EXPLICIT DYNAMIC ANALYSIS OF DISPOSABLE PLASTIC TRAYS CONSIDERING AN EFFECTOR PROGRAMMING ERROR

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ABSTRACT: The aim of the study is an explicit dynamic analysis of the elastic-plastic behavior of a plastic tray package to a faulty handling of the industrial robot. The robot is equipped with a multi-purpose effector for handling and palletizing operations in an industrial automated cell. The research is focused on the elastic-plastic behavior of the package due to an accidental impact of the robot frame effector with the clamping paddles, when the travel is incorrectly configured by the operator.

KEYWORDS: Explicit dynamics, plastic trays, experiments, verification

1. Introduction and related work

Robotic cell units are widely used in industry for rapidly handling trays packages. In the studied case a single tray package handling operation is performed. The containers are arranged in columns of 20 samples, which are placed by the industrial robot IRB 4600 in cardboard boxes, for further operations carried out by the robot and the palletizing system (Fig. 1). The columns enter the robotic cell through a tape conveyor and are then taken by the robot for storage purposes. Figure 2 illustrates the clamping system of the plastic tray.

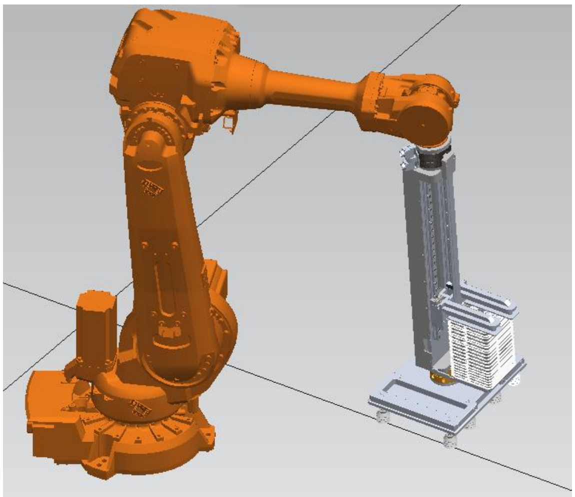

Fig. 1. Robotic unit and handled tray package in a Tecnomatix interface simulated sequence

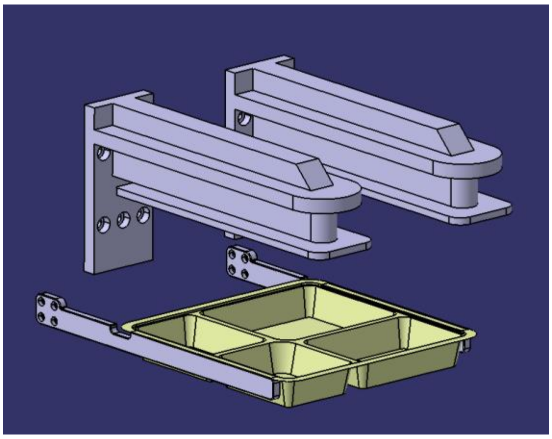

Fig. 2. Assembly of the anchoring and clamping elements of the plastic trays in the Catia V5R21

In order to efficiently perform the analysis in terms of computation time, the number of the trays in the manipulated column was reduced. Therefore, the simulation focused on the container material behavior, in order to accurately capture the plastic deformation of the trays.

Recent studies regarding computational modeling supported by experimental validation of sheet trays [1] demonstrate the topicality and importance of the research domain, but most of the assessments were related to aluminum containers and the research was devoted to the manufacturing

processes. Lindberg [2] also published a case study on the forming operations of initially plane paperboards, but the
The reported advances searched to increase the precision of the results coming from a simulation model of the tray forming and computation was performed with an implicit procedure. As such the proposed procedure is a novel approach in the filed.

The present work is divided in the following sections: chapter two describes the main preprocessing stages, chapter three is an assessment of the main results, section four presents the experimental verification of the results and the last section summarizes the main achievements and conclusions.

2. Preparation of the computation model

All the anchoring and clamping elements of the plastic trays were imported in the preprocessing module from the CAD system in a neutral step format. The geometry was then simplified and defeatured in order to allow a fine controlled mesh and to significantly reduce the computation resources (Fig. 3). The areas where the boundary conditions will be further applied are marked with a red line.

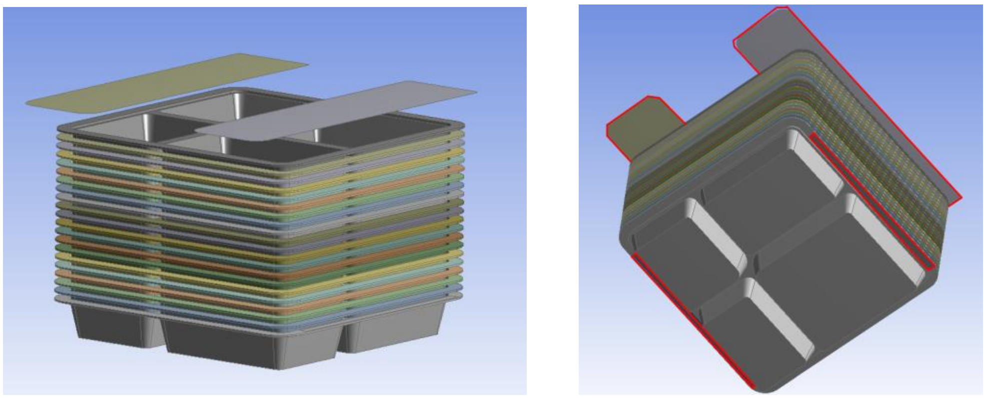

Fig. 3. Simplified geometry of the assembly

CAD details were removed and the assembly topology was cleaned (Fig. 4). The base of the trays was also simplified and the connecting rays were erased. When the primary model was ready the package pattern was generated and the column assembly was generated. Multiple checks were carried out to assure an appropriate connectivity between parts.

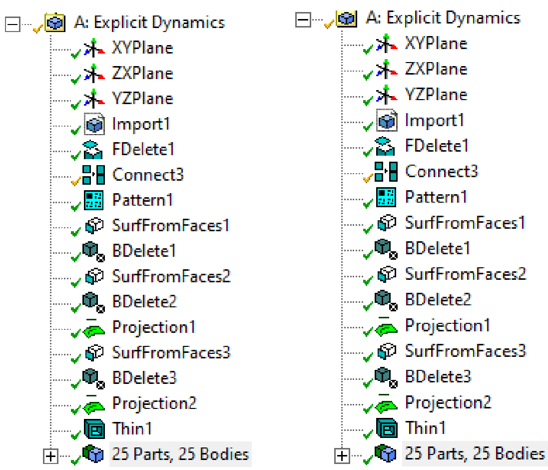

Fig. 4. Modeling and topology cleaning commands

The 3D model was then reduced to a 2D one, by extracting midsurfaces. Another important stage of the study was the assignment of appropriate materials and material laws on each component employing the Engineering database available in ANSYS and also defining new materials. A research on the web was completed to find the most appropriate material properties and material models for the components. All the data related to material definition are summarized in Table 1.

Tabel 1. Material properties

Material	Density [kg/m^3]	Young's Modulus [Pa]	Poisson's ratio	Specific Heat [J/kg ·C]
Aluminum Alloy	60	$7.1 \cdot 10^{10}$	0.33	875
Polyethylene	950	$1.1 \cdot 10^{9}$	0.42	2300
Stainless Steel	7750	$1.93 \cdot 10^{11}$	0.31	480

A high quality controlled mesh was performed and an average of 0.99 global element quality was achieved (Fig. 5). Fig. 6 illustrates the tray column mesh configuration.

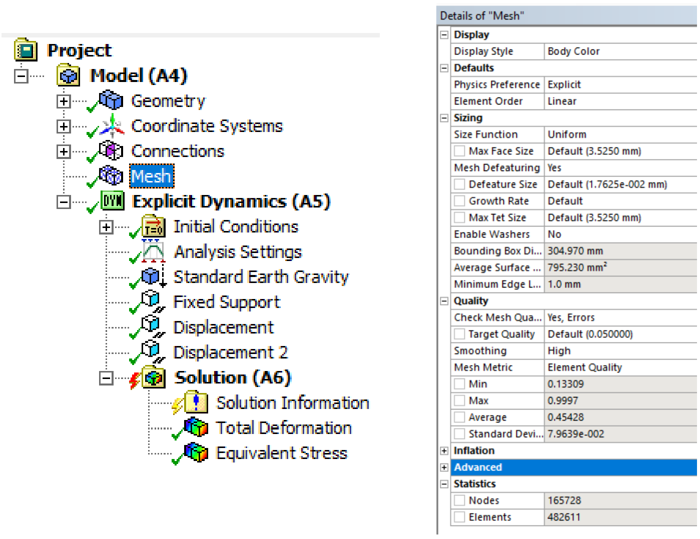

Fig. 5. Simulation work tree and mesh settings

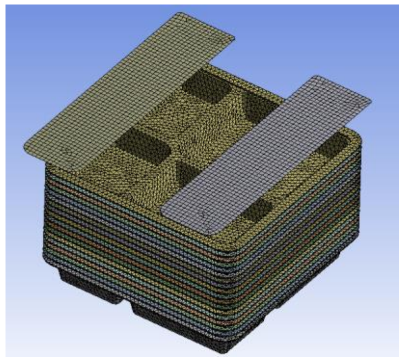

Fig. 6. Mesh details

3. Explicit dynamics analysis of the column tray

The explicit analysis algorithm works relatively easily with non-linear contacts and materials. During the computation the conservation of mass, momentum, and energy in Lagrange coordinates has to be fulfilled. These, together with a specific model of material and a set of initial data (eg. initial speeds, etc.) and boundary conditions fully define the dynamic phenomenon to be solved.

The computation algorithm calculates the accelerations at time n, the velocities at time n + ½ and the displacements at time n + 1. Based on the displacements {x}, the strains are determined. Then the stresses are calculated and the cycle repeats for the next time step.

For the Lagrange formulations, the mesh distorts with the material, so that mass conservation is automatically satisfied. During the solution the conservation of mass, momentum and energy must be conserved. That is why energy conservation is constantly monitored on the graph that also expresses the quality of the results.

Initial data:

- The clamping system moves on the Z-axis 120mm.
- The simulation time is 0.005s.

It is worth mentioning that despite successive simplifications done on the geometry and the efficient choice of the resolution settings the computation time remain high and the solution was achieved after 60 000 computation cycles performed by the explicit solver. This is why several successive treys were completed each lasting about 17-20 hours. Figures 7 to 10 plot the main simulation results.

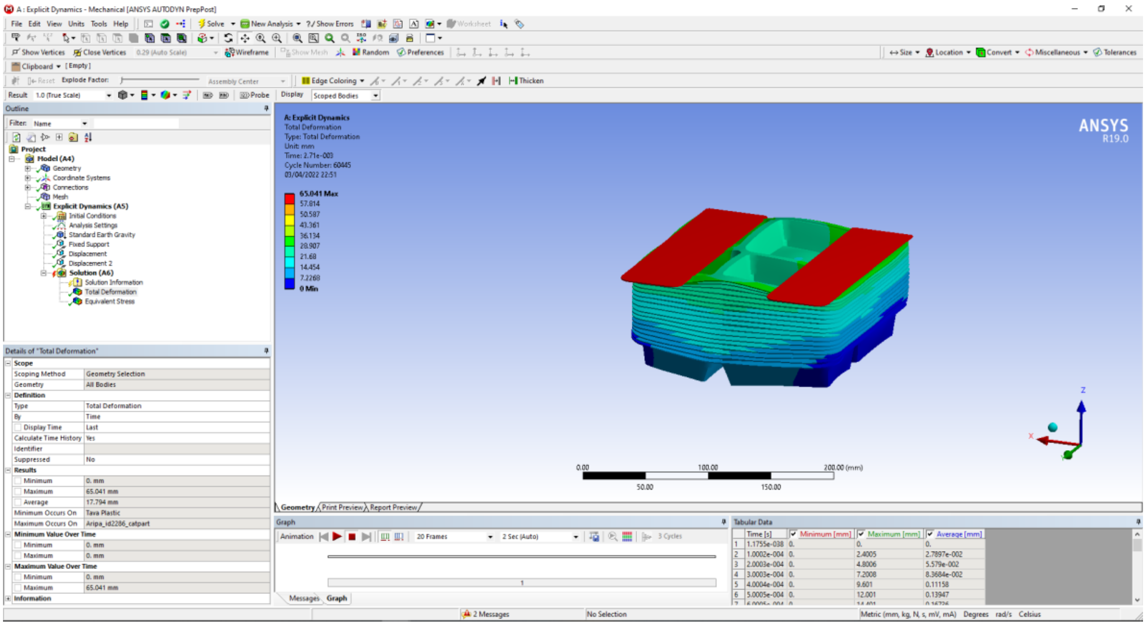

Fig. 7. Total deformation of the column tray

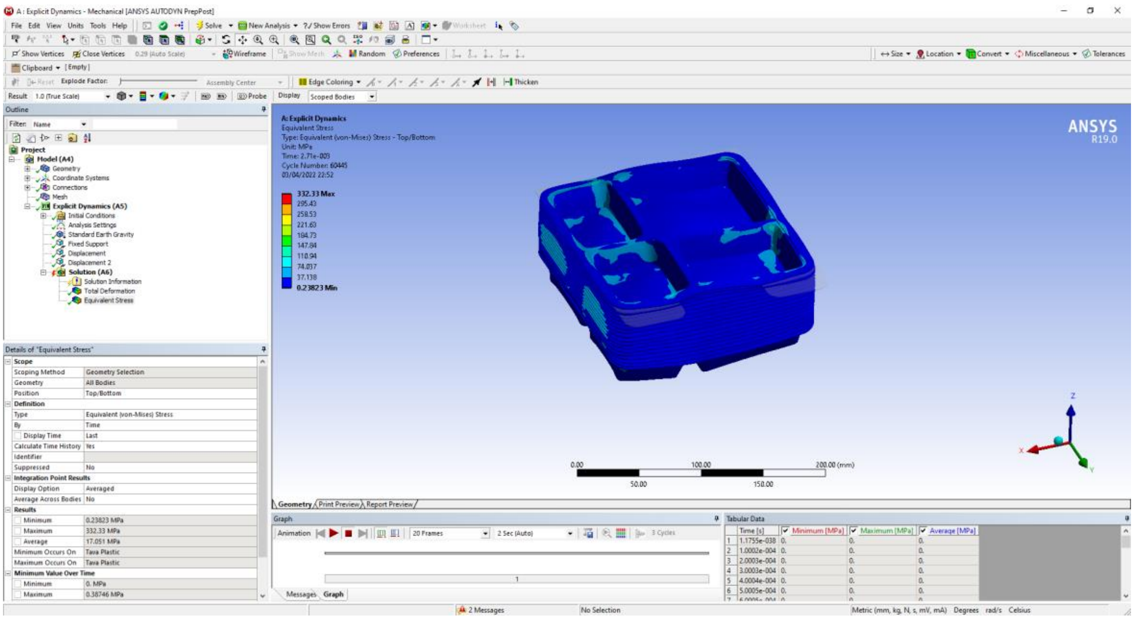

Fig. 8. The maximum equivalent von Mises stress of the column tray

The final computation took about 60 hours due to the plastic behavior of the tray pack and the fine mesh required capturing the phenomenon.

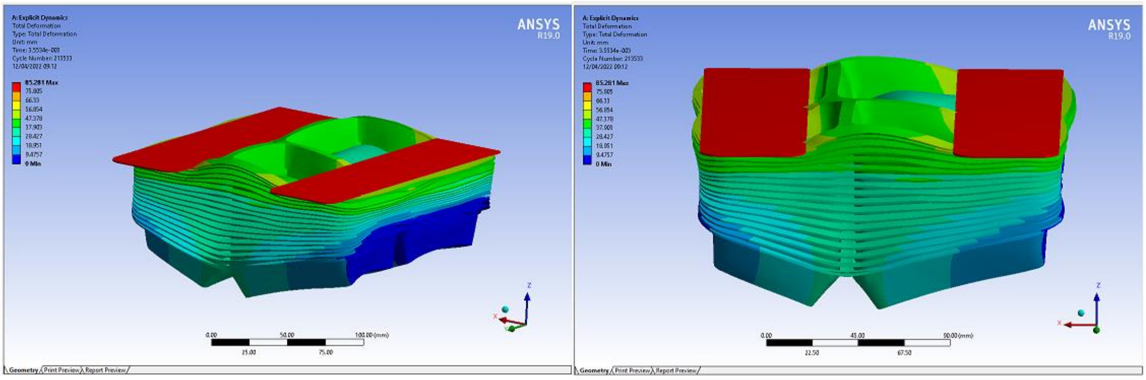

Fig. 5 Total deformation of the package in different perspectives

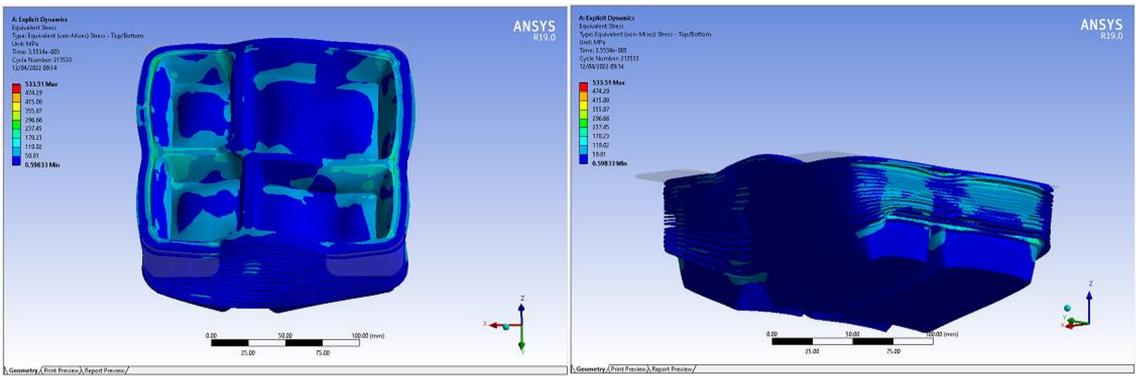

Fig. 10. Final results on the Top/Bottom part of the shell elements

4. Experimental verification of the results

Experimental investigation of the package behavior at impact with the clamping system was accomplished on an INSTRON 8872 - System for static and dynamic axial tests. The two-column system ensures increased rigidity. The drive cylinder and force cell are positioned at the top on the movable cross member. The experimental results confirmed the correctness of the calculation model and validated the simulation results. The measured exfoliation of the column reached 65 mm. The experimental results confirmed the correctness of the calculation model and validated the simulation results.

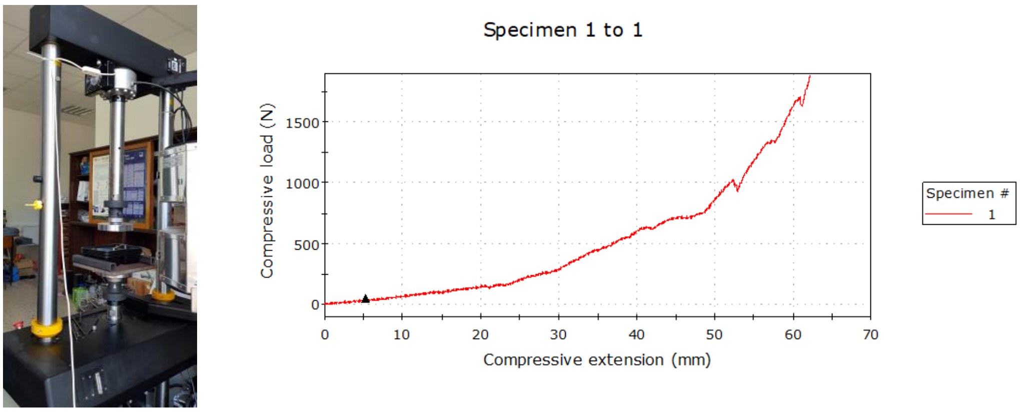

Fig. 11. Experimental setup and compressive load

5. Conclusion

The effect of the plastic deformation of the tray package has been studied by means of an explicit dynamic analysis. The results obtained on the 2D model were successful in terms of graphs and number of calculation cycles performed by the program, but the real phenomenon could not be visually captured on reduced models.

Successive material tests with composite plastics improved the results of the 2D simulations, but the final results are not realistic, because plastic containers behave as if they were manufactured of aluminum, which was not the case.

The transition from a 2D model to a 3D one brings spectacular results both from a graphical point of view but also in regard to the accuracy. The advantage of a 2D analysis is that the computation time is considerably shorter that on a 3D model. As such, the 2D analysis required 7500 calculation cycles with total time duration of 3 hours and the 3D analysis required 214 000 calculation cycles with total time duration of 60 hours.

The simplification of the geometric model was necessary at the beginning of the research as the multitude of unnecessary details would have made the analysis even more challenging. It is obvious that in an explicit dynamic analysis the accuracy of the results relies on the mesh, more then on the simulation settings. In this case a high-performance computer is required to perform the explicit dynamic analysis on a 3D model.

6. Acknowledgements

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