Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 45 (2016) 79 – 82

www.elsevier.com/locate/procedia

3rd CIRP Conference on Surface Integrity (CIRP CSI)

Development of a procedure to characterize residual stresses induced by drilling

Mathieu Girinon[a],*, Frédéric Valiorgue[b], Joël Rech[b], Eric Feulvarch[b]

[a]*SAFRAN Tech, rue des Jeunes Bois, 78772 Magny-les-Hameaux*
[b] *Univ. de Lyon, ENISE, LTDS, UMR5513 CNRS, 58 rue Jean Parot 42023 Saint-Etienne, France*

* Corresponding author. Tel.: +33477437567; *E-mail address: mathieu.girinon@enise.fr*

Abstract

Modeling residual stresses induced by drilling remains an issue. However, even if some models are under development, their validation is limited by the absence of a universal characterization method of residual stresses inside the hole. This paper aims at presenting a procedure to characterize the residual stress profile induced by drilling. The principle is based on the preparation of a reference sample that has been pre-heat treated in order to remove bulk residual stresses without modifying its microstructure. Then the sample is instrumented with strain gauges before being cut into two parts. This enables on the one hand to estimate the elastic recovery after cutting and on the other hand to provide an easy access to the surface investigated. Finally a standard X-Ray diffractometer and an electropolishing technique are combined to estimate residual stress profiles in two directions (tangential and ortho-radial directions).

Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)
Keywords: Residual stresses; Drilling; Characterization method

1. Introduction

1.1. State of the art

Residual stresses in machining are usually studied [1][2][3], including in milling [4][5] because machined surfaces are easily analyzed.

Drilling has also an important impact on the fatigue life of parts. Here, machined surfaces are confined and do not allow performing a X-ray diffraction analysis in the drilled hole. A XRD analysis can be carried out only on the sample surface [6] or directly in the drilled hole but after the sample has been cut. Nobre and Outeiro [7] use an experimental and numerical method to determine residual stresses in Ti-6Al-4V after drilling but not directly in the drilled hole.

1.2. The aim of this article

The analysis of residual stresses in the drilled hole is usually performed after the sample has been cut. No work characterizes the influence of cutting on residual stresses subsequently analyzed by XRD.

The aim of this article is to present the characterization of residual stresses by a XRD analysis in the case of drilling studies. So the error introduced by sample cutting before a XRD analysis is studied. To do so, strains on the surface of the hole are recorded during the cutting process with glued strain gauges. Then the gradient of residual stresses is analyzed.

1.3. Structure

The studied conditions will be presented beginning by the preparation of samples, thermal treatment and drilling conditions. Four samples are studied in this article under the same conditions.

Strain relaxation during the sample cutting process is studied with gauges. The influence of the unavoidable cut before a XRD analysis is well-determined.

2212-8271
Peer-review under responsibility of the scientific committee of the 3rd CIRP Conference on Surface Integrity (CIRP CSI)
doi:10.1016/j.procir.2016.02.074

Finally the XRD analysis in the drilled hole will be presented and the residual stress gradient in the hole is obtained for four studied samples.

2. Thermal treatment

2.1. Machining and thermal treatment before drilling

The samples are machined; the material used is 316L austenitic stainless steel. The material has undergone several processes with different levels of residual stresses involved.

A thermal treatment is performed to decrease the residual stress level in the material without modifying the microstructure and machining behavior of 316L. The aim is to study only the residual stresses induced by drilling and not historic residual stresses.

A thermal treatment at 610°C maintaining 2h30 is performed on the samples after the machining preparation.

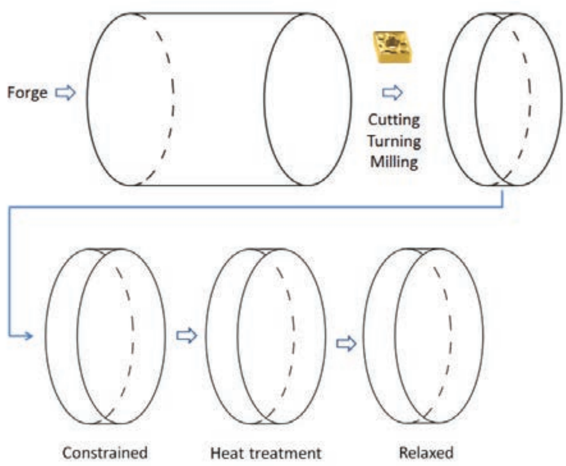

Figure1: Schema of sample preparation

2.2. Thermal treatment validation

To ensure that the thermal treatment is not intrusive, a parallel study has been conducted with other samples.

The total relaxation of residual stresses is impossible because significant hardening occurs during machining. To relax all residual stresses, a higher temperature is necessary but this thermal treatment significantly modifies the material microstructure (recrystallization) and potentially its behavior during drilling.

Residual stresses (Von Mises) analyzed on the sample surface after thermal treatment are around 100 MPa while previous residual stresses were around 700 MPa (as seen in Figure 2).

Finally, the thermal treatment used significantly decreases the residual stresses without modifying the material microstructure.

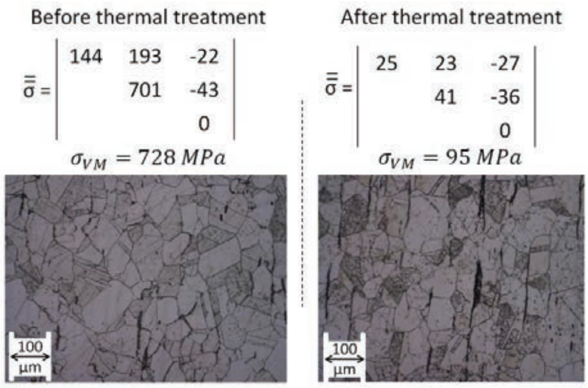

Figure 2: Sample analysis before and after thermal treatment

3. Drilling operation

The samples are dry-drilled with a cutting speed of 25 m/min and a feed of 0.1 mm/rev with a TiN coated drill of 12 mm diameter.

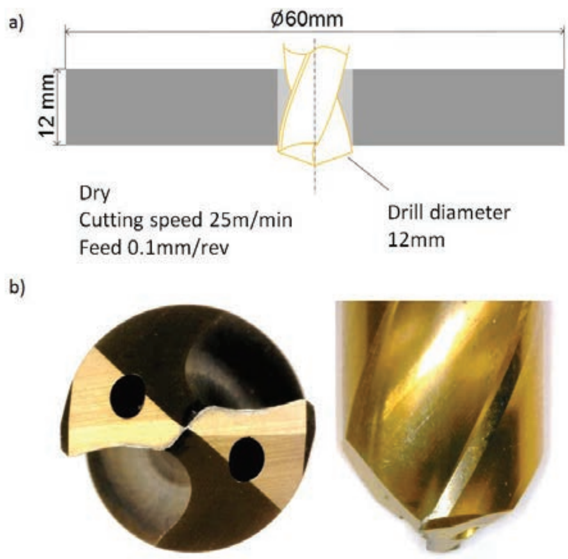

Figure 3: a) Drilling conditions b) Drill used

4. Sample cutting and its impact

4.1. Strain gauge set-up and cutting

The influence of sample cutting on the residual stresses obtained by means of a XRD analysis is studied in this part.

A strain gauge is glued in the drilled hole to record strains during sample cutting and to compare strains before and after cutting. The strains are measured in three directions 0°, 45° and 90°. 45° corresponds to circumferential direction θθ (Figure 4).