TUHH
Technische Universität Hamburg

Bachelor's Thesis Summary

Bachelor's Degree in Mechanical Engineering

Analysis of CFRP broaching experiments for the validation of an 3D kinematics model for the machining of fibre-reinforced composites

submitted by
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Scope of work or abstract

The work of the thesis is based on the analysis of forces and roughness data in the machining and manufacturing of CFRP (carbon fibre reinforced plastics) composites considering 3-dimensional engagement of the tool.

The performance of the aerospace or automotive industry, as in many others, can be affected due to the surface roughness of the carbon fibre parts produced. Mainly in the aerospace due to the importance of aerodynamic advantages. This is the main problem that is studied in this thesis, how is it possible to manufacture or machine CFRP parts or elements as good as possible, in order to minimize the damage on the surface of the part and on its properties. Furthermore, economical loses in a wrongly managed manufacturing operation for CFRP parts can be critical or crucial.

For this reason, my tutor, professor Hintze with the help of Lars Köttner and I have found this topic kind of interesting to learn about. Furthermore, the TUHH, particularly the department of production management, is very advanced in this topic, so it is a big help.

Foreword

Our objective is to discover if, in fact, it is possible to develop a general method that can always define the surface roughness and quality after the process of milling or drilling, it doesn't matter the direction of the tool or

the angle with the one it is applied into the workpiece. This way, the performance can be improved easily.

This can be very ambitious, but if you think it in another way, it could help to reduce the calculations every time a new operation is about to be taken, and a more general idea could be provided to be able to most probably compare methods.

Nevertheless, it must still be remembered that this analysis is mainly for carbon fibre reinforced plastics, what means, unidirectional laminates in most cases but also for multi-directional laminates, what comes to be composed material.

In this project, as explained before we will contribute to improve surface quality and roughness of workpieces with a general method, but for this, it is also important to understand the behaviour of the laminates also, as it is our specific type of workpiece. For this reason, is mandatory to dominate the reactions to stresses and forces as a function of the angles of the fibres of the different plies, within a multi-directional laminate.

The shear stresses and stresses on the surface of the workpiece are fundamental as well. It would not be proper to forget also from the force distribution through the workpiece, as in the end, as we will see, the cutting, passive and feed forces are of heavy importance.

Then to measure the results, we have as usual, microscopes and surface contour tools, that can solve the doubts about how the final workpiece surface is.

Thesis structure

After a brief introduction with the objectives, the main problem to be solved and the data that we are going to focus on, there is a small literature review and an explanation of the different processes studied, giving priority to the main values (data) or things we will take into account like the roughness and the forces. Most of the data used for the analysis is obtained from another previous thesis at the Production Department at the Technical University of Hamburg. The author of this thesis was C. Schütte, a doctorate student.

Later, the calculations done to complete the thesis through MATLAB will be explained, all the changes of coordinate systems will be described as well as each equation. Furthermore, all the angles used in this equations or transformations are shown in figures and named.

Moreover, the results from the MATLAB code are analysed and studied, correlations are found, and interesting results explained. Moreover, a GUI (Graphical User Interface) was developed in MATLAB so that the values of the spatial angles of the 3D kinematic model of the machining processes can be obtained in a more intuitive way.

In the last part of the thesis, the references, to show that there is a part of my work, mainly in the state of the art, based on the work of other colleagues, that decided to publish their knowledge and experience so that

science can keep evolving and the appendix with all the tables with values used, as well as the digitalized data.

Results, conclusion and outlook

After all the analysis done, it is a pleasure to have found so interesting conclusions.

So, for the spatial fibre separation angle there is a big correlation between the forces (passive, feed and cutting), and the roughness, this behaviour can be explicitly observed in a specific angle but in other values of the spatial fibre separation angle this trend is similar. So, we can reach conclusions to obtain a better result in our CFRP machining.

With the spatial inclination angle λo, we can see another so important trend. For a specific spatial fibre separation angle value this trend can be seen with greater effect, for the rest of values of this angle no clear correlation can be extracted.

No real output from the data we have evaluated was obtained in the spatial fibre orientation angle, but the correlations obtained are similar to those from the spatial fibre separation angle, anyway this trend is more visual at the spatial fibre separation angles. We did not reach a clear explanation to these behaviours. All the results can be seen more in the detail in the thesis with graphs and tables.

As the project is strictly confidential at explicit request from the Technical University of Hamburg, the results that I can provide are very limited and very few details can be provided.

In our model there are some angles that are always 0, for example the motion inclination angle 1 (v), motion inclination angle 2 (ζ) and the cutting inclination angle 2 (ξ), so in future studies, these angles could be altered to check how the behaviour would be taking them into account. So, in this study the fibre separation angle is equal to the spatial fibre separation angle what at certain point simplifies things, but as stated before, this could lead to a new study. No change in the fibre orientation angle in an active way means that is not possible to obtain a proper quality to force relation. In future research this could done also.

Furthermore, most of the data used and results are in reference to broaching, so for more detail in drilling, Brügmann (the thesis of another doctorate student at the Technical University of Hamburg) was not possible to be analysed as deep as possible because of the constant change of the fibre separation angle but maybe in future studies it could be taken into account, by implementing the digitalized data already extracted in this study.