Calculation of the non-stationary temperature distribution in forming tools - the basis for selecting suitable tribo-systems or for the assessment of tool wear approaches - a combined simulation approach.

Dr. M. Twickler [1]

Dr. Gerhard H. Arfmann [2]

Abstract:

Selecting a suitable tribo-system for a fast running cold forming operation or assessing the tool wear due to the effecting load spectrum are quite sensitive tasks for the optimization of a forming process.

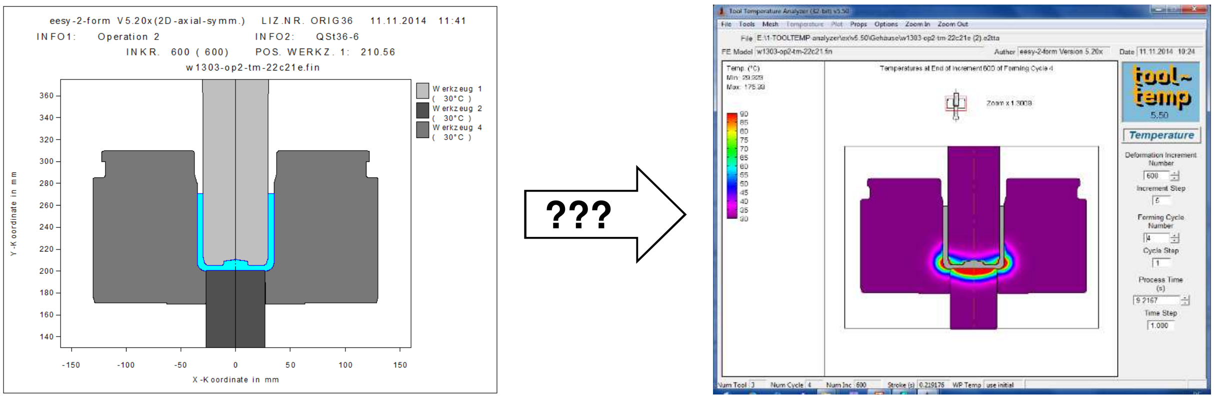
The tool temperature distribution and especially the temperature at the tool surface have a major influence on the effectiveness of the applied tribo-system and on the tool wear.

Forming simulations - as state of the art in the process layout and optimization – are focused normally on the forming component only, using the forming tool just as a forming boundary with an estimated mean tool temperature.

In reality forming tools show a significant distribution of the temperature with an un-stationary development during the start-up phase of a forming process.

The heating up of forming tools is a result of the heat flow from the forming component into the forming tools during each forming cycle.

Thermo-mechanical coupled FEM-based forming simulation are able to provide this information regarding the heat flow into the tools.



The effect of many forming cycles including the break time between the cycles and including unexpected process interruptions on the temperature development can be taken into account by a suitable and effective combined simulation approach.

The results presented here are based on a German ZIM cooperation project /1/ finished in 2014.

Key - words: Combined simulation approach, Tool temperature development, Multi cycle approach,

---

1- Dr. Michael Twickler, Geschäftsführer, CPM GmbH, Herzogenrath, Deutschland, cpm@cpmgmbh.com

2- Dr. Gerhard H. Arfmann, Geschäftsführer, CPM GmbH, Herzogenrath, Deutschland, cpm@cpmgmbh.com

Calculation of the non-stationary temperature distribution in forming tools - the basis for selecting suitable tribo-systems or for the assessment of tool wear approaches - a combined simulation approach.

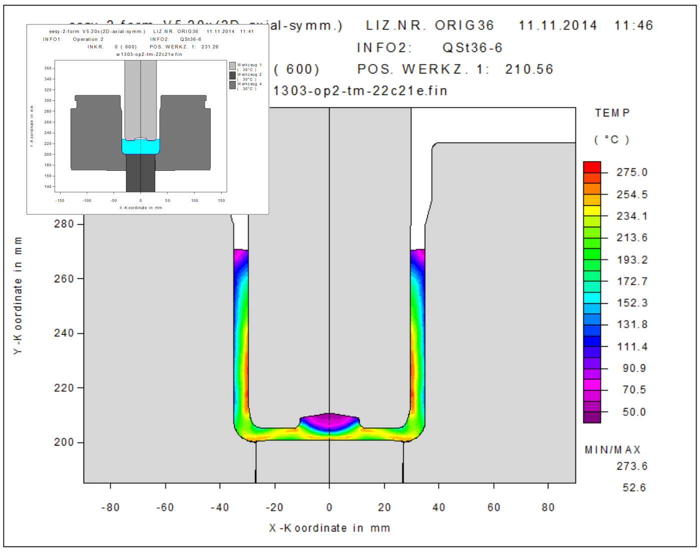
Introduction:

Due to the high energy impact at a cold forming process the involved forming tools heat up by absorbing the major part of the generated forming heat. The result is a non-constant temperature distribution inside the forming tool and especially on the important tool surface. This temperature distribution is non-stationary because usually a forming process starts with tools at room temperature. Depending on the complexity of the forming it can take a quite large number of forming cycles to reach a steady state of the temperature distribution in the forming tools. Each interruption or disturbance of the running forming process postpones the steady state to a higher cycle number.

Approach and Results:

The calculation of the development of the temperature in the forming tools requires:
- a ‘**supplier**’ of the information of the heat flow into the forming tools during a single forming cycle,
- a ‘**calculation tool**’ able to take into account a) the real tool geometry and b) the non-constant incoming heat flow for a single forming cycle,
- a ‘**feasible approach**’ for taking into account the effect of many forming cycles on the temperature development in the forming tools.

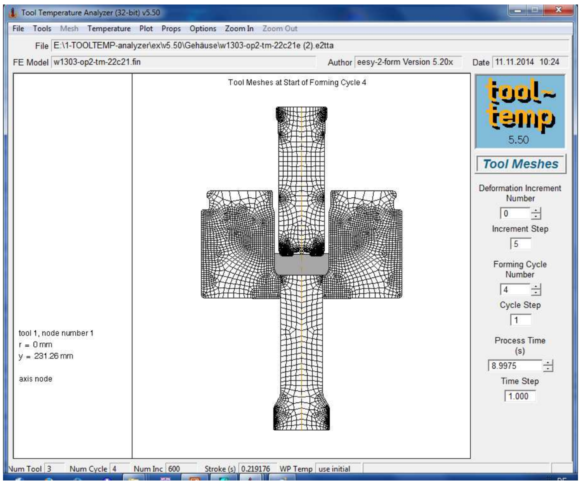
The best alternative for the ‘**supplier**’ is an FEM-based forming simulation done by a suitable simulation system and done as a thermo-mechanical coupled simulation for a single forming cycle. Suitable in this context means that the simulation system must be able to export the heat flow into the involved forming tools as function of process time and as a function of the changing contact area(s) between component and tools. The results presented in this presentation/publication are created by an ‘eesy-2-form’ version extended with the required export function /2/.

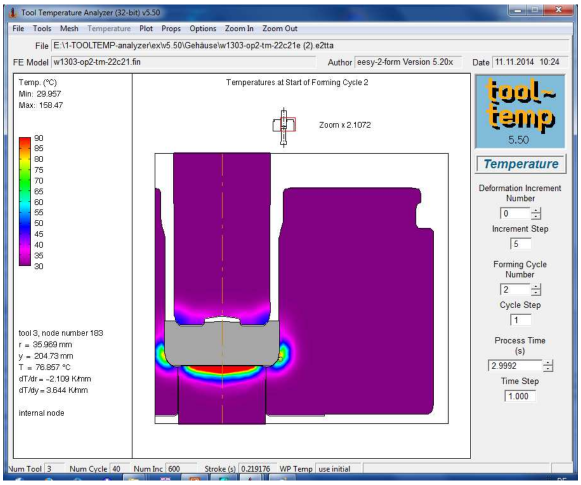


The used ‘**calculation tool**’ is the again FEM-based tool analyzer ‘tool-temp V5.50’, developed in a German ZIM project done by CPM and others. Starting from the imported information (process time, tool contours, heat flow, thermal boundary conditions, etc.) the tool-temp analyzer can do the required meshing for the forming tools followed by the calculation of the temperature development in the tools as a purely thermal FEM application. This results at first in the temperature distribution in the tools after a first forming cycle, if requested including the break time after the forming cycle to get the temperature distribution in the tools at the start of the next forming cycle.

Calculation of the non-stationary temperature distribution in forming tools - the basis for selecting suitable tribo-systems or for the assessment of tool wear approaches - a combined simulation approach.

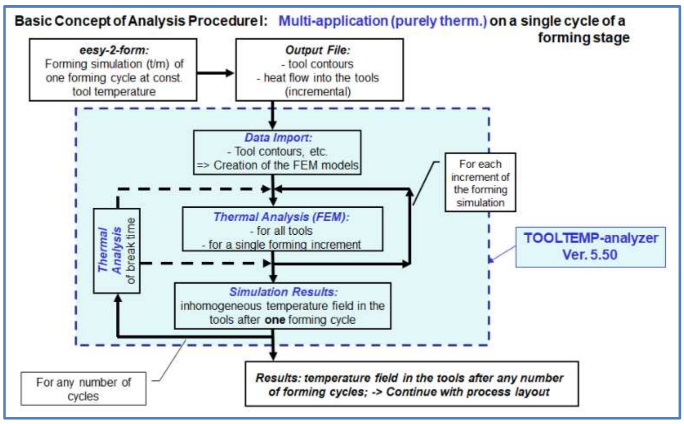
In contrast to the forming simulation, for which it is in principle sufficient to represent the forming tools just by the relevant tool contours and the tool surface temperatures, the calculation of the temperature distribution in the forming tools requires a complete modelling and meshing of the real tool geometry including a realistic approach for the thermal boundary conditions for the tool surface areas in contact to the tool holder of the forming machine.



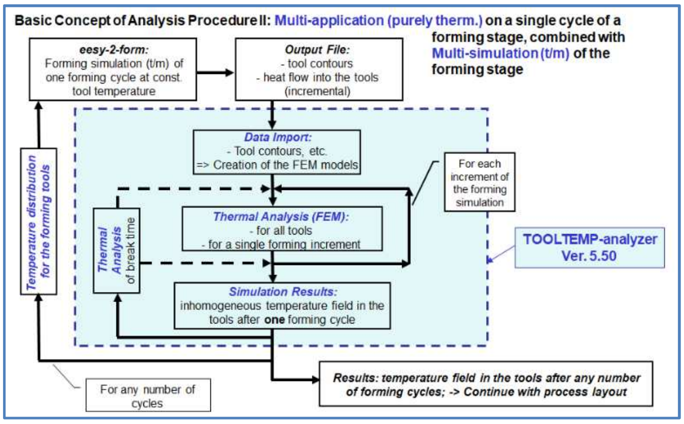


The consideration of the break time between the forming cycles is of special importance for a realistic calculation of the temperature distribution because the duration of the break time is normally significant larger than the forming time. This has the effect that the main development of the temperature field in the forming tools happens at the break time, while the much shorter forming time represents more the entry of new heat energy with a change of the temperature field quite concentrated on the surface near area. Due to this importance of the break time the different contact/no contact situations of the component and forming tools have to be models based on a precise time scale for each single sub-phase of the break time.

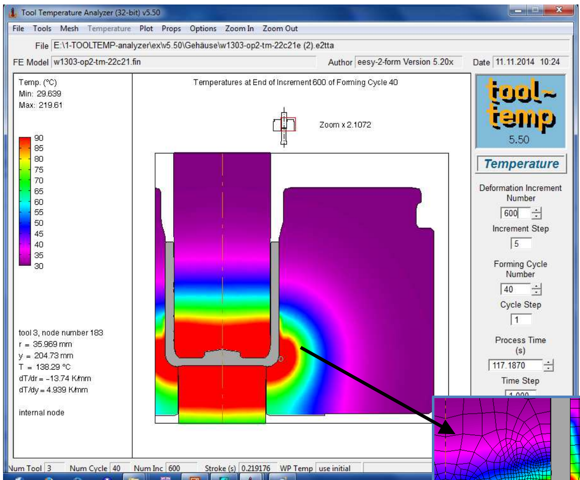
A first '**feasible approach**' for taking into account the effect of a high number of forming cycles is a combination of a single thermo-mechanical forming simulation - done for the initial forming tool temperatures (default: room temperature) - with a multiple application of the tool-temp analyzer for all requested forming cycles. The calculation of the change of the tool temperature during the break time between the cycles is included in each single run of the tool-temp analyzer as a second phase calculation. Since this approach is based on just one single thermo-mechanical forming simulation a smaller inaccuracy has to be accepted because the calculated heat flow during the forming process is calculated for the initial tool temperature.



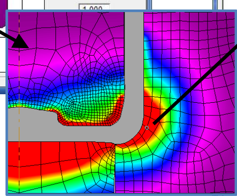
Calculation of the non-stationary temperature distribution in forming tools - the basis for selecting suitable tribo-systems or for the assessment of tool wear approaches - a combined simulation approach.

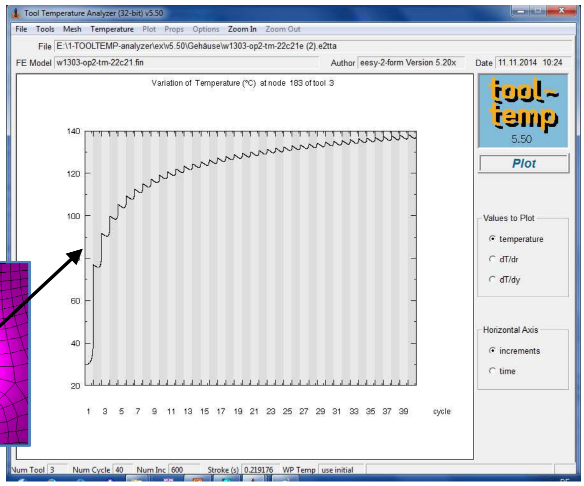


A second '**feasible approach**' for this task is to include a re-run of the thermo-mechanical forming simulation - taking into account the actual tool temperatures - into the multiple application of the tool-temp analyzer for all requested forming cycles. This requires a feedback from the tool-temp analyzer to the forming simulation system to provide the always actual tool temperatures and to initiate a new re-run of the forming simulation while waiting for the updated information of the actual heat flow into the forming tools. In this approach - which is much more time consuming then the first simpler approach - the tool-temp analyzer handles the overall controlling of this combined simulation approach and the thermo-mechanical forming simulation becomes to a sub-task of the tool temperature calculation.



The main advantage is the most accurate result for the temperature distribution in the forming tools after a high number of forming cycles.





Besides the result of temperature distribution in the forming tools - and especially at the tool surface - after a number of forming cycles the described tool temperature analysis is very suitable to determine the number of forming cycle necessary to reach a more or less steady state situation of the temperature development in the forming tools. This is important when deciding for a suitable tribo-system or- if it seems to be critical during the start-up phase of a forming process - to decide for a pre-heating of the forming tools.

Calculation of the non-stationary temperature distribution in forming tools - the basis for selecting suitable tribo-systems or for the assessment of tool wear approaches - a combined simulation approach.

Summary:

The temperature distribution in forming tools and its non-stationary development are important aspects for the effectiveness of a chosen tribo-system, for the tool wear and for a number of assessments of the forming process and the involved forming tools.
A combined approach of forming simulation and temperature development simulation - both based on the FEM technique - in conjunction with a suitable und feasible procedure to consider any number of forming cycles results in a quite realistic temperature field in the forming tools, during the non-stationary start-up phase of a forming process as well as for the steady state situation of the tool temperature.
Since the feedback of the actual tool temperature from the tool temperature analysis system (TOOLTEMP-analyzer) to the forming simulation system is of high importance for the precision of the temperature result, the TOOLTEMP-analyzer takes over the control of the whole analysis procedure acting as a server and addressing the forming simulation system as a client for requesting the heat flow information for the next forming cycle based on the currently calculated temperature distribution in the forming tools and especially at the tool surface.

Literature:

/1/ Entwicklung einer innovativen Auslegungsmethodik und computergestützter Analyse-Tools zur thermisch-tribologisch gekoppelten Analyse und Optimierung von temperaturabhängigen Prozessen in der Kaltmassivumformung; Entwicklung eines Software-Tools zur Analyse der Temperaturentwicklung in Kaltmassivumformwerkzeugen zur tribologischen Prozess-bewertung und -optimierung (TOOLTEMP-analyzer), 2011-2014.
Zentrales Innovationsprogramm Mittelstand (ZIM)-Kooperationen,
Gefördert durch: Bundesministerium für Wirtschaft und Technologie aufgrund eines Beschlusses des Deutschen Bundestages.

/2/ eesy-Software
CPM GmbH, Herzogenrath, Germany, 2017
CPM@CPMGMBH.COM