Meshless Simulation Software Applied to the Preliminary Design Phase of the Product Development Process

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The study involves the construction and validation of a product development method using meshless simulation software in the preliminary phase of a project, for the structural and functional evaluation of the concept selected in the conceptual phase, to obtain a more robust concept for the detailed phase. This enhances the efficiency of project development, significantly reducing costs and computational time. Two studies will be carried out using meshless software and finite elements to validate the proposed method. Through computational cost evaluation, it was observed that using the meshless software application method in the preliminary phase resulted in a reduction of approximately 19 times in the time invested in CAE analysis during the product's preliminary development phase.
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Due to the highly competitive engineering innovation market, product development processes are being continually improved to produce and innovate in shorter periods while ensuring product quality. To reach this goal, new technologies must be integrated into these processes. In this context, CAD (Computer-Aided Design) and CAE (Computer-Aided Engineering) technologies are tools that provide significant competitive advantages by enabling the creation and validation of virtual models under real-world conditions. These tools help to significantly reduce deadlines and costs during product development [1]. In this context, applying and integrating CAD, especially CAE, into product development methodologies presents an opportunity to optimize the product development process.

Product Development Method

The area of product development is constantly evolving, leading to the creation of various methodologies to organize and systematize this process. Some methodologies are described in the literature, while others have been developed or adapted by companies. Product development models can include only the activities to be done, or they can specify procedures and methods in greater detail [1,2]. Given this, this work will follow the product development process proposed by Amaral, Silva, and Scalice (2006), whose phases are illustrated in Figure 1.

The method divides the process into three macro phases: the first is related to the strategic planning of the product, the second to development, and the third to the phase following project completion, which involves monitoring the product or service until its discontinuation.

In the development phase, the focal point of this work, there are the stages of project planning, informational design, conceptual design, detailed design, preparation, production, and, finally, the product launch. Initially, in the informational project, based on the project plan developed in the previous stage, target specifications are defined, which include product requirements and qualitative information. After this stage, the project proceeds to conceptual design, where design solutions are identified and generated, aiming for the best solution that meets the target specifications. At this stage, a set of documents is generated with the proposed solutions, resulting in a concept.

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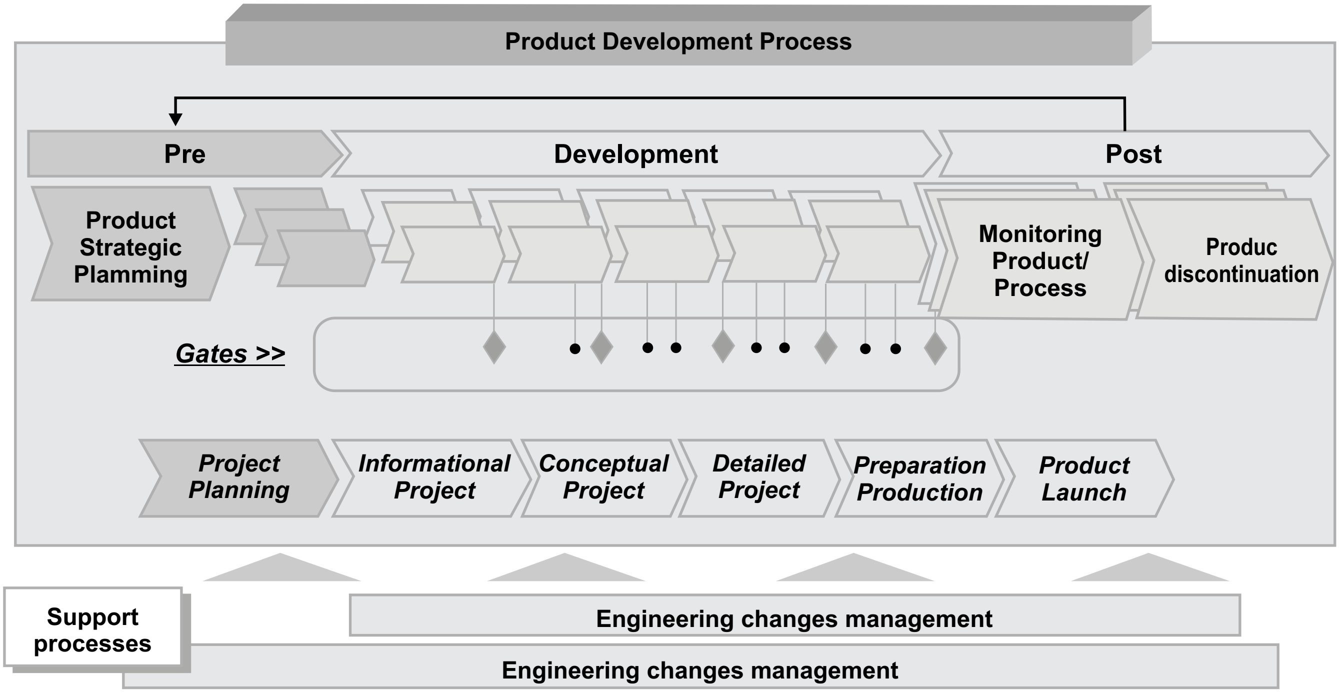
Figure 1. Steps of the product development process.



Source: Adapted from Amaral, Silva e Scalice (2006).

Before proceeding to the detailed design stage, where conceptions are converted into technical definitions, Amaral, Silva, and Scalice (2006) emphasize that other methodologies include a preliminary design stage, which is the first detailing cycle. This stage is typically included in complex projects or at the company's discretion, combining activities from both the conceptual and detailed stages. Finally, the development phase is concluded with the preparation, production, and launch of the product, and the post-development phase begins [2].

CAE: Finite Element and Meshless Methods

To analyze structures with complex boundary conditions, numerical computational methods are essential for obtaining accurate results. There are various methods with different applications, which can be based on meshing or meshless approaches. The finite element method (FEM), which is widely used and applied, provides highly accurate results but has some disadvantages, particularly in comparison to the meshless method [3].

The main disadvantages of FEM are the need to process the geometry and generate and rework the mesh, the quality of which is critical to the accuracy of the calculations and the reliability of the results, as it involves the dimensions and characteristics of the elements, among other aspects. This process is necessary to overcome element distortions, prevent errors in the simulation, and, consequently, in the results. However, this requires a longer working time, which is aggravated in complex structures with geometric discontinuities. Hence, FEM can require more time and computational cost. The meshless method emerged to overcome the difficulties associated with meshing. Using the method of dispersed nodes with points of interest eliminates the need for meshing, thereby significantly reducing the time required [4,5].

Materials and Methods

The study considered the demand for developing a support structure for a water reservoir with a capacity of 25,000 liters, featuring specified dimensions and an extension for personnel circulation during maintenance purposes. In the project, the Product Development Process, as proposed by Amaral, Silva, and Scalice (2006), was applied, following the phases briefly, as the purpose of the work is to analyze the time spent evaluating the concept during the preliminary design stage of the development phase. Although the original method does not include this stage, it incorporates it into the conceptual phase.It was decided to add it after the conceptual phase to evaluate better the concepts developed during that phase, allowing for their refinement before they are forwarded to the detailed phase.As the project progressed, the pre-development phase was deemed complete, enabling the project to proceed to the development phase.

In the informational design stage, the project's necessities and requirements were identified, and it was determined that the structure must support the weight of a 33.5-ton water reservoir and an occupancy load of 1.5 tons, applied to the upper part of the structure. A wind load of 0.4 T/m acting on the front of the structure was also considered.

In the conceptual phase, the solution principles were identified, and it was concluded that metal beams were the most suitable solution. This led to the basic development of the concepts, which progressed to the preliminary phase. In this phase, the project proceeded with the welded concept, as shown in Figure 2, of the structure to be analyzed.

Having that in view, to select the best concept to proceed to the detailed design stage, it is necessary to apply CAE to the project. Hence, the welded concept was simulated using the finite element method (FEM) in Ansys software and the meshless method in Altair SimSolid, to evaluate the performance of the two methods and ensure the same reliability of the results. Figure 3 presents the workflows for the simulations differ; the working and simulation times in both software were timed to evaluate the computational cost and the time needed to run the simulations.

Results and Discussion

Simulation Results

After conducting simulations in the Ansys and Altair SimSolid software, following the flowchart shown in Figure 4, the results for stresses and displacements in the structure were obtained. The maximum displacement found in the Z axis was -15.467 mm in the analysis carried out in Ansys, while in SimSolid, the value found was -26.1683 mm. Both results are shown in Figure 4. Figure 5 illustrates the displacements along the Y-axis. Again, the observed displacements were greater in the meshless analysis, with a maximum displacement of -6.3230 mm, whereas in the FEM analysis, it was -4.0643 mm.

Figure 6 shows the results of the equivalent stress. For these results, the values obtained for the meshless analysis in the SimSolid software proved to be more conservative, with a maximum stress of 319.1365 MPa located in the region of one of its supports (Figure 7). In the FEM analysis using Ansys software, stress peaks were observed in the same region, resulting in higher stresses due to stress concentrators caused by geometric discontinuities arising from the shell model generation process (Figure 7).

Simulation Time and Computational Cost

The total time taken to carry out the analysis in the ANSYS software was 250 minutes, of which 135 minutes were spent processing the geometry, 90 minutes were spent adjusting the contacts and loads, and 25 minutes were spent analyzing the results and making final adjustments. In the SimSolid software, the total analysis time was 12 minutes and 28 seconds, of which 10 minutes and 55 seconds were used for configuration and 1 minute and 33 seconds for analysis execution; in meshless analysis, the geometry treatment stage is not required.

Figure 2. Welded concept.

Figure 3. Simulation work flowchart.

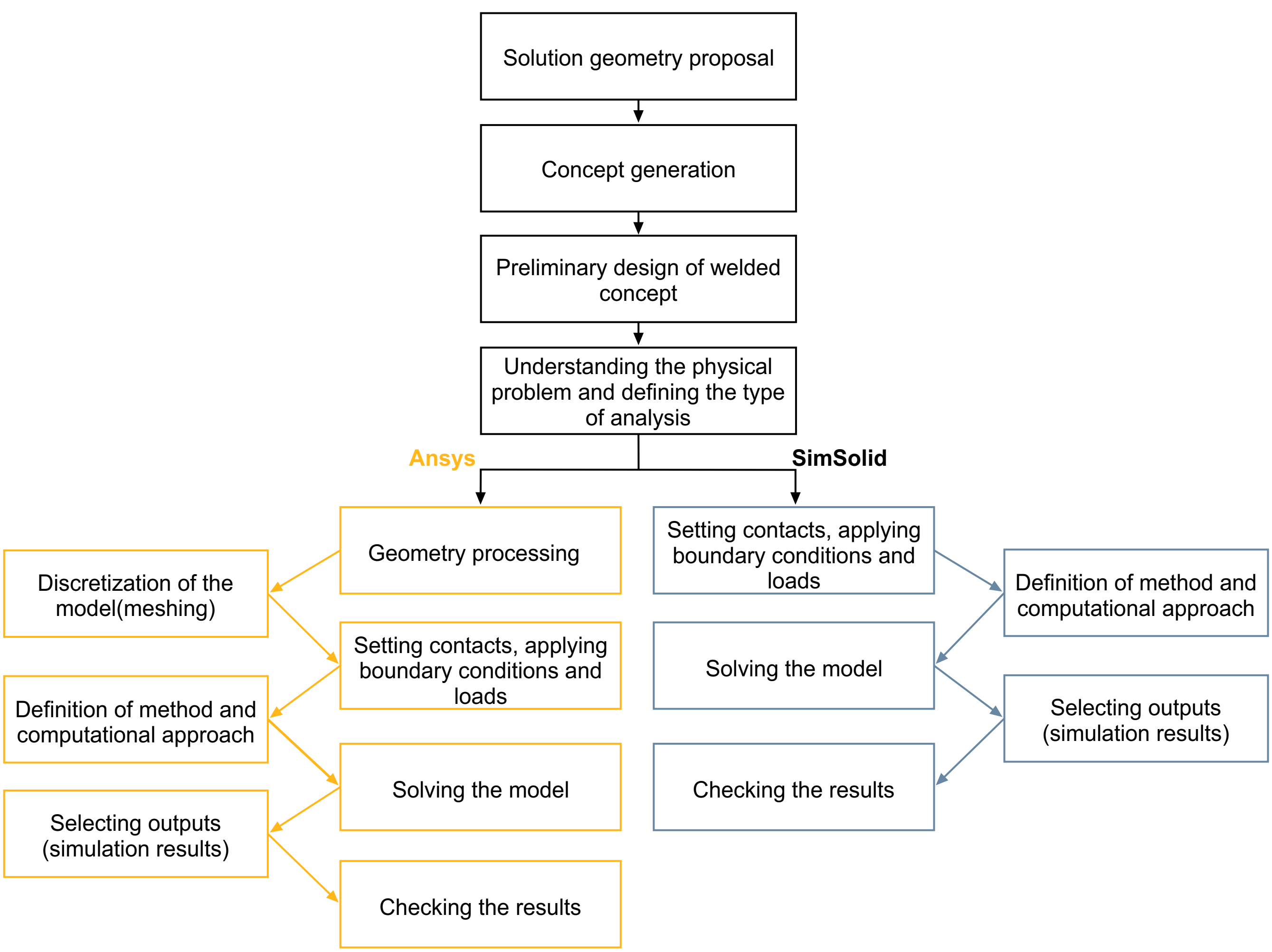


Figure 4. Z deformation results. a) Ansys, b) SimSolid.

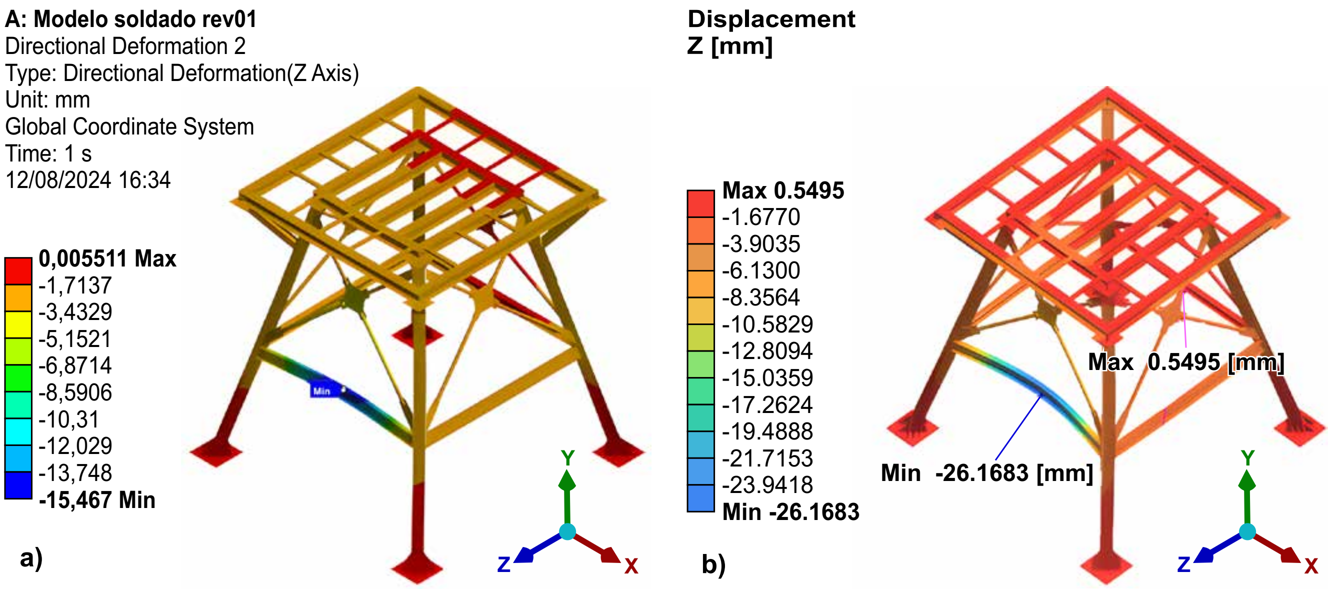
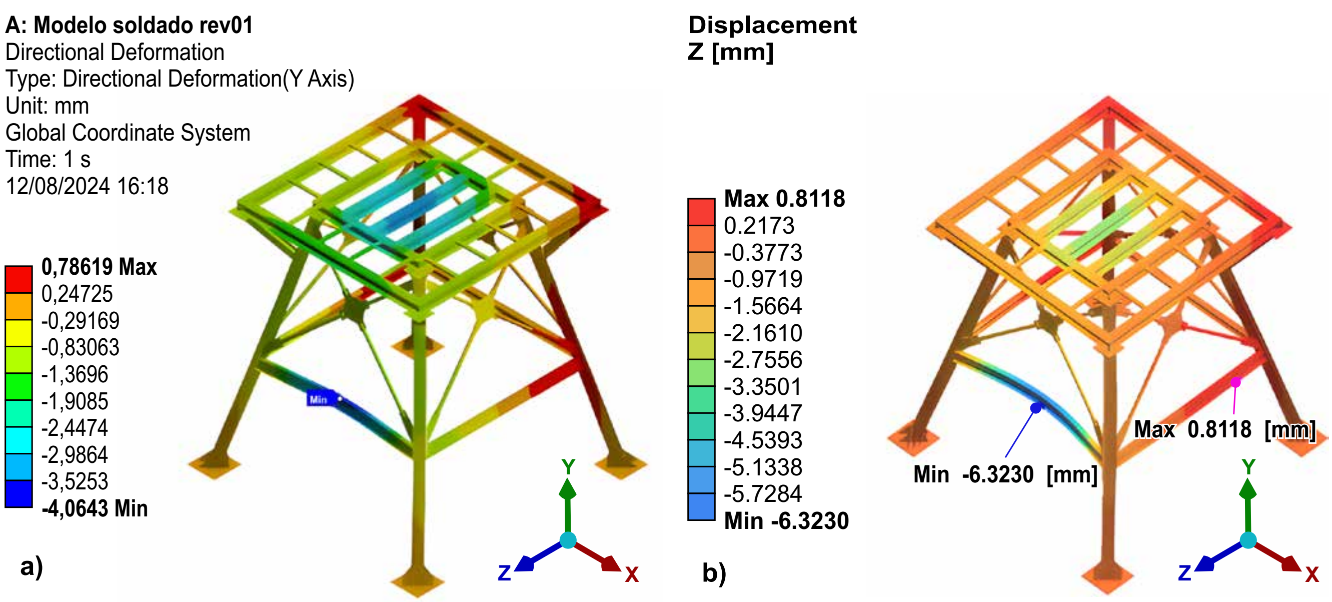


Figure 5. Y deformation results. a) Ansys, b) SimSolid.



Conclusion

Analyzing the results obtained by the Ansys and SimSolid software, it can be seen that the results from the meshless software are more conservative, with analysis times that can be 19 times shorter than those in the FEM software. It is therefore recommended to use meshless software in the preliminary design stage to obtain faster results and thus refine the concept for the following stages of design development. As the FEM software is more reliable in its results, it is recommended for use in analyses in the detailed design phase, where product specifications must be obtained. In this way, future studies can analyze multiple concepts and compare them to

Figure 6. Equivalent Stress Results. a) Ansys, b) SimSolid.

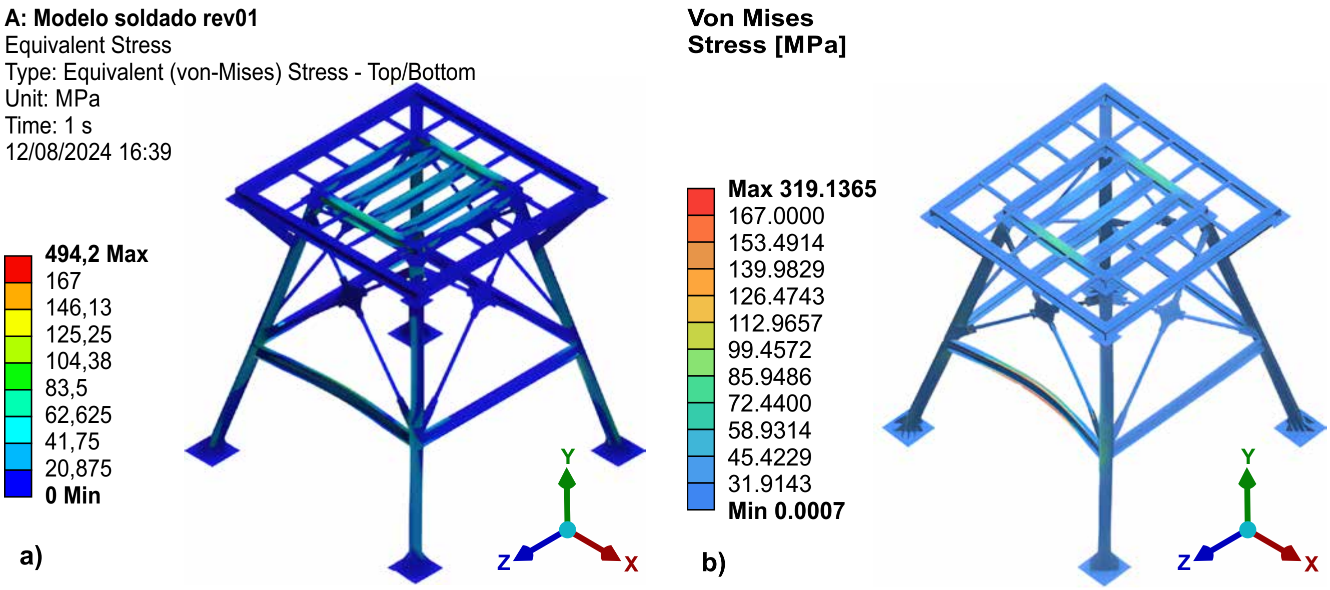
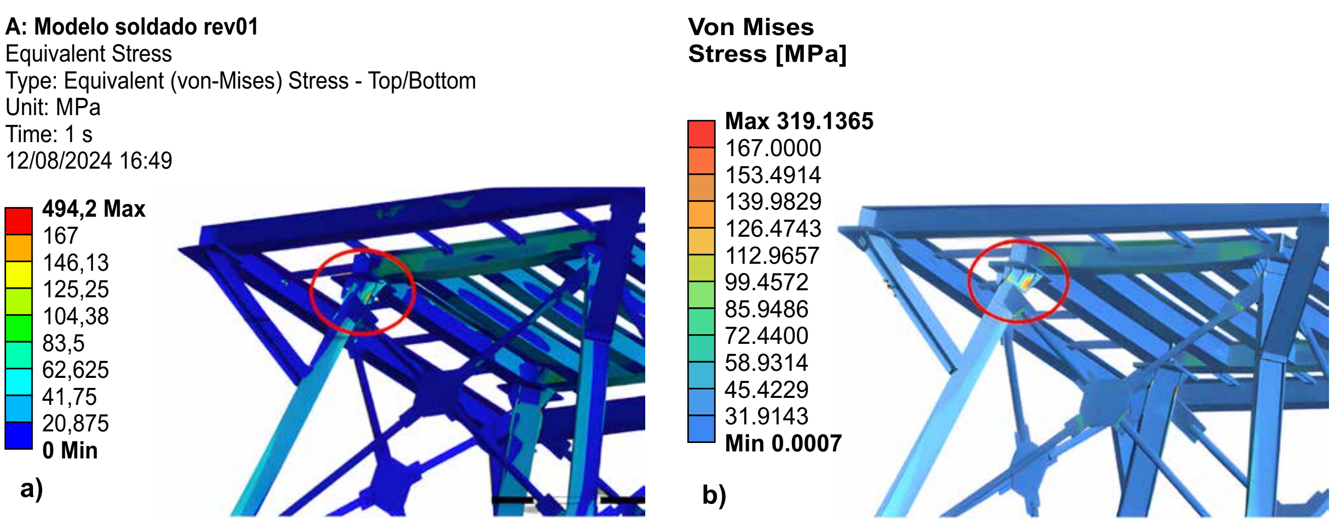


Figure 7. Region of maximum Stress Results. a) Ansys, b) SimSolid.



obtain their structural performance, and based on this, make informed design decisions to select or improve concepts.

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