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Measuring of the Plastic Deformation by Non-Destructive Method PIDAC

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Abstract: Measuring of the plastic deformation over short distances by non-destructive method is explored in this paper. PIDAC method (Predictive Instant Defect Analysis of Constructions) is based on exact indication of defined distance change between two micro tips made from hard metal, which resist to high temperature, corrosion and abrasion as well. Distance is mechanical imprinted into an indication specimen and measured by microscopy analysis. Example of experimental measurements is also described in this paper.

Keywords: Non-Destructive Test; Plastic Deformation; Microscopy; PIDAC; Distance Change.

1 Introduction

Predictive Instant Defect Analysis of Constructions (PIDAC) offers non-destructive test (NDT) technology for the precision measurement of permanent strain, with measurement accuracy of higher than ±0.01 mm on short distances [1]. PIDAC is an extremely precise, fast and inexpensive way to monitor the mechanical integrity and safety of infrastructure and machinery. The measurement can be carried out as frequently as required to determine when and if the structure has exceeded its safety limit.

The technology solves the problem of measuring permanent (non-elastic) length deformations of various materials using reference signs on the materials and a simple device for measuring the distance between reference marks. The technology offers indirect, non-destructive, yet extremely accurate measurement of linear strain in a wide range of materials. PIDAC is ideal for use in places that are not commonly accessible or that are only accessible with much difficulty, such as underwater, extreme temperature environments (from -200 °C to 1100 °C), and also in high elevations, such as bridges.

PIDAC also offers the capability of predicting catastrophic failure due to the breaking, tearing, or deforming of materials. PIDAC is ideal for failure prevention, fatigue evaluation, risk management, inspection, and rehabilitation in engineering departments such as oil and chemical industries, nuclear plants, aerospace industry, construction and utilities industries, Automotive and general machinery manufacturing, marine industry or Seismic damage assessment agencies.

Measuring length deformations in loaded/mechanically strained metallic structures and machinery has typically been carried out using mechanical or optical extensometers measuring the material stretch between two fixed points on a structure. To achieve the required results, however, these extensometers require placement of measuring points on the materials or structures with a larger spacing because of their limited accuracy. For the ascertainment of efficacy measurement method PIDAC was compared with the methods of measurement by strain-gauge extensometer. This measurement was performed continuously during the loading and so that the test specimen was fixed (by blades) on strain-gauge sensor with a resolution (sensitivity) of 0.1 microns. The comparison of these two methods is seen that differences in the measured values of the relative deformation are on relatively low level (± 7 %) and the results can be evaluated as comparable [1].

2 PIDAC

Method, enables exact monitoring of plastic deformation especially in extreme conditions, is based on exact indication of defined distance change. The applied micro tips are made of hard metal so they resist to high temperature, corrosion and abrasion as well. Distance is measured by mechanical imprint into an indication plate, having a lower hardness than said tip, at the beginning and after series load test are done.

2.1 Measuring Device

The Measuring device includes three main parts.

- *Fixed measuring element* consists sintered tungsten carbide with tetrahedron shape (the axial length of 4 mm and 3 mm in diameter, at one end ground to a quadrangular pyramid with an apex angle of about 130 °C), which is inserted into the electrically conductive capsule. Against being pulled or rotated around its axis tip is secured in a deliberately created slight gap between the inner diameter of capsule and the outer diameter of the tungsten carbide by inorganic sealant. This sealant is composed of two basic components: the steel micro shavings and corundum dust. Join is cures after a few minutes at about 60 °C and can withstand temperatures up to 1060 °C. Fixed elements are used as measuring points. Two of them are welded to the structure by machinery specialized welding set. Micro tips are welded by electric discharge 0.002 s on monitored part of construction in the distance between 1 and 2 cm.

Fig. 1: Sintered tungsten carbide with tetrahedron shape in electrically conductive capsule.

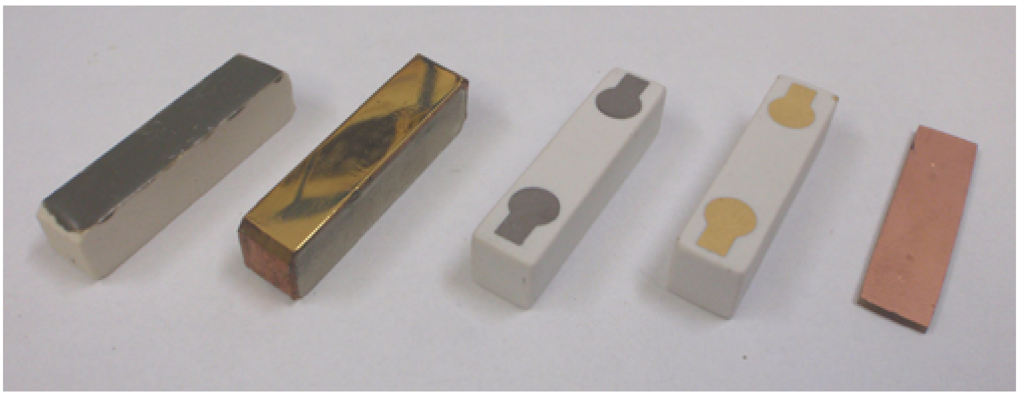

Fig. 2: Impression piece (from left: plastic, gold, titanium, gilded titanium and copper).

- *Impression pieces* made from a ceramic material (8 mm × 8 mm × 40 mm) with a very low thermal expansion coefficient to avoid the changes in the temperature of the impression piece. It has been tested several kinds of impression bodies with different surface finishes (plastic, gold, titanium, gilded titanium and copper ...). Some of the pieces had the surface impression mass divided into two parts (number 3 and 4 in Fig. 2) between them is a big gap from heat-resistant material, which makes no the possibility of thermal expansion of the impression material and due to is measurement of distance more precise.

Fig. 3: Spring-operated hammer with impression piece.

- Special *spring-operated* hammer to impact the impression piece against the reference points. The PIDAC hammer is a simple, easily adjustable spring-operated tool that holds the impression piece so the user could obtain tip impressions. The hammer has a button which, when pressed, unleashes the impression piece to the front (driven by the compressed spring). Both tips are permanently attached to the measured surface, so they can be used for measuring as frequently as needed. A great advantage of attachment of the tip to the electrically conductive structure is virtually negligible effect on the structure under tip, which can be among commonly used materials evaluated as effect of manufacturing inaccuracies of this material. In order to determine the size of the notch, caused by welding fixed measuring element, was made a scratch pattern on the axial section also with part of the measured structure. Subsequently, it was made its professional assessment. Due to the continuing discharge 80000 V in time 0.001–2 sec is temperature influence by welding machine practically zero.

Necessary component for analysis of the final data is microscope to determine the length differences between the tip impressions with the possibility to take a picture of the piece with tip impressions [2]. In case of long-term monitoring it is possible to create a strain curve of the monitored element in the given place at the given time. The standard uncertainty of measurement of distances between two imprints with respect to the manufacturing properties of optical microscope, fineness of shift and the focus to the centre of the pyramid imprint can be determined by a qualified estimate at ± 5 microns.

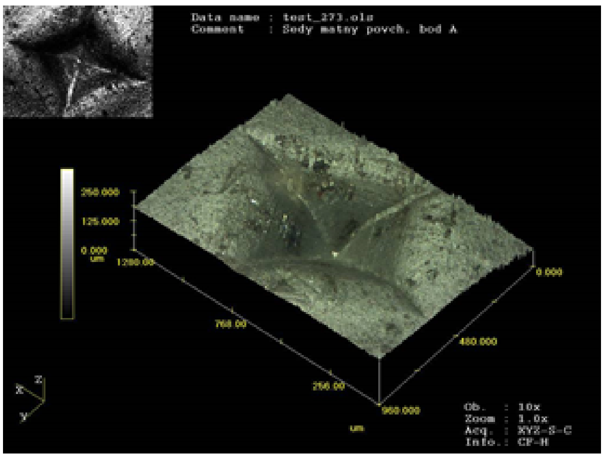

Fig. 4: 3D Detail of imprint of micro tip by microscope.

Fig. 5: Imprint in piece with copper cover.

2.2 Measured Data and Results

Once the impression has been measured, extrapolated, and compared with measurements taken before, a determination of linear deformity can be made. The strain ε [%] was calculated from the measured data according to the Eq. (1)

$$\varepsilon = \frac{(l_1 - l_0)}{l_0} \cdot 100 = \frac{\Delta l}{l_0} \cdot 100 \quad [\%], \tag{1}$$

where l_0 is distance of tips before loading and l_1 is distance of tips after loading.

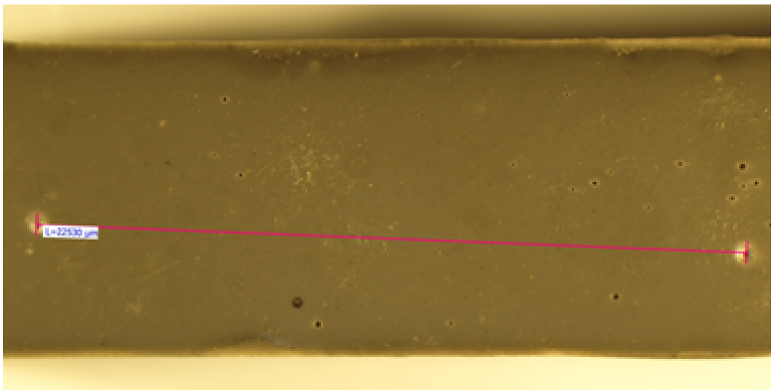

Fig. 6: Microscopy measurement of distance between two imprints.

Measurement of relative elongation can be easily performed even rosette way, if the direction of deformation is needed to know. A pair of tips is welded to an arbitrary planar array (e.g. a circle) and instead of imprint prism is used a circular disk, in which is formed a circular impression hoop. Multiple imprints are done in the same way as previously described.

3 Conclusion

Method PIDAC (Predictive Instant Defect Analysis of Constructions) offers maximum independence and ease of use by employing reference points on the materials and a simple device for measuring the distance between reference marks. The highest possible measuring accuracy is achieved as the actual mathematics and measuring is conducted in situ. Main advantage is possibility of using PIDAC in places that are not commonly accessible or that are only accessible with much difficulty. Method enables exact monitoring of plastic deformation especially in extreme conditions such as bad natural conditions, small manipulation space act. The PIDAC is used in case that wants to enhance the safety and mechanical integrity of metal elements, especially products and structures that are loaded or placed under stress or strain. This includes both producers and users of construction elements, pipelines, aircraft parts, weapons, etc. PIDAC can also be used for the measuring of micro cracks in building structures even below the water surface. Instead of welding tips can be used a special glue hardening under water at temperatures up to -10 °C or more.

Acknowledgement

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