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Numerical modeling of residual stresses in turning of a 27MnCr5 steel

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Abstract

Surface residual stresses generated by machining remain a key issue for safety components of mechanical systems. Many simulations technics have been proposed. One of the most promising is to use the hybrid approach, which combines experimental characterizations with numerical computations. The hybrid method simulates equivalent thermomechanical loadings onto the machined surface without modeling the chip removal process. After a preliminary validation of this approach during the machining of an austenitic and a martensitic stainless steel, this papers aims at validating its application on a ferritic-perlitic steel 27MnCr5. This will confirm that the model is capable of predicting residual stresses for a wide variety of alloys.

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Keywords: Residual stresses; turning; 3D numerical modeling; 27MnCr5; surface integrity

1. Introduction

Machining and material removal processes in general remain the only way to obtain accurate metallic parts. The dimensional accuracy and the surface roughness are usually easily obtained by manufacturers since they are able to control these parameters on-line. On the contrary, residual stresses is a criteria hardly measurable and understandable by operators. So residual stresses have to be modeled off-line before the cutting operation. However there is currently no click-button software to predict residual stresses. To simulate the residual stresses generation, various strategies were developed by ([1-3]). These methods aim at simulating the cutting process, including the material removal mechanisms (chip formation) which induces long simulation duration and limits the modeling to a single brief cutting operation. On the contrary, in turning, a cutting tool has several revolutions and the surface integrity is a consequence of several passes. In order to overcome this limitation, the hybrid method was developed by ([4-6]). It has been applied successfully on austenitic and martensitic stainless steel and this paper will present its application on a 27MnCr5 steel. This will provide residual stresses profiles for a new steel in order to confirm the model relevance and improve scientist confidence in this approach.

2. Hybrid Method

The hybrid method is a numerical method to simulate residual stresses generated by a machining operation which focuses only on thermomechanical loads applied by the material removal process on the final machined surface (figure 1). It has been developed on SYSWELD®. This ‘chip less’ technic has proven its ability to predict quickly and precisely residuals stress field. It requires an experimental procedure to characterize several input data such as contact length, forces and chip cross section.

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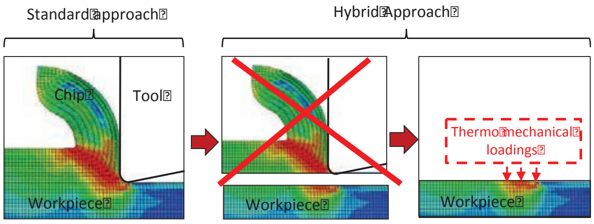

Fig.1: Hybrid method

The shape of the four thermomechnical loadings are detailed in [6].

2.1. Experimentations

The experimental campaign begins with a standard turning operation. The cutting tool is a TiN coated tungsten carbide one (TCMW 16 T3 08) . The cutting conditions are the same as the one simulated:

- Cutting speed: 200 m.min^{-1}
- Feed: 0.23 mm.rev^{-1}
- Depth of cut: 0.5mm

During the machining operation, the cutting forces are recorded with a Kistler dynamometer. After, the contact length and the chip cross section dimensions are measured with a binocular microscope. The picture 2 and 3 present these results.

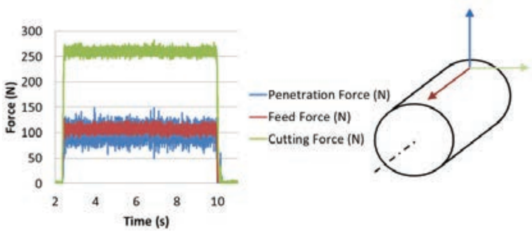

Fig.2: Cutting forces measurments

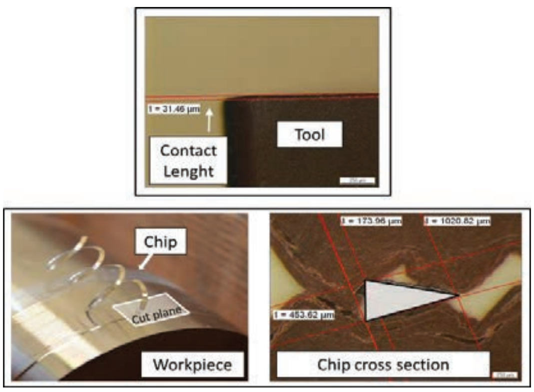

Fig.3: Contact lenghts and chip cross section measurments

The model considers two zones: a direct contact zone and an indirect contact zone. Both are affected by a single cutting pass but in a different way. The width of the direct contact zone corresponds to the feed, whereas the indirect contact zone depends on the depth of cut and on the cutting edge radius. The indirect contact zone will be affected also during the next revolutions (figure 4).

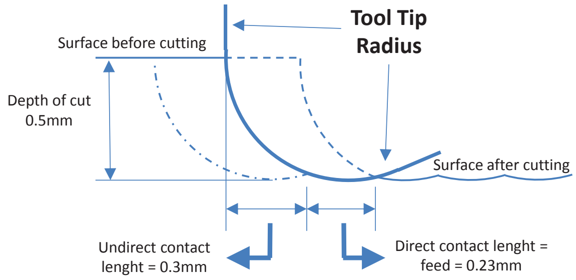

Fig.4: Cutting Sketch (rajouter le rayon de 0,8)

2.2. Friction law

The friction law is a key parameter for the hybrid method. In this article the results obtained by [7] were used. The figure 5 presents the evolution of friction coefficient depending on sliding speed. The results were obtained for a TiN coated tungsten carbide pin against a 27 MnCr5 steel.

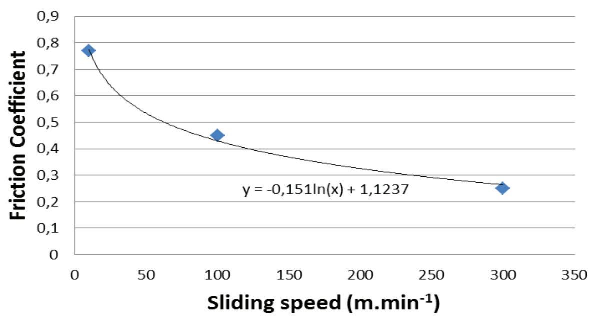

Fig.5: Friction law

2.3. Equivalent thermomechanical loads calculation

One of the key step of the method consists in estimating the thermomechanical equivalent loads. Details are presented in [6]. Figure 6 presents the values ready to be applied onto the numerical model surface.