# Improving the development of farming equipment using CAE technologies

## The deep integration of ANSYS and Spaceclaim in the design process of Maschio Gaspardo SpA allows the company to evaluate in advance the performances of its products, improving them to ensure quality

### The company

Maschio Gaspardo SpA is a leading company in the agricultural equipment market, deploying one of the widest varieties of farming implements worldwide. The production focuses on equipment for soil preparation, seeding, haymaking and crop protection.

### Spraying equipment and its engineering challenges

"Crop protection" is an expression that defines all the activities aimed to defend cultivations from threats menacing (directly or indirectly) the quality and profitability of the harvest. Usually, these activities sum up in the distribution of phytosanitary products over the fields. The distribution is performed with specific implements called sprayers, mainly built following a common design: a central tank holds the mixture to be dispersed, while lateral folding beams (called spraying booms) sustain the tubing that carries the fluid over the crop. The extension of the booms allows the coverage of a wide area of work (well over 30 meters).

Although necessary to save the crop, the use of phytosanitary products is to be limited to a minimum: in fact, it is an expense for the farmer and causes the reduction of quality of the harvest, being it exposed to chemicals.

To ensure that with minimum quantities of phytosanitary the full protection of the crop is still reached, structural and dynamic performances of the spraying equipment are crucial: the stability of the booms ensures homogeneity and accuracy of the dispersion, reducing the need for over-spraying. Lightweight booms with low inertia allow for the use of active control systems, that continuously and efficiently modify the geometry to better follow the profile of the soil, holding a constant spraying height. Furthermore, the reduction of weight and inertia is extremely important to grant maneuverability both on the road and on the field, enabling higher working speed. The direct consequences are the reduction of working times and the improvement of response time against threats, especially on large cultivations.

Therefore, the structural and oscillatory behaviors of the spraying booms define the capability of standing out amongst the competitors in the sprayer market. The study and optimization of these factors become a priority in the design process. To ensure that the new, top of the line spraying boom developed by the company will meet the

"Using ANSYS and this new design procedure, Maschio Gaspardo SpA avoids the use of the old "trial & error" approach that required the production of a large number of prototypes. Now we are able to save design and manufacturing time, manpower and money, producing and testing only a limited number of already well optimized prototypes" says Natalino Dorigutto, Project Manager at Maschio Gaspardo SpA

performance requirements defined and expected by the customers, ANSYS software has been deeply integrated in the design process, helping designers from the first design steps to the testing and validation process of the final product.

**The new spraying boom**

On the new spraying boom project, specific constraints posed by the market have defined the general layout of the structure, consisting of a series of sections joined with hinges and hydraulically actuated.

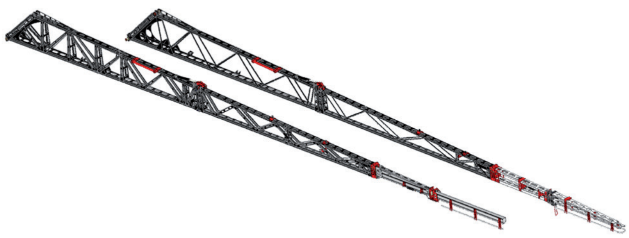

*Figure 1 - On the left, MY15 spraying boom in its final design. On the right, M16 boom in an advanced stage of development*

The benchmark for the study has been defined considering a similar model of boom from the previous year. The new boom's performance needs to at least match this baseline, while providing a significant reduction in weight. For sake of simplicity, the old model will be referred as "MY15" and the new one "MY16", accordingly to the years of development (Fig. 1).
FEM models of both MY15 and MY16 have been built using similar simplifications and procedures: the aim was to obtain a significant comparative result, but at the end of the project the results also proved to be compatible with the absolute measurements.
Geometries have been defeatured following standard practices, taking advantage of almost all Spaceclaim capabilities. Midsurfaces and beams were extracted, negligible features were removed and geometries were rearranged

*Figure 2 - On the left, original geometry for MY16 as received from CAD. On the right, geometry after the defeaturing process*

to match the configurations required for the study (Fig. 2).
Connections, joints, local refinements and point masses have been introduced in the ANSYS Mechanical model transferring named selections and coordinate systems from Spaceclaim to ANSYS: this is a significant advantage in terms of productivity, since a rearrangement of the geometry in Spaceclaim no longer requires the user to manually adjust all the features in ANSYS Mechanical once the geometry is updated. In a similar manner, meshing is built using named selection to automate the process of region selection in case of geometry modification.
To model weld joints of adjacent components, the "share topology" feature has been widely used, ensuring a quick and computationally light representation. In this way, also, information on the welds are not lost: in fact, local shell-to-solid submodelling is always available to further investigate the welded region if required, enabling to focus all the computational resources on a small portion of frame.
Hydraulic actuators have been represented either with rigid bodies or with springs and dampers elements (set up to match experimental data). The representation is chosen accordingly to the requirements of the tests to be performed on the physical prototype at the end of the project (Fig. 3).

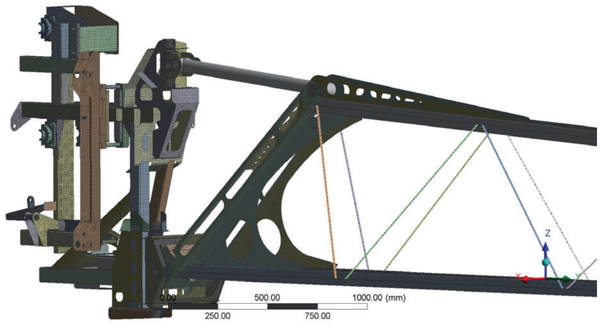


*Figure 3 - Example of mesh obtained on the defeatured geometry prior to the simulation of the whole assembly*

**Stage 1. Torsional analysis**

An important but sometimes overlooked problem is the torsion of the boom during the opening motion. This is a problem that lies outside of the working conditions mentioned before, but it is of the utmost importance to provide the farmer with the feeling of a robust implement. A "weak" boom, that twists more than expected, will not be accepted (Fig. 4).

*Figure 4 - Effect of low torsional stiffness on older boom models*

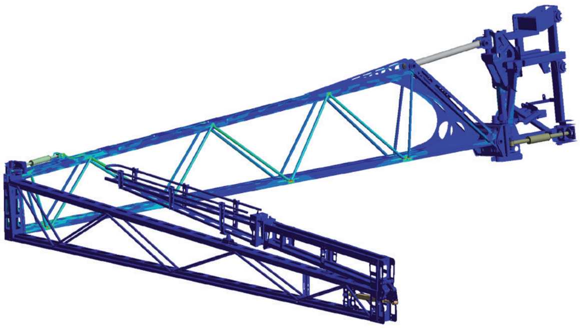

*Figure 5 - Example of torsional analysis performed"*

The Mechanical model shows that the new MY16 boom, reinforced with local plates, manages to maintain the performances of the older model, thus satisfying the requirements of the project (Fig. 5).
The defeaturing performed moving from tubular components to beam elements allows the designers to receive information on axial and bending loads acting on the tube, defining safety factors against elastic instability. Tube diameters have been reduced where possible and corrective actions have been enforced where needed.
This analysis also informs on the loads on the various hinges, allowing the definition of contact pressure and the correct sizing of bushings.

### Stage 2. First bending analysis

For safety purposes, booms are required to have the so-called "safety joint" at a certain distance from the tip: if the boom hits an obstacle (namely a tree, a pole etc.) between the safety joint and the tip, the applied force/displacement will disengage the joint. Regulations require the boom to sustain the hit undamaged below a certain speed. To compare the safety coefficients of the worst-case scenario hit, static analyses are set up for both MY15 and MY16: static structural analyses are considered suitable being low the speed defined by regulations (Fig. 6).

*Figure 6 - Example of bending analysis to evaluate the stress state in case of activation of the safety joint*

The analyses once again assess the quality of the MY16 design, which shows safety coefficients in the range or above those of MY15.
As a side result, the analysis provides with a first indication of the bending stiffness against actions in the direction of forward motion.
Moving from Stage1 to Stage2 of the study, features set up in Spaceclaim and ANSYS to automatically adjust and rebuild the models really come in handy, requiring only a small number of inputs from the user to adapt the model to the new configuration.

### Stage 3. Second bending analysis

Spraying booms hold spraying nozzles, which are all required to have the same ground clearance along the boom. On a perfectly flat field, this produces a constant spraying pattern beneath the implement. If the boom is subjected to large vertical displacements along its path, however, the spraying pattern becomes irregular. Also, active control systems are hindered, being the actual position of the nozzles different from that assumed by their software. It can easily be thought of adjusting the height of the nozzles to counteract the effects of the deformed shape, but this is not sufficient: the position will be correct in steady conditions, but during field use a high value of stiffness is required to avoid noticeable deformations when the sprayer hits uneven tracks.
Therefore, stiffness in the vertical direction must be evaluated. This is carried out in this stage (Fig. 7).

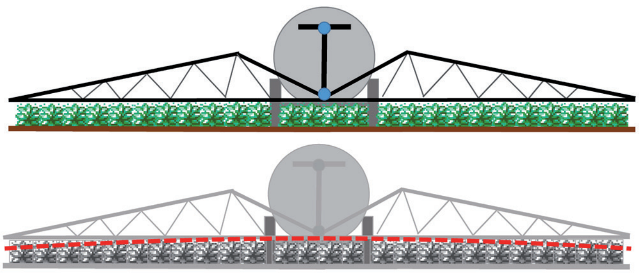

*Figure 7- Bending effect on the vertical plane. On top, ideal condition. Below, actual configuration*

The Mechanical model predicts a vertical stiffness for MY16 close to that of MY15, which satisfies the imposed requirements: spraying nozzles are held on an almost horizontal line over the 36 meters of width of the sprayer.

### Stage 4. Modal analysis of the structure

Analyses performed to this point aimed to define the behavior in static situations: stiffness and mass interacted but an overall view of the relationship between them is lacking. To address this, modal analyses are performed on MY15 and MY16 booms. Modal analyses sum up the results of interest in a convenient way, providing with "comparable" indexes (natural frequencies and mode shapes) while also informing the team of designers about possible resonance problems.
Usually, a problem with the comparison of modal results

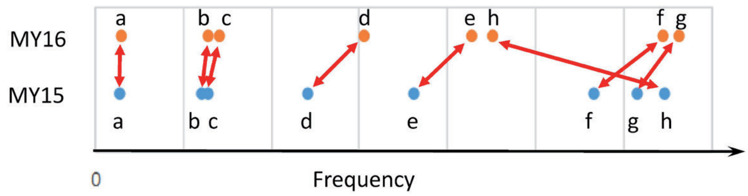


*Figure 8 - Mode shapes and associated frequencies: comparison between MY15 and MY16*

on complex structures consists in recognizing the same mode shape on different geometries. This process becomes extremely tricky when modes clearly distinct on one geometry tends to become mixed on another.
In this case, MY15 and MY16 are different products that share many core features of the base structure: this leads to similar mode shapes and to ease of comparison of the output (Fig. 8).

The results are promising: moving from MY15 to MY16, every mode shape is shifted to higher frequencies. Considering the frequencies of common excitations acting on the system, it can be stated that this shift has a positive effect on the boom's behavior: the appearance of detrimental mode shapes will be reduced, leading to a more stable boom. A significant exception is that related to the torsional mode: its appearance (mode "h") is anticipated to lower frequencies, but this is

*Figure 9 - Overshoot of an older model of spraying boom during the braking action*

not considered as a problem being the torsional mode hardly subjected to any excitation during field use.

## Stage 5. Transient simulation of a braking action

To this point, the static and modal results have been extremely useful to compare MY15 and MY16, but the behavior in a real-case dynamic scenario is still unknown. To evaluate this situation, a braking simulation is performed. This condition is chosen being it the most demanding, from a structural point of view, during field operation. It's also extremely useful to evaluate the quality of the spraying action: the backward and forward motion associated to the booms during braking is one of the major causes of over-spraying on the crop, situation that needs to be avoided reducing the amplitude of the movement and its duration (Fig. 9)

The simulation is run assigning to the structure an initial velocity, then a deceleration is imposed to the joints connecting the booms to the main frame of the sprayer, accordingly to experimental data (Fig. 10).
Once again, MY16 proves to be an efficient design. The deceleration input excites only the first mode shape in the horizontal plane (which is similar to the deformed configuration observed in Stage 2), and MY16, which has a much lower inertia than MY15, reduces the overshoot of about 20% compared that of the old model (the overshoot is defined picking as a reference the main frame of the sprayer).

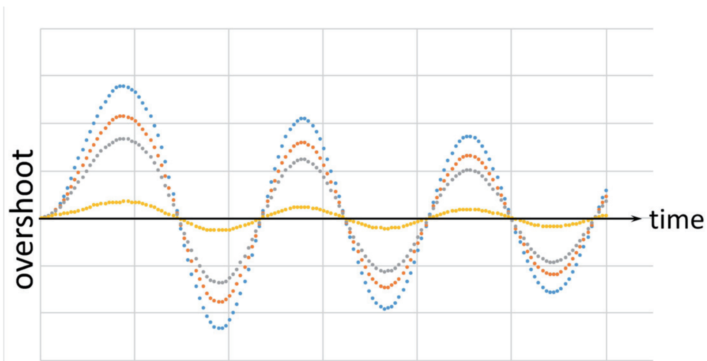


*Figure 10 - Overshoot of a boom in the transient analysis. Different colors correspond to different positions on the boom, picked to evaluate how different nozzles are affected by the braking action*

## Conclusions

The new design of the boom has been thoroughly evaluated during the project, using static, modal and transient analyses. The FEM team and the design team of Maschio Gaspardo SpA interacted profitably to address weaknesses emerged and to further improve the weight reduction and the safety coefficients of the product.

The final design, transferred to physical prototype, has behaved accordingly to the analyses (thus validating the numerical work) and has satisfied the project requirements: the new boom is lighter than the old model and exhibits significant improvement in stability. The wide use of FEM analyses reduced the need for prototypes and shrank the development time compared to old projects. During the creation and elaboration of this product, performed along the renewed R&D guidelines of Maschio Gaspardo SpA, Ansys acquired such an importance that it became an irreplaceable tool of the design process. Its conjoined use with Spaceclaim has further improved its capabilities, allowing for fast transfer of geometry, defeaturing and analysis, even with complex and large assemblies.

*Violato Valentino*
*R&D Dept. Maschio Gaspardo SpA*