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POSSIBILITIES OF RESIDUAL STRESS MEASUREMENT IN DIFFERENT MATERIALS BY THE HIGH-SPEED HOLE DRILLING METHOD

MOŽNOSTI MĚŘENÍ ZBYTKOVÝCH NAPĚTÍ V RŮZNÝCH MATERIÁLECH VYSOKORYCHLOSTNÍ ODVRTÁVACÍ METODOU

Abstract

A hole-drilling residual stress measurement method is one of the most frequently used methods. Theoretically, this method is usable for different materials independently of their thermal and electrical conductivity, magnetic properties, crystalline structure etc. However, the measured material should be drilled out without producing any additional residual stresses. The drilling process influences significantly practical utilization and measurement accuracy of the hole-drilling method. This contribution is focused on the high-speed hole-drilling method with expected negligible additional residual stress production. Possibilities of the method usage are discussed from the point of view of the drilling process. An influence of a suitable drilling mill selection and an influence of measured material properties on the measurement accuracy are discussed. Measurement examples of hole-drilling residual stress analysis of different materials (cast iron, cermet, plastics and steel) are shown.

Abstrakt

Odvrtávací metoda je jednou z nejčastěji používaných metod pro měření zbytkových napětí. Touto metodou lze teoreticky měřit zbytková napětí na nejrůznějších materiálech, nezávisle na jejich vodivosti, magnetických vlastnostech, krystalické struktuře apod. Její praktické použití a přesnost měření jsou ovšem výrazně ovlivněny možností odvrtání materiálu bez vnesení přídavných zbytkových napětí. Práce se zaměřuje na vysokorychlostní odvrtávací metodu, u které se ve většině případů předpokládá minimální ovlivnění materiálu. Jsou diskutovány možnosti použití metody pro různé materiály z hlediska procesu odvrtávání, výběr vhodné odvrtávací frézy a vliv vlastností materiálu na přesnost měření. Jsou uvedeny příklady měření zbytkových napětí na čtyřech různých materiálech – na vzorcích z litiny, cermetu, plastu a oceli.

1 INTRODUCTION

The hole-drilling method [1] is one of the most often used residual stress measuring methods. It is based on a drilling of a small hole into the measured surface that causes an original residual stress relieving. The stress relieving is accompanied by a deformation near the hole. This deformation is measured and subsequently used for the original residual stress evaluation. The method makes it possible to measure a macroscopic residual stress in a sample surface plane and residual stresses depth-changes. The method resolution and maximum evaluation depth depend on an individual measurement configuration. It is applicable for a wide range of materials independently on their physical properties, only the Young's modulus and Poisson's ratio are needed. The method is not suitable for in-plane stress gradients measurement or for inhomogeneous materials, where the in-homogeneities size agrees with the method resolution.

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End-milling cutters are used for the hole drilling in most cases and the relieved deformations are mostly measured by resistive strain gauges [2]. A high-speed drilling is the preferred drilling technique, because it is assumed of a negligible influence of the drilling process on an original residual stress in a measured sample. A drilling mill is mostly driven by an air-turbine of the speed about 300 000 rpm. Using of a suitable mill type and drilling parameters to drilling an exactly defined hole without producing of additional residual stresses in a measured sample is crucial for precise and repeatable measurements.

2 USING OF THE HIGH SPEED HOLE-DRILLING METHOD

Practical usage of the hole-drilling method is limited above all by capability to drill an exactly defined hole without producing of additional residual stresses. This limitation is especially important in the case of high-speed hole-drilling method. The mill speed is up to 300 thousand rpm, however, the torque is low and higher cutting forces can broke the drilling process. It is possible to influence the drilling process by using of a suitable mill and partially by the mill axial feed speed.

Four different material types were analyzed to compare and discuss possibilities of the high-speed hole-drilling residual stress measurement method: cast iron, cermet, plastic and steel. All the measurement were performed using commercial residual stress device HBM SINT MTS3000.

2.1 Cast iron

Cast iron belongs to brittle, homogeneous and good machinable materials. Standard tungsten-carbide (T-C) mills or T-C mills with TiN coating can be used to produce a good quality hole of required depth about 0.6-0.7 mm. Drilling problems connected with a mill wear can occur after drilling out of this depth. In Fig.1 a) there is shown an example of relieved strain during drilling of a cast iron sample. The strain profiles are smooth and also the residual stress evaluation scatter obtained by repeated measurement on one sample is low. It shows that good defined and precise drilling makes it possible a good repeatable measurement.

a) **Cast iron sample** b) **NiCrBSi sample**

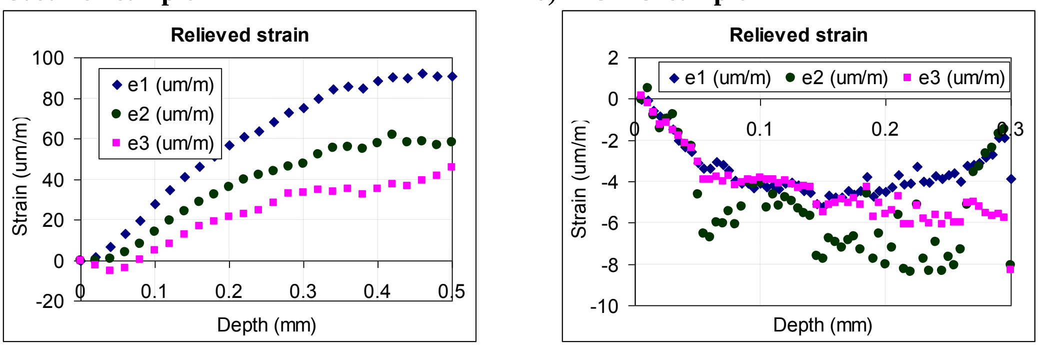

Fig.1 An example of relieved strain depth profile (T-C mill) on cast iron sample (a) and relieved strain depth profile (diamond mill) on NiCrBSi sample (b).

2.2 Cermets

Cermets are hard, wear resistant, composites (ceramics-metal). Drilling of such materials is practically impossible using a standard mill driven by an air turbine. The mill wear is too fast and the drilling process is broken after a few steps. However, it is possible to drill cermet samples using diamond mills. In Fig.1 b) there is shown an example of relieved strain during drilling of NiCrBSi coating produced by high velocity oxygen fuel spraying technology. The relieved strains show that the drilling process was unstable. A microscopic analysis revealed that the walls of the hole were not perpendicular and the sample material was sunk into the mill instead of drilling in the mill center. It is caused by an inhomogeneous material structure and too fast mill wear. An accuracy and repeatability of the measurement is worse in this case than by the cast iron residual stress measurement. However, other experiments show, that better results could be obtained in some cases - for example on cermet samples produced by sintering technology, although their hardness exceeds the hardness of cermet materials produced by thermal spraying.

2.3 Plastics

Plastics are soft and formative materials, which have mostly low melting point and low thermal conductivity. The temperature at the mill-sample contact rose rapidly during drilling experiments after a few steps and the drilling process was broken. The temperature rise indicated an intensive plastic deformation. Subsequent microscopic analysis showed, that the mill deformed the sample and it was pushed in the sample instead of its drilling. Despite of drilling axial feed speed modification it was unable to drill out the plastic sample using this technology. The drilled material is shown in Fig.2 a).

a) b)

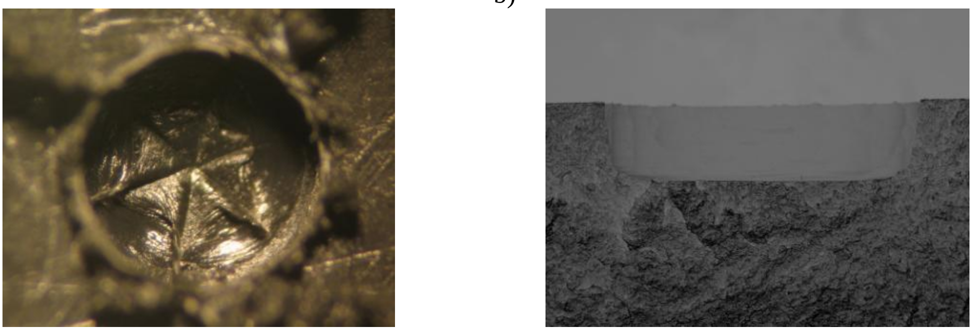

Fig.2 The hole created into plastic sample (a) and the hole drilled into a steel sample (b) by high-speed drilling using a T-C mill.

2.4 Steel

Steel is one of the most often used and most important technical materials. Steel properties are strongly influenced by added agents and its heat treatment. It can be "soft" and shapeable or hard and ductile in dependence on these factors. Three different steel samples are shown as an example: ČSN 11418 (standard quality carbon steel), ČSN 19436 (tool carbide steel for low temperature applications) a ČSN 19552 (medium-doped tool steel for high temperature applications).

The residual stress measurement on steel ČSN 11418 was fully successful using standard T-C mill. It is shown in Fig.2 b) that the hole was good defined. The residual stress measurement is sufficiently accurate and repeatable similarly as in the case of cast iron samples. The experiments performed with steels ČSN 19436 and ČSN 19552 samples (not quenched) showed, that the standard T-C mill with TiN coating is not applicable for these materials. Therefore, special extra hard drilling mills (SINTCTT) supplied by HBM were used. Both samples were drilled out successfully using these mills. The quenched sample from the steel ČSN 19552 was drilled out successfully using the SINTCTT mill as well, but next experiments showed that this tool is not applicable for the quenched steel ČSN 19436. Diamond tools are generally not suitable for steel. However, the quenched sample from steel ČSN 19436 was drilled up to desired depth using this tool. Other experiments showed that the diamond mill is not applicable for the sample from the steel ČSN 19552. A small mill wear after drilling out of the steel ČSN 19436 sample and fully worn mill after drilling of the steel ČSN 19552 sample are shown in Fig.3.

a) b)

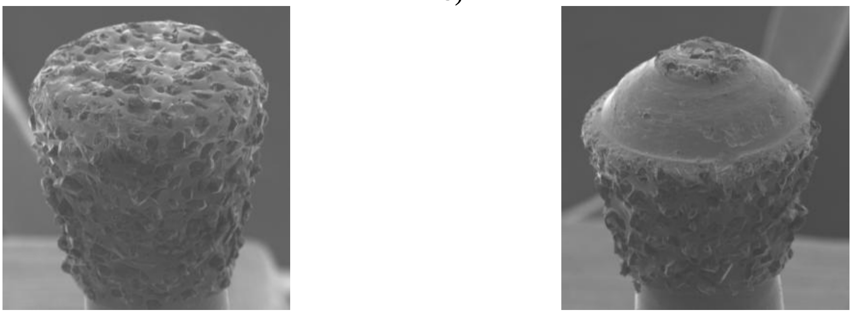

Fig.3 Diamond mill after a drilling of a quenched steel ČSN 19 436 (a) and steel ČSN 19 552 (b)

It can be summarized, that for both tool steels before quenching can be used the high-speed hole-drilling method and the measurement can be accurate and repeatable enough. Drilling of both materials after their quenching is more complicated and also the measurement accuracy and repeatability is worse. However, if suitable drilling mill and parameters are used, it is possible to measure residual stresses also in these materials using the HBM high-speed drilling device.

3 CONCLUSIONS

The presented examples show that the high-speed drilling residual stress measurement device is suitable for an analysis of standard metal materials, for example cast iron or some steels. The common T-C mills or T-C mills with TiN coating are usable for these materials. The relieved strain profile is smooth and the measurement is accurate and repeatable. Hard and brittle materials (cermets for example) could by drilled efficiently by the diamond mills. However, the structure of the materials can influence the results repeatability and the results quality could be lower in some cases. The diamond mills could be used also for some kinds of steels. In some cases, when neither the T-C or diamond mills are suitable, the special SINTCTT mills could be used. The HBM measurement device seems not to be suitable for plastics.

The examples used in this contribution show some limitation of the high-speed hole-drilling residual stress measurement technique dependent on measured material properties. The choice of suitable drilling tool and drilling parameters can influence the results quality. In some cases, a classical low-speed drilling technique could by used (electrical drilling device). It would make it possible to use this method also for plastics or to drill hard steels by standard T-C mills. However, this way is disputable from the point of view of an influence of the drilling process on original residual stresses in the measured material. Despite of described problems, the high-speed hole-drilling method is one of the most universal residual stress measurement methods.

ACKNOWLEDGEMENT

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