Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 184 (2017) 16 – 21

Procedia Engineering

www.elsevier.com/locate/procedia

Advances in Material & Processing Technologies Conference

Novel Non-Contact Evaluation of Strain Distribution Using Digital Image Correlation with Laser Speckle Pattern of Low Carbon Steel Sheet

N.Mashiwa[a], T.Furushima[b]*, K.Manabe[a]

[a]*Department of Mechanical Engineering, Tokyo Metropolitan University,1-1 Minami-osawa, Hachioji, Tokyo 192-0397 Japan*
[b]*Deptartment of Mechanical and Biofunctional Systems, Institute of Industrial Science, University of Tokyo, Komaba 4-6-1, Meguro, Tokyo 153-8505, Japan*

Abstract

An uni-axial tensile test is one of the general methods to obtain plastic properties for estimating deformation behavior of materials in the simulation of practical metal forming process. Non-contact measurement is generally used because of determination of accurate plastic properties excepting for contact effects. In the conventional method, strain distribution of specimen sprayed with random pattern is measured by digital image correlation (DIC). However, sprayed treatments on the specimen surface is unsuitable under various testing conditions, for example an elevated temperature, micro scale, and large deformation. Thus, non-sprayed specimen is desirable under such test conditions. In this study, we propose perfectly non-contact strain distribution measurement by using DIC with laser speckle pattern generated on specimen surface by irradiation of laser source. True strain in the un-axial tensile test is measured by following methods (1) laser speckle pattern by DIC, and (2) conventional measurement method with tracking gage marks. As a result, strain level measured by DIC with laser speckle pattern has good agreement with that of conventional extensometer. Furthermore, the strain distribution can be measured successfully under uniform and non-uniform deformation during necking by proposed method. Thus, we can verify the validity of proposed measurement method for determination of plastic properties.

Peer review under responsibility of the organizing committee of the Advances in Materials & Processing Technologies Conference

Keywords: Laser speckle pattern; Non-contact; Digital image correlation; Strain distribution measurement; Plastic deformation

* Corresponding author. Tel.: +81-3-5452-6809; fax: +81-3-5452-6809.
E-mail address: tsuyoful@iis.u-tokyo.ac.jp

Peer review under responsibility of the organizing committee of the Advances in Materials & Processing Technologies Conference
doi:10.1016/j.proeng.2017.04.065

1. Introduction

In recent years, metal forming processes becomes more complex such as press working of complex and micro forming. From this background, it becomes more important to obtain accurate mechanical properties of materials. A tensile test is the most commonly method to obtain mechanical properties of materials. There are various contact and non-contact techniques for measurement of surface deformation and strain. For example, strain gage and contact-type extensometer are mentioned as contact techniques. They have some problems like limit of measuring range of strain and restraint of specimen. Especially, in the case of decreasing thickness, restraint of specimen has large effects on measured mechanical properties. Meanwhile, there are Moiré interferometry [1,2], Holography [3], Electronic Speckle Pattern Interferometry (ESPI) [4,5] and Digital Image Correlation (DIC) in non-contact techniques. Raul R et al [2] reported that Moiré interferometry was used to evolution of the deformation process of an aluminum sample subjected to a uni-axial tensile deformation and they were able to identify the area where strains began to localize and to observe the appearance of the diffused necking. In the case of ESPI, strain rate field of semi-hard copper sheet at different loading steps and strain localization onset were obtained accurately by Bruno Guelorget et al [4]. However, these techniques require complex and substantial systems to measure accurately. In constant, nowadays DIC has been used widely as a full-field measurement method that can obtain displacement and strain fields. As a reason for this, firstly, DIC software comes into wide use by development of image processing technology. Secondly, it requires relatively simple experimental setup. In conventional DIC method, specimen surface is painted by spray to generate random speckle pattern in order to determine the displacement and strain field by analyzing the evolution of random speckle pattern on specimen surface captured on images. For instance, Z.T. Xu et al [6] obtained the forming limit diagrams of sheet metals by utilizing these advantage of DIC method. Nevertheless, treatment on specimen surface with paints in conventional DIC method. This treatment can prevent application to some situations such as experiment at elevated temperature and large deformation because of durability of paints. Therefore, non-sprayed specimen is desirable under such test conditions.

Laser speckle pattern formed by reflection and scattering of light is used various fields for measurement. In medical field, Laser Speckle Contrast Imaging (LSCI) is a full-field optical technique to monitor microvascular blood flow with high spatial and temporal resolutions [7]. Besides, in engineering field, S. Seebacher et al [8] reported that determination of material parameters of micro components by using laser speckle pattern and measuring its displacement. However, in these cases, generally, optical setup and procedure of image processing become complication.

From these background, the objective in this study is proposal of novel non-contact evaluation method for plastic deformation that do not required paints on specimen surface. We used laser speckle pattern due to reflected and scattered of coherent laser beam irradiated on surface instead of conventional sprayed pattern. Utilizing this proposed method, strain and strain distribution are measured qualitatively and quantitatively easily under uni-axial tensile test to evaluate plastic deformation.

2. Experimental procedure

2.1. Laser speckle pattern

Fig. 1 shows schematic illustration of formation of laser speckle pattern. Laser speckle pattern is formed on images as result of light distribution when a coherent laser beam irradiated on surface is reflected and scattered by the micro structures on the surface [9]. Most surfaces of object have larger roughness than wavelength of irradiated laser beam. When laser beam irradiates on such surface, scattered light interfere with each other. Surfaces generally have irregularity in surface roughness, so that laser speckle pattern mirrors that irregularity. Because appearance of laser speckle pattern depends on surface condition irradiated laser beam, it represents more reliably deformation of specimen surface. In this study, we use laser speckle pattern instead of conventional sprayed pattern and obtain displacement and strain fields by using DIC.