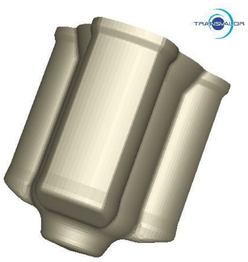
# FORGING DIE LIFE PREDICTION

Typically, when people are interested in tooling life (die,…),a standard approach is to do a stress analysis of the forming stage and eventually compute some abrasive wear but a closer look will show that the accumulation of the blows may have to be taken into account. In case of hot or warm forging, the tooling properties will heavily depend on local die temperature which cannot be obtained only from one simpleforming stage simulation. If the new demand on weight reduction has shifted the focus on part properties, the production cost shouldn't be forgotten and die life remains one of the major aspects of that cost. A large amount of work has been done so far on die stress analysis but, as the goal is not to produce one single part but several tens of thousands; temperature and maximum stress at first blow are not enough. To holistically predict the production cost, steady state temperature needs to be taken into account. To illustrate this point, we use another very typical automotive component, a Constant Velocity Joint.

## CONSTANT- VELOCITY JOINT EXAMPLE

### PROCESS

The CV joint another millions pieces component. A typical process for this kind of part is a 3 or 4 stages warm forging sequence. Compared to hot forging, it is a 'near net shape' process and compared to cold forging the requested forging load is manageable. As usual, if this process offers advantages it also comes with difficulties, one of them being the life of the punch which is threatened by different phenomena's: wear of the shoulders due to important flow along the punch, overload due to the relative punch low section, mechanical or thermal fatigue due to the alternative loading/unloading, heating/cooling phases. Among the different aspects quoted above, the overload is probably the easiest to predict using a FEM simulation tool. To achieve that, a classical approach is to use an 'uncoupled approach'. The idea is:



- To perform the forming stage simulation using a rigid dies assumption while recording the normal stresses at the surface of the die
- To apply these stresses as a loading case to the die in a separate computation. To make it simple, die is usually considered as pure elastic.

Results of such a simulation are typically both equivalent stress and first principal stress. Based on that, it is possible to guess whether or not the die is strong enough to sustain such a loading.

### FULLY COUPLED APPROACH

The drawback of such an approach comes from the fact that die elasticity is not taken into account

during the forming simulation. This leads to force and stress overestimation as well as omission of the die elastic compression.
In real life forging, people increases the punch stroke to obtain the correct component final shape. To validate the uncoupled method, we have computed an example using both a fully coupled analysis and uncoupled technics. In this simulation, the punch is considered as a deformable body and FORGE® solves in a unique set of equations both component and punch velocity/pressure fields. In the coupled approach, the stroke of the press has been increased of 1.5 mm to counterbalance punch elasticity. The coupling between different deformable bodies is achieved through the creation of so called 'contact' elements. These elements make possible an effective implicit coupling by creating some supplementary terms in the system of equations to be solved. The quality of the results relies on a good adaptation of the mesh on both sides of the contact area. An easy way to evaluate the quality of the coupling is to check the continuity of the normal component of the normal stress across the border between two bodies in contact. Figure 1a displays zz in the component and in the punch. In the center area,
as the contact surface is almost horizontal; zz is a good approximation of the normal stress.

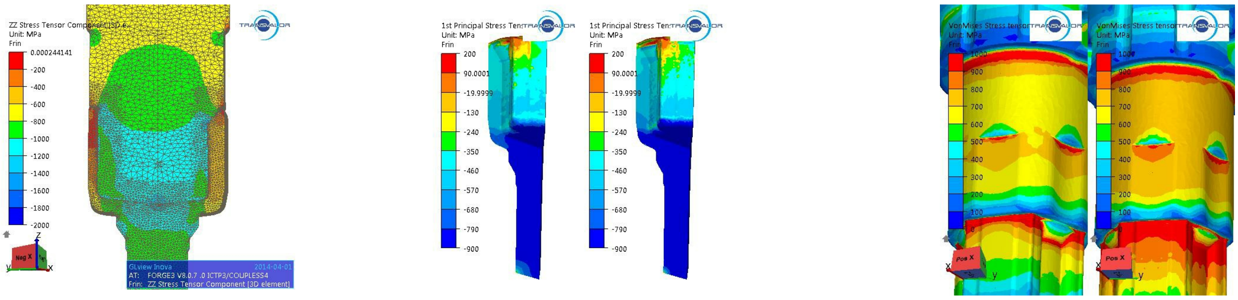


*Fig.1a, zz stress tensor component and Fig.1b, First principal stress in the part (coupled and rigid) and Fig. 1c, Equivalent stress in the punch (coupled and post process)*

**STEADY STATE APPROACH**

As we have seen above, the uncoupled approach is very time effective. This can be used to reduce computation time but it also opens other perspectives. So far, we have been focusing on the stress level in the punch but other reasons for die damages could be either wear or fatigue. If we consider wear, the most classical model might be the 'Archard' model:

$$\delta h = \int K_W K_F \frac{\sigma_n \Delta \vec{v}}{H_v(t)} dt ,$$

To evaluate such a formula, knowing the evolution of the temperature at each point of the die is required. When a coupled analysis is performed, a thermal resolution is also done but the result will depend deeply on the initial temperature distribution. Ideally, many computations should be done until the steady state is achieved. The idea is then to do a kind of post process approach. At first coupled analysis is performed and both 'mechanical and thermal loading' are stored. Given the post process analysis of a die being very short, it is then possible to apply this loading many times until the convergence is reached. The result is called the steady state situation. In order to have more realistic results we also include in the loop waiting phase and lubrication phase.

This approach has been tried on another CVJoint displayed on Figure 8. Final shape can be seen on Figure 8a and 8b while Figure 8c and 8d display respectively the temperature and the stress along z axis.

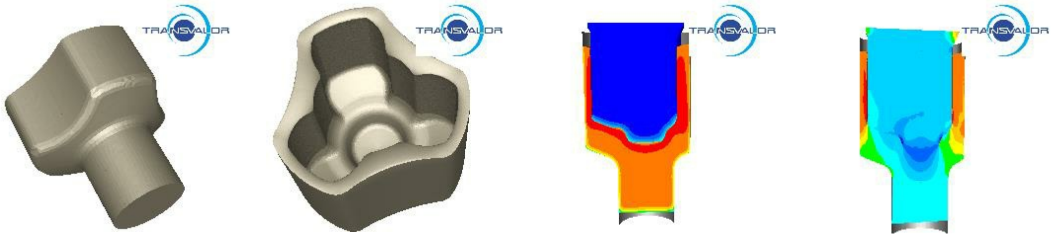


*Fig.2a, Final shape* *Fig.2b, Final shape* *Fig.2c, temperature* *Fig.2d, zz stress component*

The temperature in Figure 2c corresponds to the temperature after one blow knowing that initial temperature was set to a uniform 200$^{\circ C}$. We have then applied the mechanical and thermal loading top the punch until convergence has been obtained. Figure 3 displays temperature in the punch after the first blow (3a), after the first cooling (3b), after a blow in steady state situation (3c) and after cooling in steady state situation (3d).

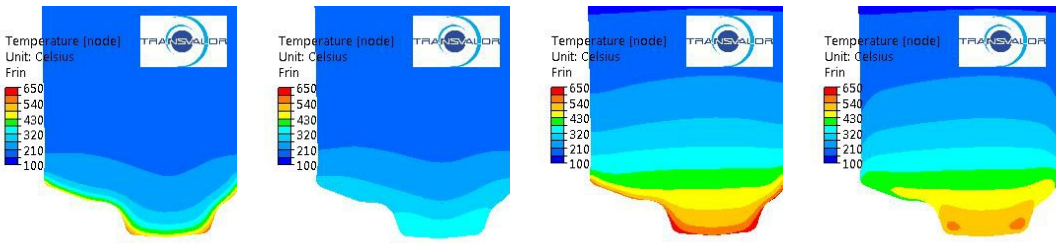



*Fig.3a, Final shape* *Fig. 3b, Final shape* *Fig.3c, temperature* *Fig.3d, zz stress component*

As it can be seen, the thermal situation after many blows differs from the initial one. As consequence, the results in terms of Archard wear differs a lot as it can be seen on Figure 4 Not only the maximum value are very different but also the location of such a maximum.

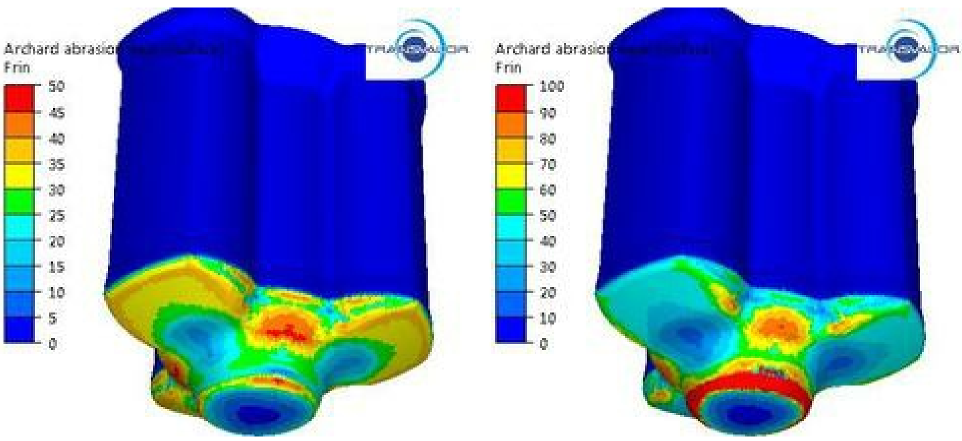



Fig.4, Archard die wear with different punch temperature

**CONCLUSION**

In this paper we have seen how the most recent progress Simulation techniques now make the prediction and validation of new phenomena possible. Consequently it dramatically changes some of the simulation results. This is done by increasing the simulation's scope along the time line thanks to a steady state approach.

**TRANSVALOR AMERICAS CORP - 17 North State Street, Suite 1700, CHICAGO, IL 60602**
Tel: (312) 252-7371
Fax: (312 252-7373
Email:bruno.castejon@transvaloramericas.com