Editorial

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Abstract: The service life of mechanical components is highly influenced by its surface integrity. Among the key parameters considered in the design of critical parts, surface roughness, residual stresses and metallurgical damages are of importance. Advanced machining processes become more and more productive, which leads to an increasing concentration of energy in the material removal area. As a consequence, the generated surfaces are highly influenced by the thermomechanical loadings supported during the cutting or abrasive process. In the same time, industry tends to decrease the weight of their components. The combination of both evolutions induces an increasing risk of breakage in use. For this reason, an improvement of the capability of manufacturers to predict the consequences of their processes becomes more and more important. This Special Issue of *IJMMM* has selected some research papers related to the characterisation and to the modelling of the surface integrity induced by machining processes and by additional mechanical post-treatments.

Keywords: residual stresses; microstructure modification; surface roughness.

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Biographical notes: Joël Rech received his PhD in Mechanical Engineering from the 'Ecole Nationale Supérieure d'Arts et Métiers' (Paris, France). Currently, he is the Head of the Department of Manufacturing Engineering at the 'Ecole Nationale d'Ingénieurs de Saint-Etienne' (Saint-Etienne, France). He is leading a research team in the Laboratory for Tribology and Systems Dynamics (LTDS) in the field of Machining Processes.

1 Introduction

The choice of manufacturing processes is based on cost, time and precision. The precision of a surface is usually based on two criteria: the dimensional accuracy and the surface roughness. However, another criterion has become more and more important: the performance of the surface. The word 'performance' has different meaning depending on the context but is mostly linked to fatigue, corrosion, wear and strength. It is usually assumed that the performance was directly related to the surface texture. The irregularities of the surface, especially the valleys or grooves, induce stress concentrations which enables the plastification of the material and the crack propagation. As a consequence, a smooth surface is supposed to limit the risk of crack initiation.

However, the surface roughness criterion does not enable to explain everything. It is clear that the subsurface is as important as the surface texture. Especially, the microstructure and the residual stress state are strategic parameters. The effect of the mechanical state of the subsurface (the residual stress state) has much more influence on the fatigue resistance of a piece if its surface roughness is below a limit. This underlines that external parameters and internal parameters are both strategic depending on the context of application. For that reason, the term 'surface integrity' has been introduced some years ago, which aims to describe the state of a surface (from its external and internal point of view) with regard to its potential performance. His definition is "the topographical, mechanical, chemical and metallurgical worth of a manufactured surface and its relationship to functional performance"

A surface can be defined as a border between a part and its environment. One particular piece belonging to a mechanical system has several surfaces. In a common way of doing, engineers design pieces in order to satisfy a list of criteria in relation to the function of each surface. Some surfaces have a mechanical contact with another part, whereas other surfaces have just a contact with air or oil, etc. As a consequence, the specification of each surface is different depending on its function:

- mechanical functions (capability of carrying mechanical loads)
- thermal functions (heat resistance or temperature conductivity)
- tribological functions (surface interaction with other surfaces: rolling, sealing, sliding, etc.)
- optical functions (visible appearance, light reflection behaviour)
- flow functions (influence on the flow of fluids).

From a global point of view, surfaces have to support: chemical aggressions, tribological solicitations, mechanical pressure, heat transfer, etc.

The aircraft industry was among the first to consider the surface integrity of their pieces, since the consequences of a breakage are always dramatic from a human and from an economical point of view. Such an industry has a double objective: designing aircraft with a minimum weight (i.e. with pieces having small sections) and producing pieces with a high degree of safety. Moreover, an additional objective becomes more and more present: the economical competition, which induces a high pressure on production costs, obliges the factories to produce faster and faster. The combination of these three objectives (thin, fast and safety) makes their job very difficult. In such a context, the surface integrity of their pieces is of primary importance.

Such objectives become also more and more critical in other kind of industry, such as automotive industry, because car makers are engaged in a run with two objectives:

- Weight reduction in order to reduce gas consumption.
- Increase of motor engines power in order to satisfy pollution criteria. This induces an increase of the mechanical stresses supported by the pieces in the power transmission.

These two contradictory objectives give more and more importance to the impact of the surface integrity on the reliability of cars.

2 Impact of the surface integrity on the fatigue resistance

Residual stresses can have a large variety of profiles depending on the manufacturing procedure. The magnitude and the sign of the residual stress will have a significant effect on functional performance. A common idea consists in preferring compressive residual stresses in the external layer because it tends to close surface cracks. However, the fatigue resistance properties of a surface depend on the thermomechanical loading supported by the surface (bending, tension, torsion, rolling, etc.). For example, a rolling contact would be much more interested in having a peak of compressive residual stresses in the sublayer, where the shear stresses are maximum. This would limit the pitting fatigue in some typical applications such as bearings, camshafts, etc. On the contrary, if a part is submitted to a bending loading (similar to a standard for points bending test in laboratory), the external residual stress state is of high importance. So the correlation between the fatigue resistance of a part and its surface integrity depends strongly on the loadings supported by the surface (thermal, mechanical, chemical) and on the material and on the manufacturing process. It is very difficult to define universal ideas in this area. In the current context, it is highly necessary to validate the performance of a surface through appropriate fatigue tests. However, research projects have to be launched in order to improve the capability to link the surface integrity of a surface with its functional performance without spending a lot of time and money for post-validation.

3 Link between the surface integrity and its manufacturing procedure

The evaluation criterion of a process depends on the functionality of the machined surface and on the economic efficiency of the process. Usually, the last machining operation is always suspected of being responsible for a breakage. Indeed, it is very important to keep in mind that the state of the subsurface is the consequence of the superposition of the individual stresses induced by all manufacturing sequences: from the purchase of the raw material to the superfinishing operation, including the machining in the low hardness state, the heat treatment, the semi-finishing operation in the hardened state, etc.

Each machining process has his own 'signature' on the surface integrity, since it removes layers from a workpiece with its specific mechanism. But this signature has a spectrum of characteristics depending on the conditions of application (cutting conditions, lubrication, wear of cutting tools, etc.). For example, a gentle hard turning operation will generate a very smooth surface (R_a ~ 0.3 µm) and will induce compressive residual stresses, whereas an abusive hard turning operation will induce tensile residual stresses associated with microstructure modifications. The main difference between these two configurations comes from the heat, the strains and the strain rates induced by the machining process.

As a consequence, it is impossible to give detailed informations about the surface integrity induced by each type of machining processes whatever the conditions of applications used by any end user. It is only possible to provide some general trends about the usual surface integrity observed in some current machining applications when they are used with relevant conditions.

Industry is looking for rapid methods enabling the prediction of the residual stress and microstructural states after each machining operations. Numerical models have made large progress during the last 10 years. However, a lot of research efforts are requested in order to develop models for each specific cutting process and work material.

4 Impact of the surface integrity on the dimensional accuracy

Each machining sequence introduces a modification of the stress state of the piece. It produces relaxation inherent to the layer removal (modification of previous residual stresses) and induces additional stresses. Each production step can influence distortion by generating a distortion potential which is inherently stored in the workpiece and passed to the subsequent production steps. Distortions are influenced by:

- steel production
- metal forming
- cutting
- heat treatment
- fine finishing.

Between two manufacturing sequences, the surface residual stresses are balanced by bulk residual stresses of the opposite sign. Sometimes if machining is only carried out on one side of a component with a large amount of material removal, the residual stresses can result in considerable distortion during the cutting process and after the cutting process when the workpiece is released from his clamping system.

The modelling of the superposition of residual stresses produced by the various sequences of a manufacturing process and the relaxation induced by machining remains an issue for industry. They are willing to have a single software able to predict the result in order to make the optimisation of their manufacturing procedure. A large amount of the knowledge necessary to reach this objective is already available, but this knowledge is disseminated all over the word. We hope that a leading company will be able in the future to create a connection between these people in order to reach this objective.

5 Current Special Issue

From a large number of submissions, the Special Issue features nine peer-reviewed papers. Residual stresses, surface roughness, microstructural damage induced by machining processes or post-treatments are highlights topics carefully selected in order to cover a wide range of applications. The Editorial Board of *IJMMM* hopes that this Special Issue will play a role for the improvement of the knowledge in surface integrity of machining processes and for the identification of possible research directions in future.

I would like to thank all the authors who have contributed to this issue. I would also like to acknowledge a great contribution made by the reviewers.

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