Critical aspects in simulating cold working processes for screws and bolts

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In this short article we will endeavor to scrutinize the field of cold working process simulations for screws and bolts as it currently stands: namely what is possible to simulate and what significant results can be attained. In this regard, we will follow a screw and a bolt from the wire coil through to implementation. (fig. 1).

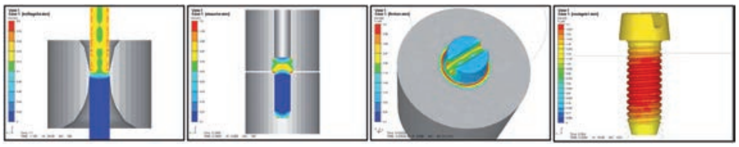

Fig. 1 – production sequence of a screw

a. Wire drawing: The productive process starts with a wire coil, whose material has already been threaded, with a section reduction that has been formed and whose surface has hardened. This is required for a correct prediction of material sliding in the following deformation phases.
b. Extrusion operation of the shank and the head formation: this is usually 'axisymmetric', and is simulated with quick 2D analyses which are able to accurately predict the material flow.
c. Shaping and finishing operations: details like the hexagonal shape and the cutting/Star/Allen wrench prints are attained in the final phases and require a 3D simulation. This can be simplified by applying symmetry planes. During these stages, maximum attention must be paid to the filling of the shape and any possible fold formations.
d. Flash trimming: this isn't always necessary, but it allows for the elimination of excess material on the head due to the applied deformation. It can be simulated, in order to calculate the total force necessary for shearing and subsequently upsetting the materials. Otherwise a Boolean removal of the material in the burr can be performed, thereby generating the correct geometry for subsequent calibration stages.
e. Thread rolling: final operation which is very delicate: the thread passes through knurled rollers, capable of shifting the material and creating the thread. In this stage, which is difficult to simulate due to the number of rotations involved, the focus is on evaluating the correct amount of material increase involved to form the threads.

If we further reduce the analysis of the upset forging operations, the distinctive characteristics of the process are:

- The utilization of automated multi-station machines, where the product of each operation is transferred to the successive one. In the simulation, it is important to allow for the setting of a sequence of 2D and 3D operations, automatically transferring all calculated results from one stage to the next, i.e. solving an entire sequence of operations in one single step. In a more advanced analysis we could also take into account the deflection of the press (fig. 2), which is related to the different loads that each station has to support.
- The necessity of considering the elastic return at the point of extraction of the piece from the matrix: it is

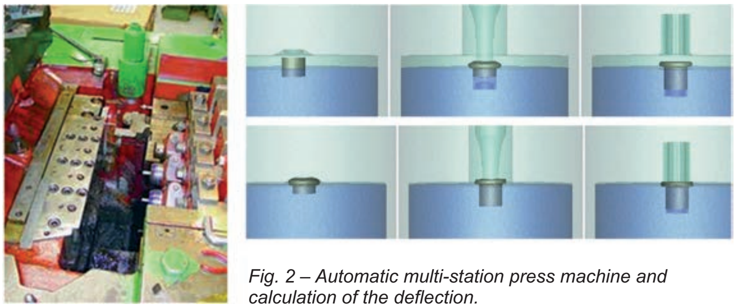

Fig. 2 – Automatic multi-station press machine and calculation of the deflection.

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important to compute the elastic part of the deformation at the opening of the presses (i.e. elastic spring-back)

The designer is usually interested in two aspects of result analysis:

- Filling: Is there enough material to fill up the measurements between the matrices/ punches / dies? Or is something missing based on a miscalculated estimate of the entry material or an incorrect distribution in the preceding stages? A 'contact' tool is an effective way to visualize parts that are in contact with the matrix, and parts that are not (fig. 3). By following the material flow via velocity vectors, together with the visualization of each point of contact, you can understand in detail how the material may be formed. This identifies possible isolated pockets of non-contact or possible defects due to the trapping of lubricants;

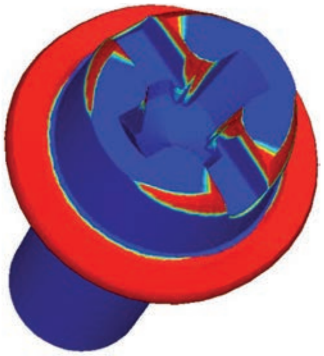

Fig. 3 – contact analysis – the missing parts are in red

- Creation of folds: the dimensions of the matrix force the material to fold into itself, producing folds that can be critical to the quality of the piece if they remain inside and are not eliminated by any subsequent shearing. It is therefore critical to correctly trace these folds when the material is being deformed. Marker highlighting (fig.4) represents a good solution to this. It is therefore possible to not only locate the position and depth of a fold, but also to understand if it will remain inside the piece or if it will be located in the burr;

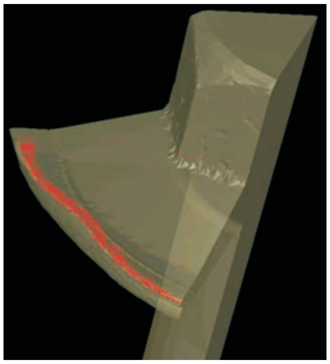

Fig. 4 – A fold traced with markers

Some other results that are usually calculated are the respective deformations of material, which can be useful in identifying the areas that are the most stretched, as well as the temperature distribution, which highlights any possible overheating. It is interesting to evaluate the fiber material as well, which can guarantee the material's correct orientation and can highlight any folds under the surface.

The piece obtained by a complex sequence of operations can be compared with the measurements needed, displaying any shortcomings and machining allowances (fig. 5).

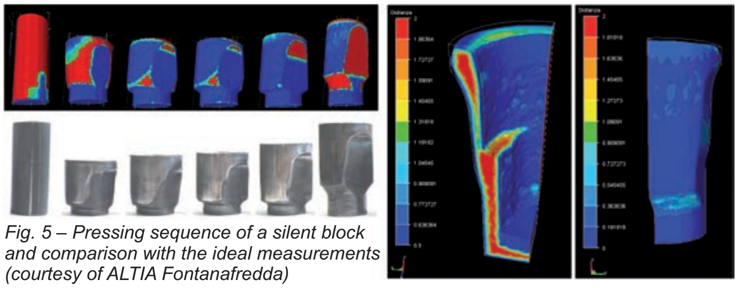

Fig. 5 – Pressing sequence of a silent block and comparison with the ideal measurements (courtesy of ALTIA Fontanafredda)

The following is an example of how this simulation helped engineers fix a press defect which was on the external part of a screw head (fig. 6). The "barrel" configuration, chosen for the shape of the head, resulted, during the subsequent phase of finishing, in a deformation of material on the external surface and in an incomplete filling of the internal imprint. Since intervention in the mold finishing wasn't possible due to its constrained measurements, various

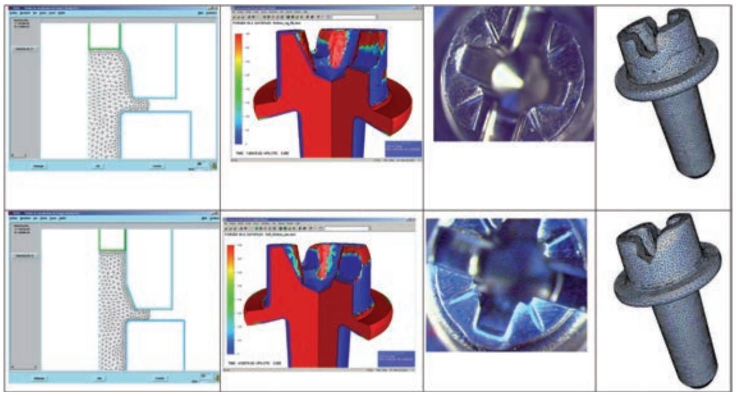

Fig. 6 – "Barrel" configuration with defect and "Cone" without defect (courtesy of Legrand)

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possible measurements of the forming stage had to be evaluated. The axisymmetry helped simplify the calculation. This, in turn, allowed for the possibility of an automatic chaining of operations to calculate different parallel sequences. The best configuration turned out to be "cone" shaped one, which was capable of distributing the material in a different way. The external defect was eliminated and we also obtained greater coverage of the imprint, which decidedly improved the transfer of torque from the screwdriver during operation.

Another significant example is related to the field of bolt production, where the analyses were performed on all production stages (fig. 7). The molding sequence here was improved so as to limit the missing fillers, which are typical in hexagonal shapes due to wire deformation. We therefore simulated the shearing phase in order to determine the shape of the sheared surface. The bolt was then subject to a nylon to metal snap-fit analysis. After this, the coupling was evaluate during rotation, so as to calculate the final torque.

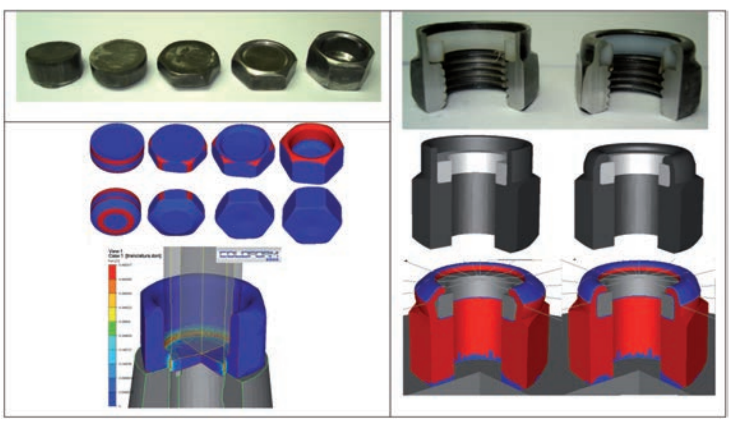

Fig. 7 – Molding bolt. Deformation process, shearing and nylon to metal snap-fit (courtesy of Da-Tor S.p.A.).

Modeling of plate cutting processes is also possible. These processes are normalized for the production of flat, round washers or other similar objects that are shaped differently. For the simplest types a punch is used, which can shear a certain portion of material, leading it to break locally. In these cases it is critical to evaluate the quality of the shearing surface, the profile variation of the punch and die, as well as the materials used. It is therefore necessary to be able to model the entire rupturing procedure, from the surface curvature close to the punch, to the upper sliding surface, to the start and spread of the fracture (fig 8a). Once the parameters of fracture propagation have been established, the measurements taken from the simulation's results are very close to the findings of the actual process.

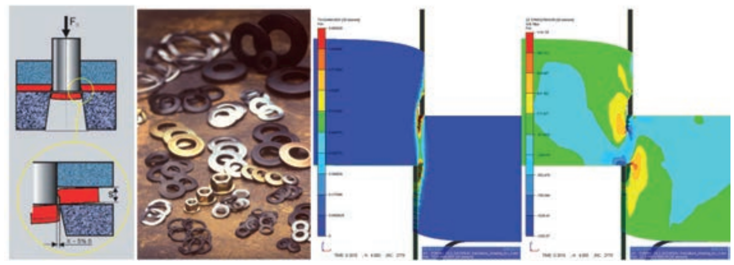

Fig. 8a – Washer shearing (courtesy of Panzeri S.p.A.)

There are other precision shearing processes, among which is 'fine blanking', whose objective is to achieve the sharpest possible cutting surface with very strict tolerances. A simulation tool here must be able to quickly setup multiple floating-die operations, include auto-adaptive mesh functions (which are able to enhance the details of the sheared areas), so to allow the simulation of this process to be addressed with the required accuracy (fig. 8b).

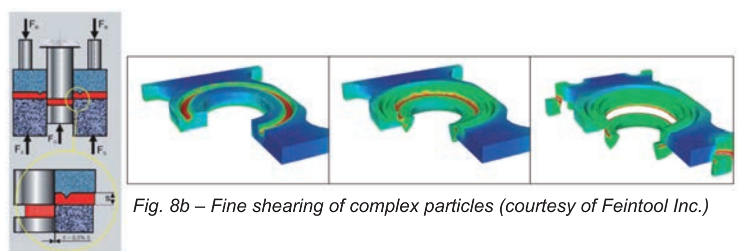

Fig. 8b – Fine shearing of complex particles (courtesy of Feintool Inc.)

In the field of cold forging, the "tools" are usually dies and steel punches/plugs, and therefore basically the same as the material that needs to be upset. The surface of the die/punch is also subject to significant deformations, which can bring about a loss of tolerance to the final piece, or even lead to its fracture. This is why "armored" configurations, with tungsten carbide (TIC or TCT) are often used, pre-loaded for interference through one or more levels of

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external rings (Tool-stack). This device allows you to create an internal state of compression, capable of lowering the load levels incurred during molding. Considering the molds "rigid" can therefore be a good approximation in terms of material flow, but it doesn't allow you to obtain information about the deformation or rupture of the tools. So it is necessary to perform an analysis of deformable molds that takes all these effects into account. A simulation tool should allow users to specify the measurements and materials of each insert with relative interference between the rings – i.e. by using a "virtual interference fit", which can calculate the effects resulting from armoring the insert's outer surface (fig. 9).

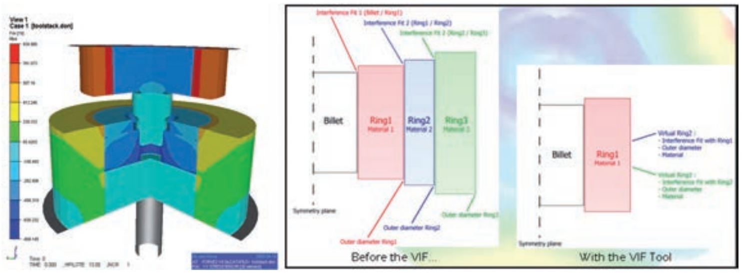

Fig. 9 – Deformable mold analyses of pre-loaded inserts and virtual interference fit

With regard to possible mold ruptures, the deformable mold calculation allows you to calculate which areas are most subject to stress. In the case shown below, a fracture of the extrusion matrix was encountered during production. This was due to the excessive tensile stress accumulated. A subsequent simulation (fig. 10) identified the area with most stress and allowed for intervention - through the appropriate external armoring - so as to decrease the stress level in the critical zone. This new configuration has eliminated the rupture and has significantly increased the useful life of the molds.

Fig. 10 – Analysis of the molds for the configuration of fork spanner cold forging (courtesy of Omega IFS S.r.l.)

Another point of interest, in the field of cold forging of screws, is the thread rolling operation for formation between two suitably knurled rollers. (fig.11). The process is well known industrially, but its successful setup depends on experience: the position of the screw's entry between the rollers and the duration of the rolling are both critical. When taken from a simulation point of view, it is necessary to have a robust calculation on a very high number of increments, as well as great detail about the areas where the material will "fill up" the profile. It is therefore necessary to correctly calculate all the sliding of a screw between the rollers, as well as the local deformation on the threads, thanks to an auto-adaptive mesh that keeps regenerating during the calculation. All the calibration operations of this process can be conducted virtually, basically eliminating interventions on the machine itself.

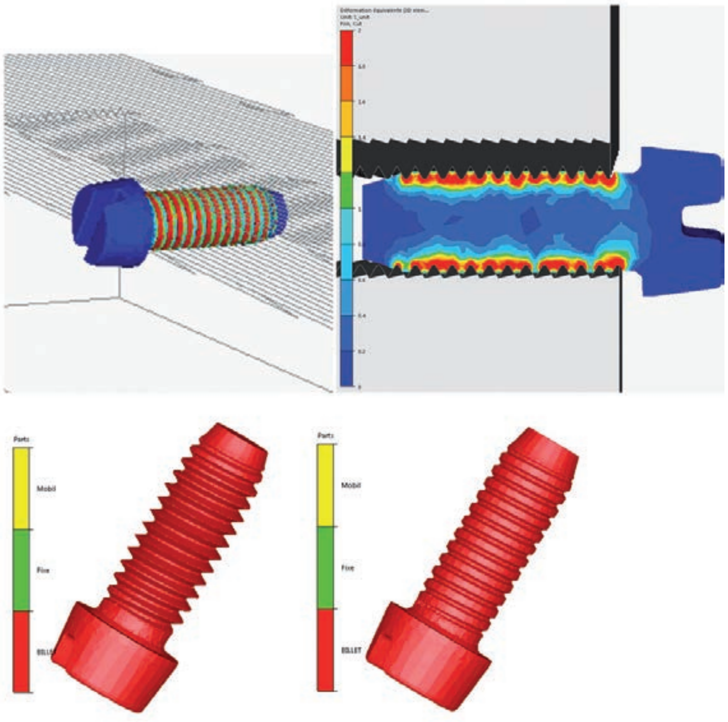

Fig. 11 – Thread rolling – the position of the screw with respect to the rollers influences the filling of the profile

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