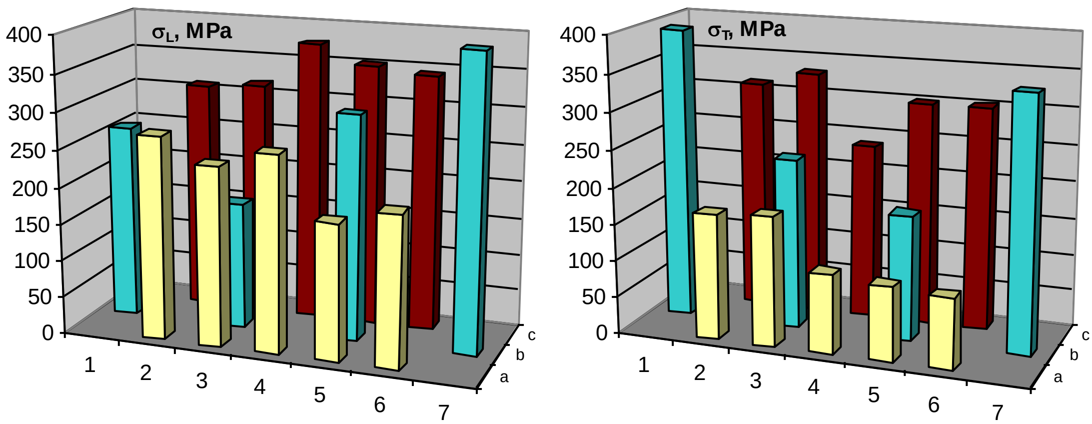

Fig. 2 Stresses σ_L, σ_T on the surface *A* obtained by static measurement.

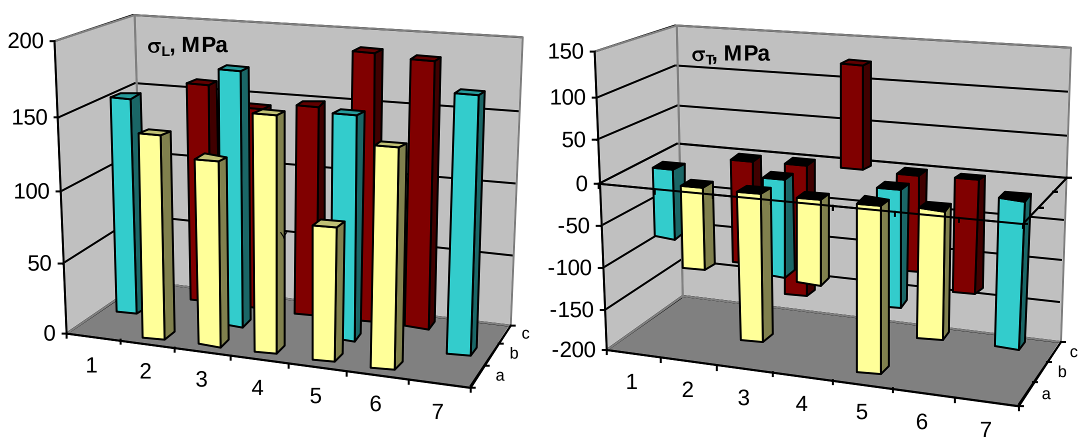

Fig. 3 Stresses σ_L, σ_T on the surface *B* obtained by static measurement.

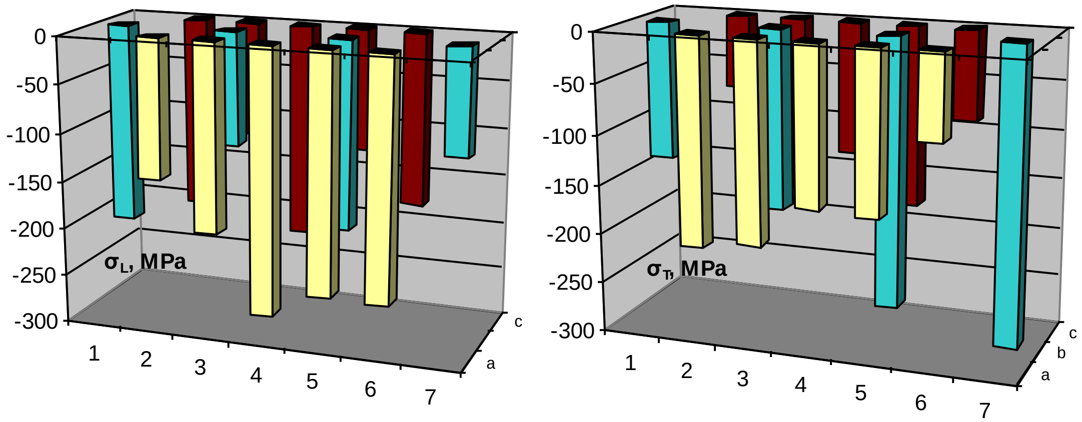

Fig. 4 Stresses σ_L, σ_T on the surface *C* obtained by static measurement.

4 CONCLUSIONS

The obtained results of X-ray diffraction residual stress measurements allow us to draw the following main conclusions:

- The individual machined surfaces could be characterised by qualitatively different states of microscopic residual stresses.
  - In the case of the milled sample *A* both the measured stresses σ_L, σ_T are tensile as a result of prevailing thermal processes during milling.
  - Since the ground surface *B* displays tensile stresses σ_L in the direction of machining, the values σ_T in perpendicular direction are compressive.
  - In both the analyzed directions of the scraped surface only compressive residual stresses were found. This is evidence of the predominant effect of plastic deformation accompanying surface scraping.
- Taking into account the experimental inaccuracy being approx. 40 MPa, it is evident from Figs. 2 – 4 that residual stresses obtained in grid points are inhomogeneous on all the surfaces.
- Evaluating stress inhomogeneities when all three kinds (***static measurement***, ***L-measurement*** and ***T-measurement***) are performed it could be stated that the milled surface (*A*) has the lowest degree of stress homogeneity. The stress non-uniformity of samples *B* and *C* decreases with increased irradiated area in the case of ***L-*** and ***T-measurements***.

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