

Time and Cost Reduction in Evaluation Processes for New Parameters in Manufacturing Processes

Fritz Klocke, Dražen Veselovac and Sascha Gierlings

Werkzeugmaschinenlabor (WZL) der RWTH Aachen

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ABSTRACT

Once qualified, manufacturing processes for safety critical components in aero engines are “frozen”, that is no changes are permitted to be made without a time consuming and costly re-validation. Moreover, the material selection for components in modern aero engines, due to high mechanical and thermal loads in operation, is limited to a small range of super alloys. These difficult to machine titanium and nickel based alloys are on the one hand a significant expense factor themselves, and cause considerable costs due to high tool wear on the other hand. Thus, it is intended to carry out time and resource saving experiments and - ideally - being able to transfer available results to similar processes. Using smart experimental design deploying relationships of physical measures involved, the effort of testing can be reduced. This paper explains the method's mathematical background, how the selection of the regarded parameters is carried out as well as the reduction of system inputs. Furthermore the approach is demonstrated by means of experiments. Having analysed and discussed the experimental results, the method's efficiency is evaluated.

INTRODUCTION

The manufacture of components in modern gas turbine engines is by nature very conservative. For rotating parts a high level of integrity in terms of material and manufacturing quality is required to avoid primary failures. Thus they are subject to special controls and designated as critical, flight safety part or life controlled

part. In order to achieve a high quality standard in manufacturing minimising the probability of failures' occurrence, in a first place all manufacturing methods are examined to establish a set of operational parameters which will deliver acceptable quality. In machining this could be an acceptable range of cutting speeds, feed rates, tool shapes, and - sharpness, etc. Moreover, focusing on one component its manufacturing process is subdivided into several manufacturing methods that again produce a part or part feature. In case of a turbine disc for instance the different machining processes could be broaching fan slots, drilling holes, and different milling and turning operations during its entire manufacturing process. Having validated the feature quality regarding its required quality aspects the machining process is “frozen”. This means that the production of the particular feature may not be changed unless a new evaluation of a different process is carried out and has proven to generate a sufficient quality. Taking into account that small deviations in machining parameters, tool shape, or tool coating is considered a change in process inputs, the evaluation and validation of manufacturing processes. In the aero industry are time consuming and thus rather costly processes that often restrain newly developed tools from being introduced into the production.

This situation could be significantly improved by reducing the effort und therewith time to carry out tests evaluating new machining parameters, tools or even new materials for engine components. The approach discussed in this paper is to deploy similarity laws in order to take advantage of physical relationships between parameters,

reduce the number of test to be performed and hence being able to save time on the one hand as well as resources in form of tools, material and machining time on the other hand.

MAIN SECTION

In the following, the physical model describing a turning process, the application of the similarity law as well as the carried out experiments are presented, analysed and discussed.

1. PHYSICAL MODEL OF THE CONTACT ZONE

When new machining processes have to be evaluated in manufacturing industry the objective is to identify a set of process parameters that lead to acceptable part quality at long tool life within preferably short machining time or material removal rate, respectively. All these factors are directly linked to the cutting conditions that are present at the interface of cutting edge and work piece. In the following paragraph the physical model is introduced. The model includes all physical measures that are considered to have an influence on the relationship between cutting parameters and cutting result.

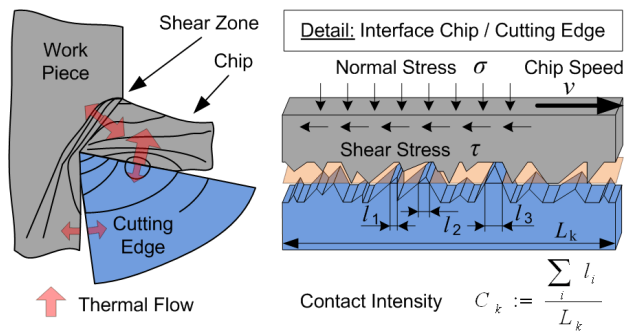


Figure 1: Physical model for the interface between chip and cutting edge [1]

In Figure 1, the size of the respective arrow represents the level of thermal energy as well as its flow direction within the system. In the figure's left-hand side the contact area at the chip moving over the cutting edge is presented greatly enlarged. Besides the chip flow the directions of the normal stress, shear stress as well as the contact lengths are highlighted.

Due to the cutting forces, very high pressure acts at the interface between the lower chip side and the cutting edge surface. During the machining operation the actual value of the normal stress is equal to the materials' yield stress, even if cooling lubricant is employed. The shear stress in contrast is independent from the normal stress and has to overcome the material's value of shear yield stress in order to move over the cutting edge surface. According to [1] three different cases that occur at the chip to cutting edge interface have to be distinguished. Figure 2 (a) shows the logarithmic diagram plotting the shear yield stress over the contact temperature. The

indicated retain temperature is the temperature value at which the material's stability strongly decreases. Thus, exceeding the retain temperature results in an asymptotic decrease of the shear yield stress in turn. Due to the geometric surface structures the value of the contact intensity defined in Figure 1 is smaller than one, as long as the contact temperature between chip and cutting edge is lower than the retain temperature. At a certain temperature value the lowest-melting material fractions at the tips of the lower chip side being in contact with the cutting edge start to melt. Consequently the contact intensity is getting higher. Once the restrain temperature is reached, the material is soft enough to cling to the cutting edge surface. As a result the contact intensity has advanced to its maximum value.

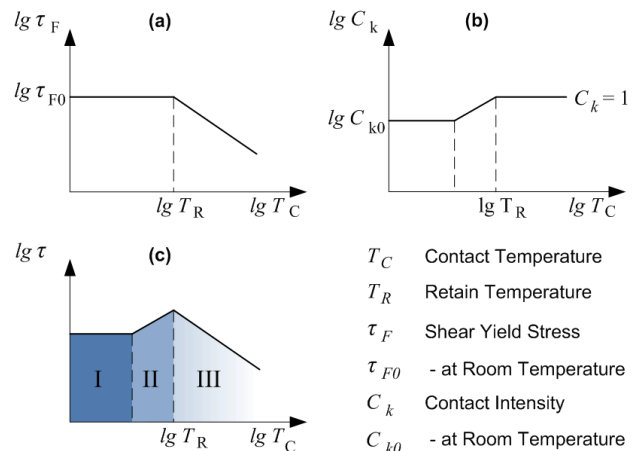


Figure 2: The three sections of machining [1]

Summing up the logarithmic diagrams in Figure 2 (a) and (b), they merge to a diagram in which the shear yield stress is plotted over the temperature again (c). In the combined diagram three sections are marked that can be designated to characteristic ranges of chip formation. In Section I, the machining conditions are independent from the temperature in the contact zone, Section II is the range where the generation of built-up edges is most likely and Section III finally is the range of ideal machining with respect to cutting conditions as well as operating efficiency.

In summary, it can be stated that the contact temperature can be regarded as a reference for the quality of the cutting process. The temperature occurring in the contact zone during machining, however, is very difficult to measure and hence cannot be monitored. For that reason the theory of similarity mechanics is deployed to represent the cutting process with the aid of cutting parameters instead of using the temperature.

2. THE APPLICATION OF SIMILARITY MECHANICS

Similarity laws are often applied in hydraulic and aerospace engineering when it becomes too difficult to analyse complex problems deploying analytical