

Tube stamping simulation for the crossmember of rear suspension system

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Abstract: A recent innovation project at Magneti Marelli Suspension Systems aims to test the feasibility and performance of an innovative and patented shape for the crossmember of a rear suspension system. The component is realized starting from a tube, then deformed plastically, and finally quenched and tempered to reach the mechanical performance required to fulfill the technical specification. The stresses under operating loads and the elasto-kinematic performance of the suspension greatly depend on the stiffness and shape of the crossmember. In this paper the simulation contribution to this project regarding the multi-step stamping process is presented. Abaqus Standard and Explicit have been used to manage the forming operations, re-positioning and spring-back. The software has succeeded in anticipating some critical issues in the tryout phase, thus reducing time and optimizing the component, by analyzing virtually a number of variants.

Keywords: Forming , Suspension, Tube, Tube Bending.

1. Introduction: the “twist beam” rear suspension system

Magneti Marelli Suspension Systems supplies a wide range of OEMs with suspension components and complete front and rear suspension modules. It has 2 R&D centres and 8 manufacturing locations spread across Europe and America. Its headquarters are located in Turin, Italy.

In this paper a new methodology for the design of the cross-member of a “twist beam” rear suspension system (fig.1) is presented.

The design of this component is often a complex procedure, due to the several functions and requirements to fulfil:

- Weight and cost targets
- Structural resistance: mission loads and misuse conditions can be critical, both on the base material, and on the interfaces (usually seam weldings) between the external longitudinal arms, and the cross-member
- K&C performances: the inertial properties of the cross sections of the cross-member (bending and torsional stiffness, shear center and centroid position), and their values along the beam, determine some of the most important elasto-kinematic performance parameters of the suspension system.

- Layout constraints: the cross-member must guarantee the right clearances towards the boundary devices: exhaust system, fuel tank and pipes, spare wheel well.
- Technological requirements: the material and the thickness must be compatible with the welding operation with the external arms.

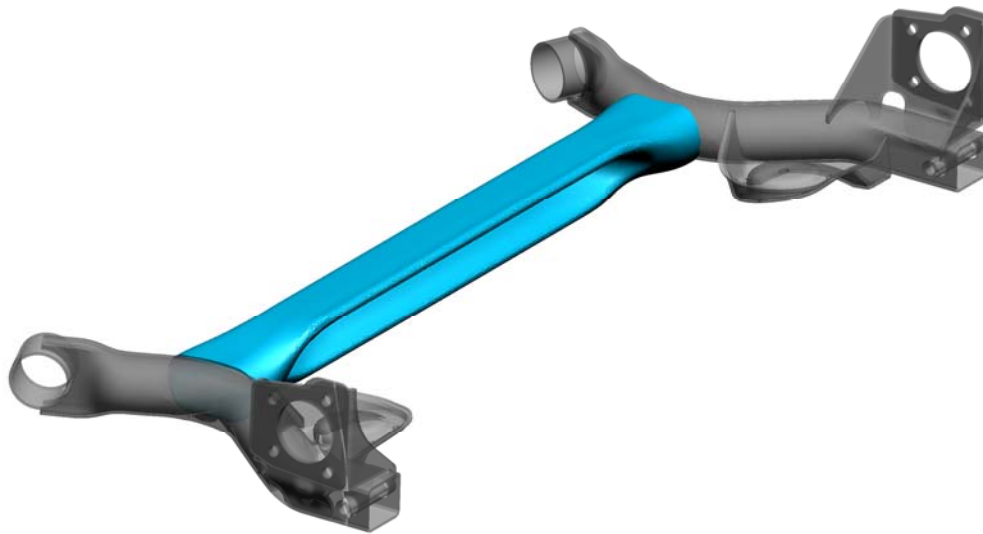


Figure 1. Example of twist beam axle with closed-section cross-member

The cross-member is commonly made of formed steel sheet (with or without a stabilizing bar) to form an “open section cross-member”, or of a formed steel tube to form a “closed section cross-member”.

Recently, Magneti Marelli Suspension Systems started the development of a twist beam axle for an AWD car, with a closed cross-section. The cross-member needs a cambered shape (front view, see fig.2), due to the strong layout constraints towards the power shaft and the differential. Three different zones form the cross-member.

- The drawn portion: it defines the roll stiffness of the suspension, required by the technical specification.
- The interface zone: it must guarantee the needed structural resistance, minimizing the stress on the welding connection.

- The transition zone: its smoothness is crucial for the feasibility of the stamping process, and to keep the stresses under operating loads below the allowable values

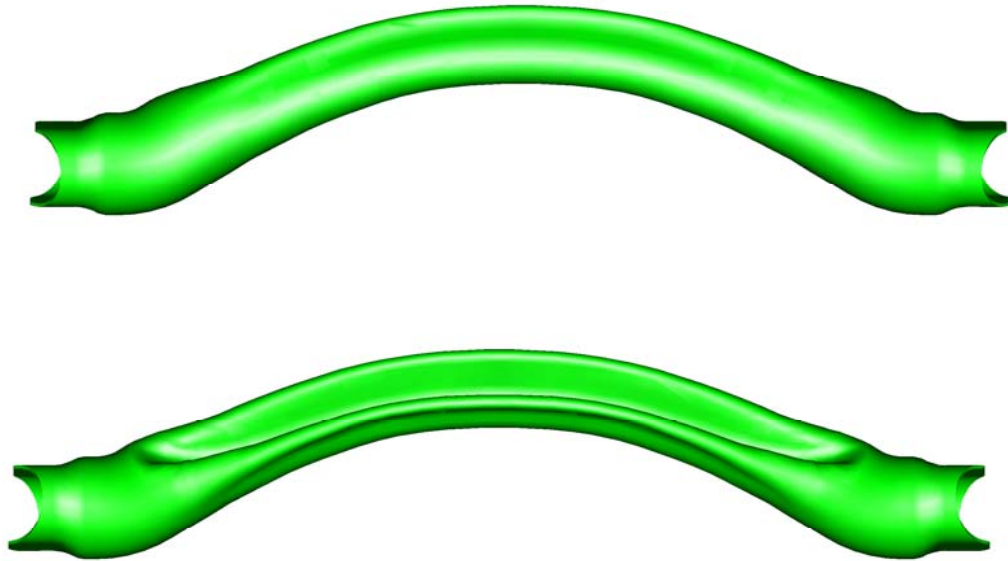


Figure 2. Front and rear view of the cambered cross-member

2. A new design approach

Magneti Marelli developed a new, CAE-driven approach to the design of the cross-member: the classic design methodology can be compared to the new one, in fig. 3.

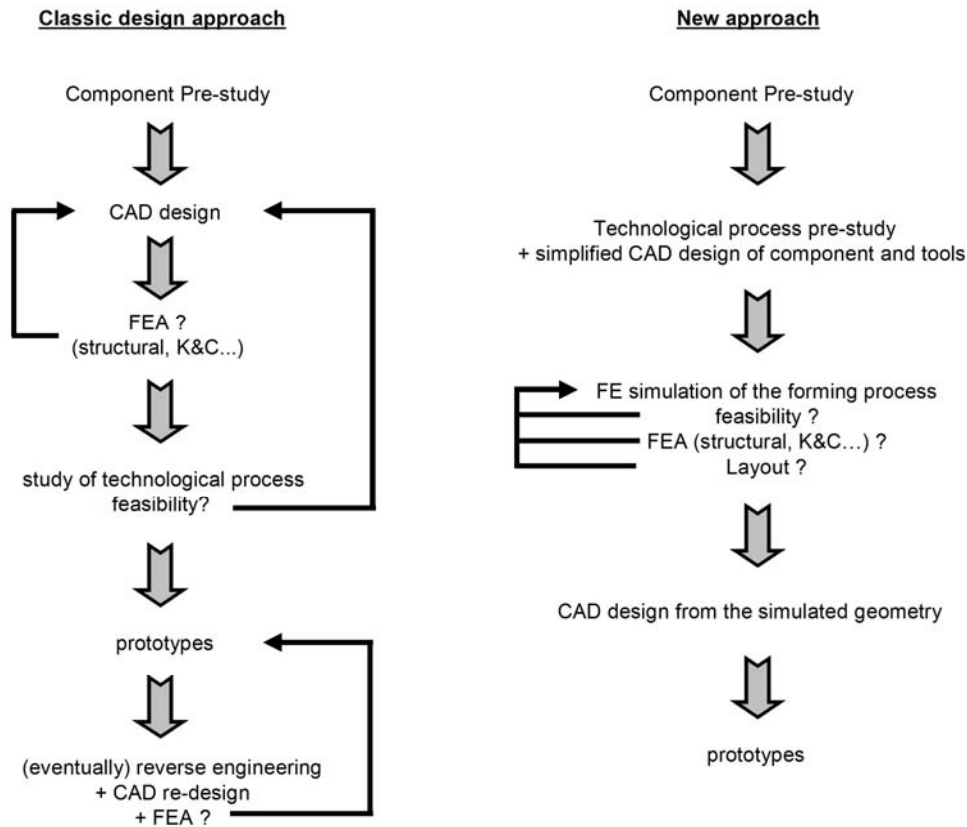


Figure 3. Comparison between the two approaches

The main advantages are:

- Better control on component costs, and on the technological process (feasibility outputs, number of steps required, troubleshooting anticipating the physical tryout phase)
- Better precision on layout verifications and structural FEA (simulated geometry in advance of the prototypes, map of thickness), leading to a better “design optimum” search
- Higher efficiency: the loops are kept inside the same environment (it’s a CAE-based approach).

3. Focus on the methodology

3.1 The first application

The methodology has been developed and applied on the recent “AWD twist beam” project.

The core of the methodology regards the simulation of the technological process: all the steps of the process have been simulated by using Abaqus. The geometry and the mechanical properties of the tube have been experimentally measured. A proper elasto-plastic model has been created, based on a series of traction tests (see fig. 4).

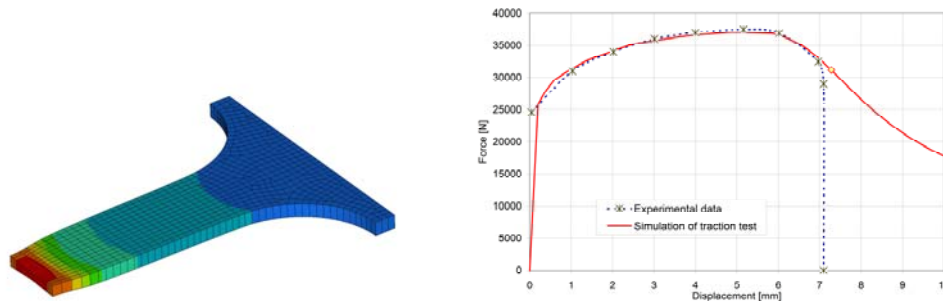


Figure 4. Elasto-plastic tuning of the material model

Abaqus/Explicit has been used for all the metalforming steps, while Abaqus/Standard has been used for the springback and re-orientation operations. Geometry, thicknesses and stress/strain status have been transferred between the simulation jobs, by means of the *IMPORT technique. In fig. 5 some snapshots of the forming steps are shown. Each technological operation comprises a number of sub-operations (for example blankholder closing, drawing) : they have been modeled using a number of STEPS inside the same simulation job.

The element model used in the simulations is continuum shell SC8R for the tube, because it demonstrated in the initial benchmarks the best performances with respect to contact interactions. The tools are modeled as surfaces of element type, on rigid bodies, moved by imposed displacements with appropriate amplitude curves.

Self contact in the inner surface of the tube has been adopted, because, during the drawing operation, contact closes in some areas (see Sec.A in fig. 7).

The mass scaling method has been used to reduce the computational time, after a first tuning phase, which led to the best compromise between kinetic energy / plastic dissipation work ratio and computational times.

Abaqus release 6.8.3 has been used, on two HP BL460 blades (two quad-core processors each one, 3GHz, 16 GB RAM), with Red Hat Enterprise Linux Server 5.2 (64bit).

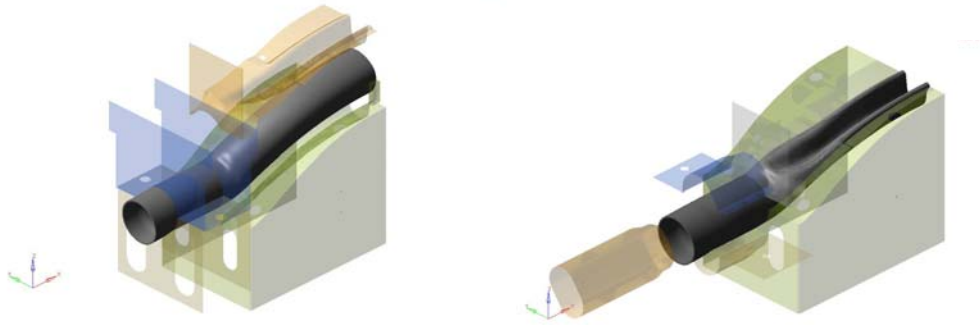


Figure 5. Two moments of the forming process

At the end of the process simulation, the FE model has been used as input for the classic FE analysis (structural, K&C performances), as well as layout verification (a load-deformed tassellated geometry has been generated by the FE mesh, under the critical mission loads).

Validation of the methodology comes from the comparison between the simulated geometry (blue colour), the real geometry generated by a reverse engineering 3D machine on the first prototype (red colour), and the original CAD geometry (green colour) (see fig. 6 to 9).

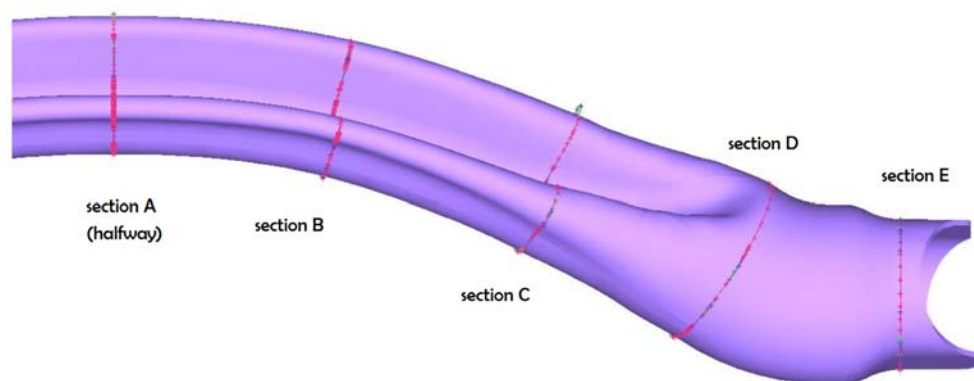


Figure 6. The cross-sections used for the shape comparisons

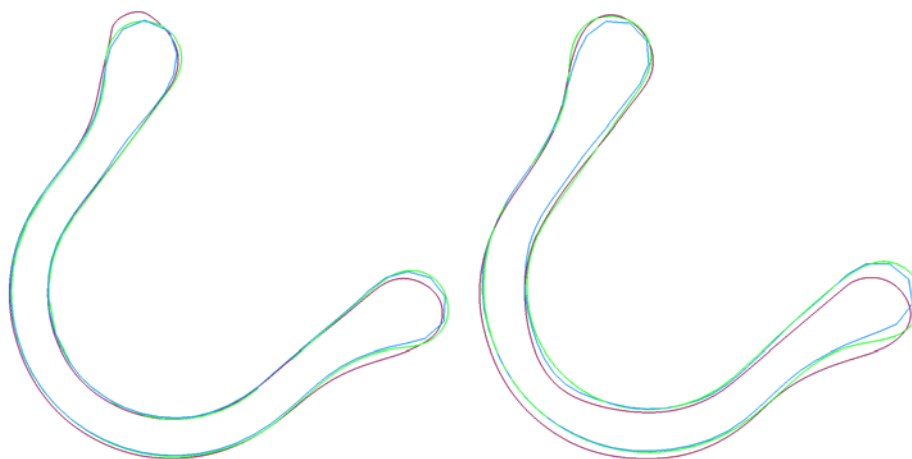


Figure 7. The shape comparisons: cross sections A and B (drawn portion)

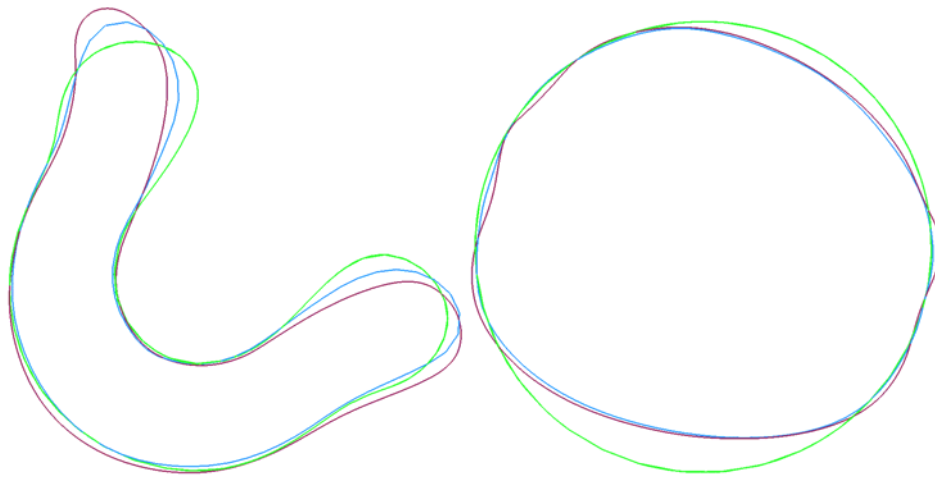


Figure 8. The shape comparisons: cross sections C and D (transition zone)

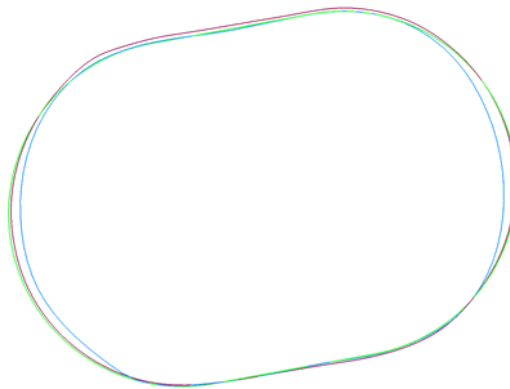


Figure 9. The shape comparisons: cross section E (interface zone)

Quite interesting are the results on the “transition zone”, where the final shape cannot be properly designed in advance by the CAD system, because of the absence of an inner constraint on the tube: this fact lets the material flow in an unpredictable behaviour.

3.2 The current step

The good correlation between the simulation and the first prototypes let us go on to the optimization phase, in order to improve the K&C performances, without sacrificing the structural resistance. At this point the design has been entirely carried on the CAE environment: different processes have been tested virtually, by changing the geometry of the tools on morphing-parametric FE models.

3.3 The next step

The development will proceed with the robustness virtual analysis of the process, testing the effects of:

- the mechanical property variations of the raw material,
- the geometric variation of the original tube (tolerances on thickness, diameter),
- the wear of the tooling, based on shear pressure maps, indicating the most stressed parts of the stamping tools,

on the performances of the axle (roll stiffness, structural performances).