Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 46 (2016) 331 – 335

www.elsevier.com/locate/procedia

7th HPC 2016 – CIRP Conference on High Performance Cutting

Influence of machining on the microstructure, mechanical properties and corrosion behaviour of a low carbon martensitic stainless steel

S. Bissey-Breton[a,c], V. Vignal[b,c]*, F. Herbst[b,c], J.B. Coudert[a,b,c]

[a]*CEA Valduc, 21120 Is sur Tille, FRANCE*
[b]*ICB UMR 6303 CNRS, Université Bourgogne-Franche Comté, BP 47870, 21078 Dijon, FRANCE*
[c]*LIMPE (Interaction Matériau-Procédé-Environnement), LRC DAM-VA-11-02, Dijon, FRANCE*
* Corresponding author. Tel.: +33-03-80-39-61-60. *E-mail address:* vincent.vignal@u-bourgogne.fr.

Abstract

The influence of cutting conditions of a low carbon martensitic stainless steel (15.5wt.% Cr, 4.8% Ni, 1% Mo, 0.9% Mn, 0.24% Si, 0.1% Cu, < 0.06% C and 77.46% Fe) on the microstructure is first studied using electron backscatter diffraction and transmission electron microscopy. The mechanical and corrosion behaviours of this stainless steel are then investigated. It was found that the microstructure is significantly affected near the machined surface. The formation of grain sub-boundaries or a refinement of the microstructure is observed depending on cutting conditions. Both lead to an increase of the hardness. In addition, the microstructure refinement yields to a huge increase of the average pit surface area. By contrast the average pit density is not affected by machining conditions.

Peer-review under responsibility of the International Scientific Committee of 7th HPC 2016 in the person of the Conference Chair Prof. Matthias Putz

Keywords: machining; stainless steel; corrosion; mechanical properties.

Peer-review under responsibility of the International Scientific Committee of 7th HPC 2016 in the person of the Conference Chair Prof. Matthias Putz
doi:10.1016/j.procir.2016.04.016

1. Introduction

Machining is used in numerous industrial sectors to produce workpieces with required shape, dimensions, and surface finish (surface characteristics such as roughness and subsurface characteristics such as texture, residual stresses and microstructure). One of the great challenges of modern machining is to optimise surface finish for the increase of the performance and lifetime of workpieces. Numerous experimental studies have quantified the influence of cutting parameters on the surface and sub-surface characteristics of metallic alloys [1,2].

By contrast, only a few experimental investigations have been carried out to study the performance of workpieces machined under different cutting conditions and it would be interesting to link both. This includes the mechanical behaviour [3], the resistance to crack initiation and propagation [4] under external loading and the corrosion behaviour [5,6].

Martensitic stainless steels (MMS) have a complex microstructure composed of martensite laths, austenite film between laths and ferrite islands. It is therefore interesting to quantify the influence of machining on the surface finish and the performance of this complex microstructure. The surface roughness produced by turning of MMS was already measured [7]. In a previous work [8], it was found that machined samples made of MSS can be classified into three categories based on the observable deformation: samples with severe observable deformation, noticeable observable deformation and no observable deformation. The observable deformation was qualitatively assessed from optical observations of cross-sections using ferrite islands as deformation indicators. It was also found [8] that severe observable deformation is generated under machining performed with the highest value of the feed rate, *f*. By contrast, there is no observable deformation in two configurations: machining with the lowest value of *f* or machining with intermediary values of *f* and the lowest value of the cutting speed, V_c.

In the present study, microstructural changes induced by machining of MSS are quantified by means of electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM). Samples representative of the first (severe observable deformation) and the third (no observable deformation) categories were selected. The corrosion behaviour of these two samples was then evaluated using the potentiostatic pulse technique (PPT). Obtained results were discussed considering microstructural changes determined previously and machining conditions (values of *f* and V_c).

2. Experimental

The studied material is a low carbon MSS. Its chemical composition is (wt.%): 15.5% Cr, 4.8% Ni, 1% Mo, 0.9% Mn, 0.24% Si, 0.1% Cu, < 0.06% C and 77.4% Fe. The material underwent a heat treatment at 1040°C, followed by an oil quenching, and a tempering treatment at 570°C.

Investigations were carried out on two machined samples extracted from the non-orthogonal design of experiments described in [8]: Sample #1 with no observable deformation (f = 0.1 mm/tr and V_c = 73 m/min) and Sample #2 with severe observable deformation (f = 0.3 mm/tr and V_c = 182 m/min). In both cases, the depth of cut was set at 4 mm and no lubricant was used.

The orientation of grains was determined on cross-section surfaces using the INCA Crystal EBSD System coupled with a field emission scanning electron microscope (JEOL JSM-6400F). EBSD measurements were performed with a step of 30 nm. The grain angle tolerance was set at 15°. Surfaces were ground (emery papers), smoothed (diamond pastes). A specific vibratory polishing was then carried out (VibroMet 2 vibratory polisher from Buehler).

FE-TEM investigations were carried out using a JEOL JEM-2100 microscope with a LaB6 source operating at 200 kV. For sample preparation, classical grinding, polishing and dimpling methods (Dimple Grinder Model 656 from Gatan) followed by ion beam milling (PIPS Model 691 from Gatan) were used on the opposite face to obtain a sample thickness that would be transparent to high energy electrons.

Corrosion tests were carried in 0.1M NaCl at 25°C using the PPT method [9]. It consists in applying a potential of 1 V vs. SCE for 3 s and then a potential of 0 V vs. SCE (passive behaviour) for 2 s (30 cycles). The specimen surface was cleaned in ethanol under ultrasonics and the zone of interest was observed by optical microscopy. Surface defects existing before machining were identified before the PPT test.

3. Results and discussion

3.1. Microstructural changes in MMS after machining

EBSD analysis was first performed on Sample #1 (no observable deformation). The IPF map (Fig. 1(a)) does not reveal any preferential orientation and any grain refinement in the close vicinity of the machined surface. By contrast, the