ROBOTIZED PALLETIZATION CELL WITH TWO INPUTS AND TWO OUTPUTS, FOR CARDBOARD BOXES, INTEGRATING AN INDUSTRIAL ARTICULATED ARM ROBOT

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The paper includes the stages of modeling and 3D design of a robotic palletizing cell with 2 inputs and 2 outputs of cardboard boxes integrating an ABB IRB 460 robot. technological for the parts to be manufactured separately and to verify the operating parameters following all stages of the CAE process.

1. Presentation of the robotic cell

The robotized cell for palletizing cardboard boxes with two inputs and two outputs comprises a FANUC M-410iC / 110 palletizing robot, a pallet dispenser and a system for arranging cardboard separators outside the cell.

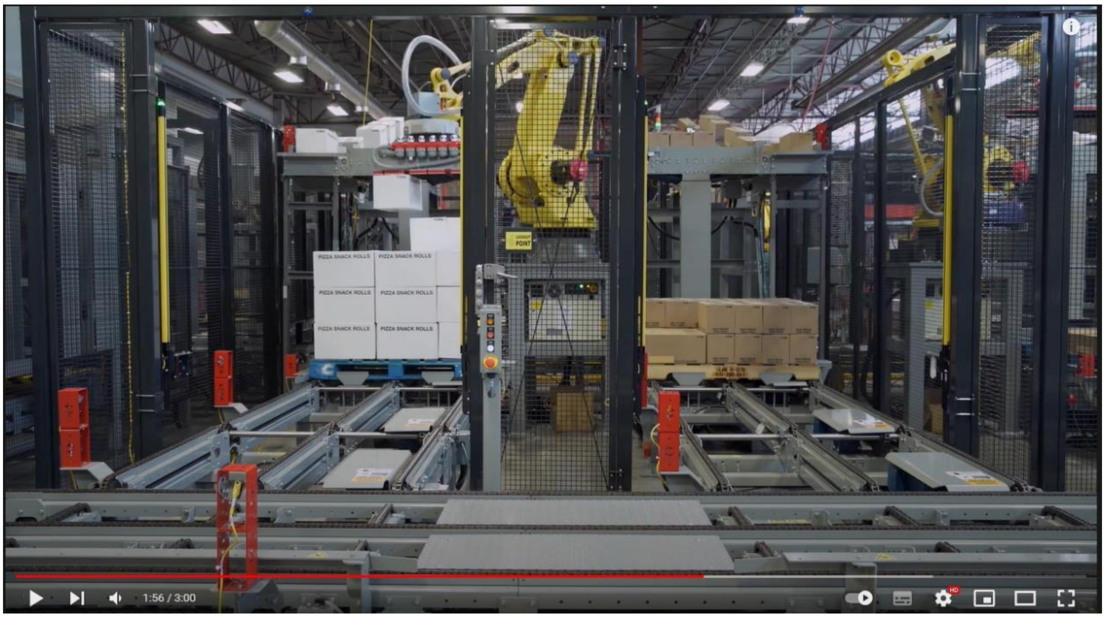


Fig. 1 Front image of the cell

The inlet conveyors in the cell are represented by the long, inclined conveyors, where in extension there is a roller conveyor.

Fig. 2 Image with tilted input conveyor

The boxes, when stopped in the stop, will be pushed by the piston located on the side of the conveyor. Finally, the boxes are transported on the central belt conveyor, also provided with a stop and a piston, which have the role of centering and fixing the boxes, so that they can be picked up by the robot.

Fig. 3 Picture with the box pickup area

The pallets on which the boxes will be placed will first leave the pallet storage, outside the cell. Parallel to the conveyor on which these pallets are transported is another conveyor, which will have the role of feeding the pallet storage. Subsequently, a portal robot will have a separator on each pallet.

Fig. 4 The pallet distributor outside the cell

From here, the pallet can continue on two routes: the first would be if the lifter remains high and then the pallet will reach the conveyors with 3 chains in extension, or, the second case, in which the lifter goes down, the pallet is driven on the transverse conveyor with 2 chains, it will reach the second lifter, which will lift the pallet and will continue its route on the conveyors with 3 chains in extension.

Once in front of the robot, the stopped pallets are ready to be loaded with 2 types of boxes. This palletizing operation is performed by the central robot, FANUC M-410iC / 110, placed on an overhead support and equipped with a vacuum effector. The effector is custom-made, because it has several groups of suction cups that allow you to take over a different number of boxes.

Fig. 5 Cell overview

The stack includes 4 rows of boxes of 10 boxes per row, respectively 14 boxes per row.The complete stacks will be transported outside the cell, where there are two other elevators, which when they go down, allow the stacks to continue the route on the conveyor with 3 output chains.

2. Kinematic diagram of the robot

Although the video for the foundation of the diploma project includes the Fanuc robot variant, due to the absence of internal documentation, I chose to equate it with the ABB IRB 460 robot, having the same load-bearing masses and radii of action.

Fig. 6 ABB IRB 460 robot overview

From the captures in the datasheet, the following defining parameters of the robot can be noticed:
• Maximum distance: 2.4 m;
• Load carrying capacity of the arm: 110 kg
• Number of ACN: 4;
• Mounting method: ground location;
• Repeatability in position: 0.02 mm;
• Dimensions of the robot base (1007 x 720 mm);
• Robot weight (925 kg).

Axis number	Workspace	Maximum speed/axis
Axis 1: Arm rotation	+165° to -165°	145°/s
Axis 2:	+85° to -40°	110°/s

Axis 3	+120° to -20°	120°/s
Axis 4	+300° to -300°	400°/s

Spațiu de lucru robot IRB 460-110/2.4

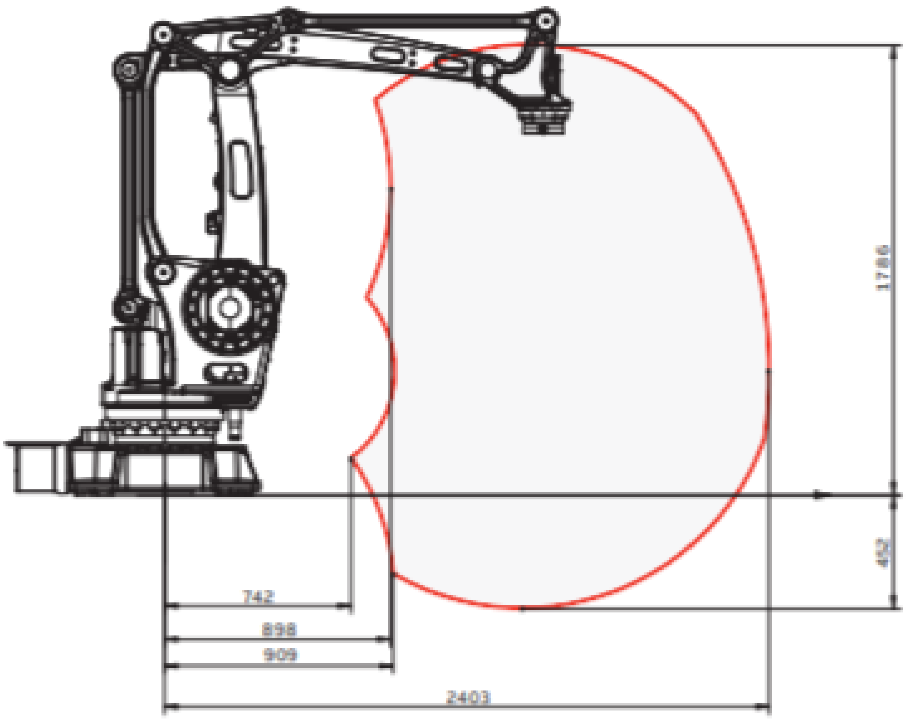


Fig. 7 Robot workspace

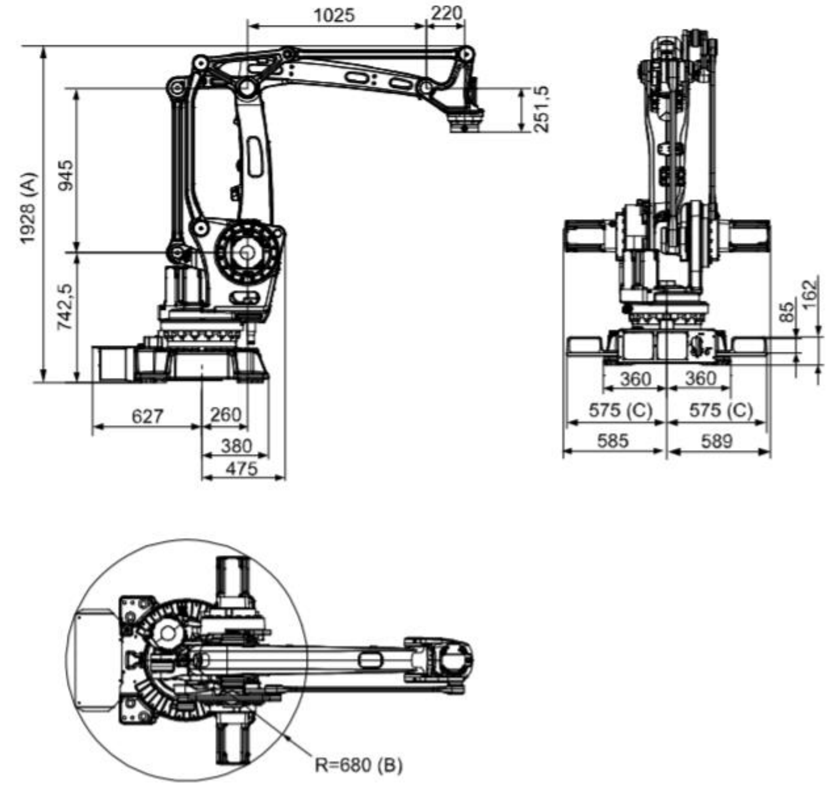


Fig. 8 The dimensions of the robot

The structural kinematic diagram shows the main axes of rotation and the passive torques of the robot, which form the triad and the dyad of the robot specific to the palletizing robots.

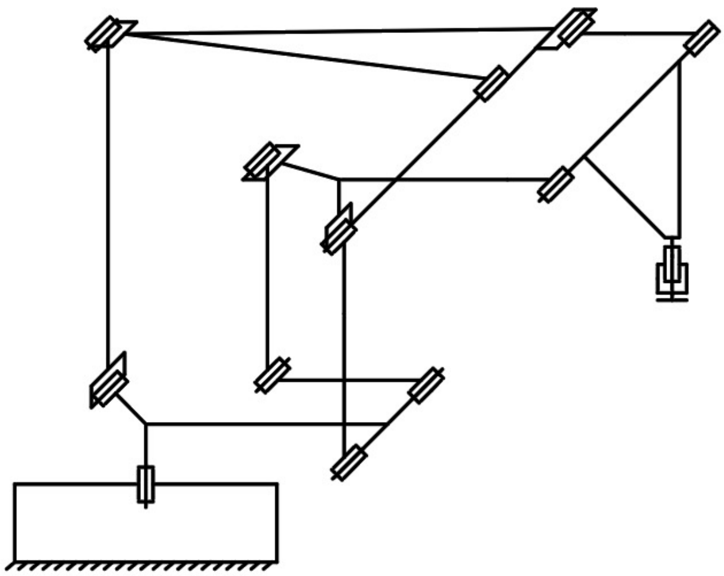


Fig. 10 Structural kinematic diagram of the robot

3. Internal structure

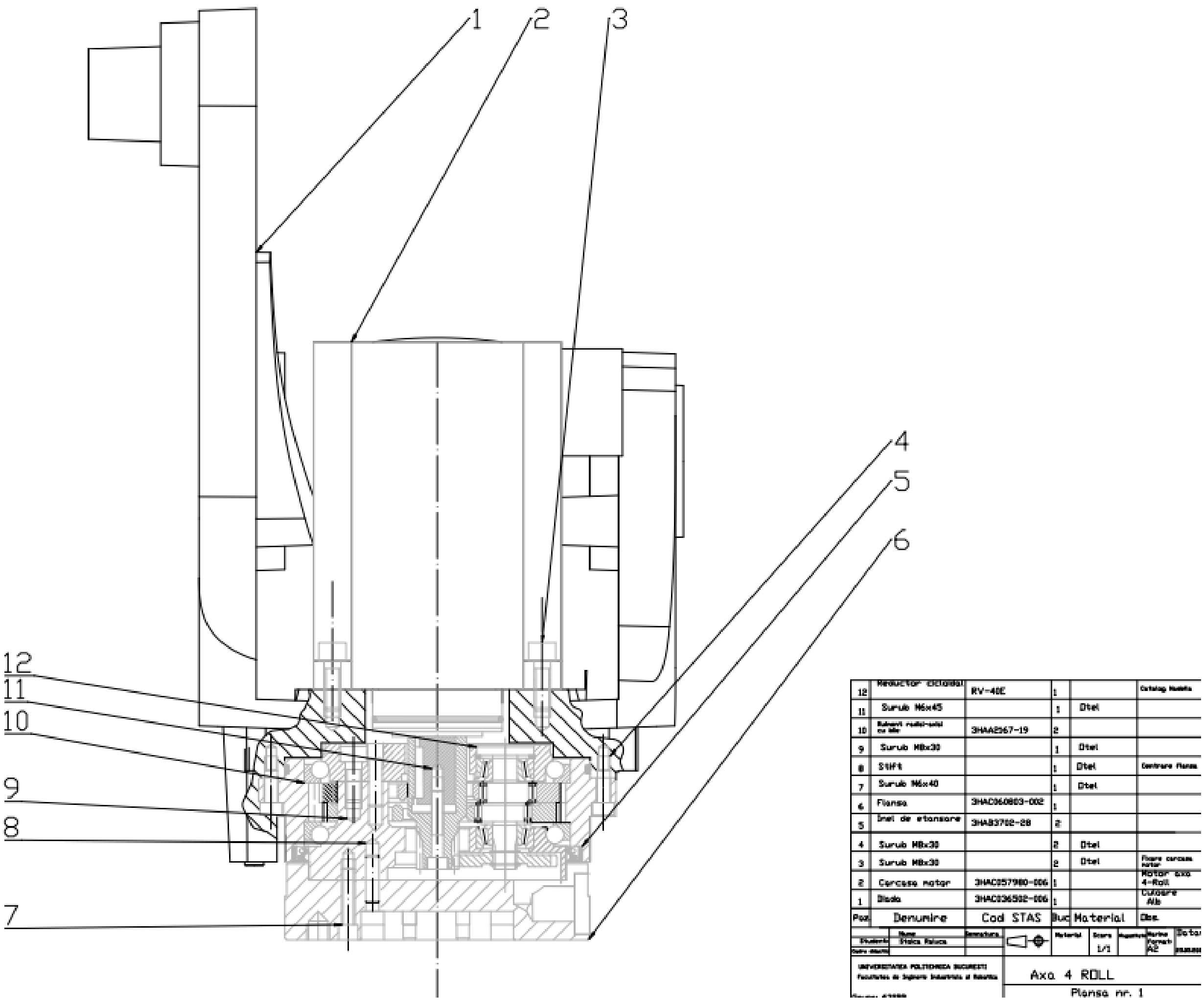


Fig. 11 Internal structure axis 4 ROLL

3. The technological film of the piston guide

To make the guide model in the figure below, we started from the execution drawing below. The overall dimensions of the piece are 200x40x80 mm.

To make the technological film, it is necessary to mark all the surfaces to be processed.

The material from which the piece is made is A356 aluminum alloy, which allows the piece to be made by cutting from a bar with a square section measuring 80x80x500 mm.

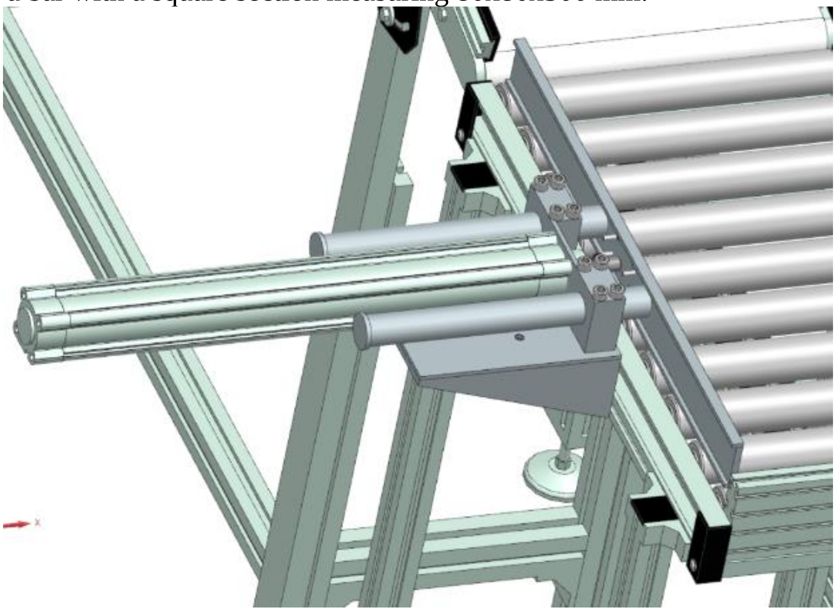


Fig. 13 3D model of the piece

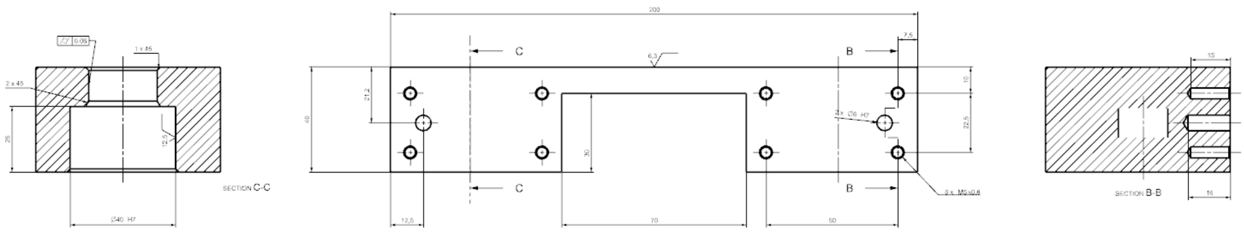


Fig. 14 Execution drawing of the piece

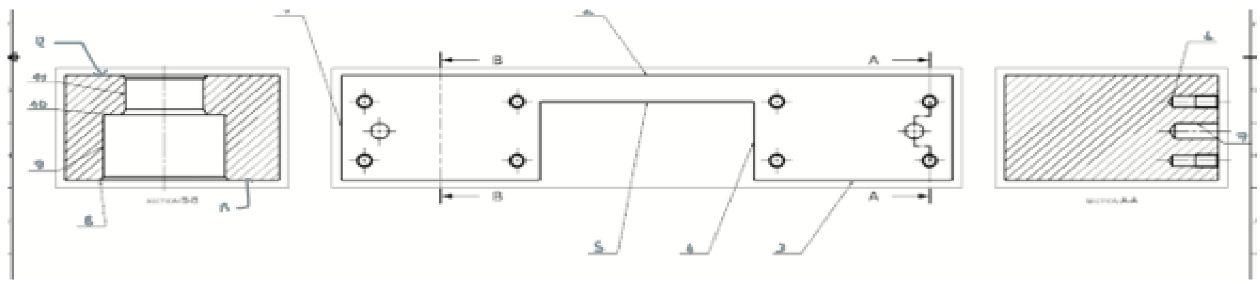


Fig. 15 Drawing with numbered surfaces

4. Scheme of surface operations

After grading the surfaces, it is necessary to establish the roughness, the main size and the shape and position tolerances.

S_k	Forma suprafetei	Dimensiuni principale[mm]	Rugozitatea R_a [µm]	Treapta(clasa)	Toleranta de forma[mm]	Pozitia reciproca	Alte conditii
S1	Plan	200	6.3	IT13			
S2	Plan	40	6.3	IT13			
S3	Plan	65	6.3	IT13			
S4	Plan	30	6.3	IT12			
S5	Plan	70	6.3	IT12			
S6	Cilindrica interioara	M5x15	3.2				
S7	Cilindrica interioara	∅6	1.6	IT7			
S8	Conica(tesitura)	1x45	6.3	IT13			
S9	Cilindrica interioara	∅40	12.5	IT13		Baza de referinta	
S10	Conica(tesitura)	2x45	6.3	IT13			
S11	Cilindrica interioara	∅26	12.5	IT7		⌭ 0.06	
S12	Plana						
S13	Plana						

Fig. 16 Establishing roughness and tolerances

Once these dimensions have been established with the tolerated dimensions, it is necessary to identify the role of the surface.

Categoria de suprafata	Codul suprafetei	Rolul suprafetei
Principală (funcțională)	S11	Bază de referință a piesei, asigură ghidarea unei piese de tip arbore (tija pistonului)
	S6	Asigură centrarea în corpul ansamblului
	S7	Asigură fixarea piesei prin șuruburi
	S9	Suprafeța pe care se va monta lagăr
Tehnologica	S1, S2, S3, S4, S5	

Fig. 17 Determining the role of the surface.

Finally, the workpiece processing stage can begin. Depending on each surface, the tool to be used for machining that surface will be calculated, as well as the necessary machines that will be used for cutting operations.

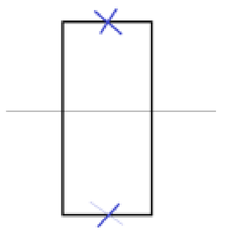
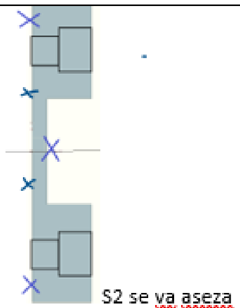
Operatie				Utilaje si sdv-uri	
Nr si denumire	Schita simplificata a operatiei	Fazele operatiei		Utilaj si scula aschietoare	Dispozitiv de prindere si verificare
		Nr.	denumire		
10.Operatie complexa		1	Orientarea si fixarea sf	Centru de prelucrare: EMCOMILL 350 2.CoroMill 245 3.CoroMill 390 4.CoroMill 390 5.CoroDrill 880	Prinderea se realizeaza cu menghina Verificarea se realizeaza cu subler
		2	Degrosare si finisare S2		
		3	Frezare S4, S5		
		4	Degrosare si finisare S3		
		5	Gaurire S9, S11		
20.Operatie complexa	 S2 se va aseza pe masa(reprez. Prin 4 puncte)	1	Orientarea si fixarea sf	Centru de prelucrare: EMCOMILL 350 2. CoroMill 245 3.CoroDrill 860 4.CoroMill Plura 5.CoroMill Plura	Prinderea se realizeaza cu menghina Verificarea se realizeaza cu subler
		2	Degrosare si finisare S12, S13		
		3	Gaurire S7		
		4	Gaurire cu tarod S6		
		5	Frezare S10, S8		

Fig. 18 Phases of the operation

5. The CAE process of the box alignment system

An interesting element of the cell is the box alignment system, which consists of a piston mounted on the side of the conveyor and a stop located at the end of travel of the transport system.

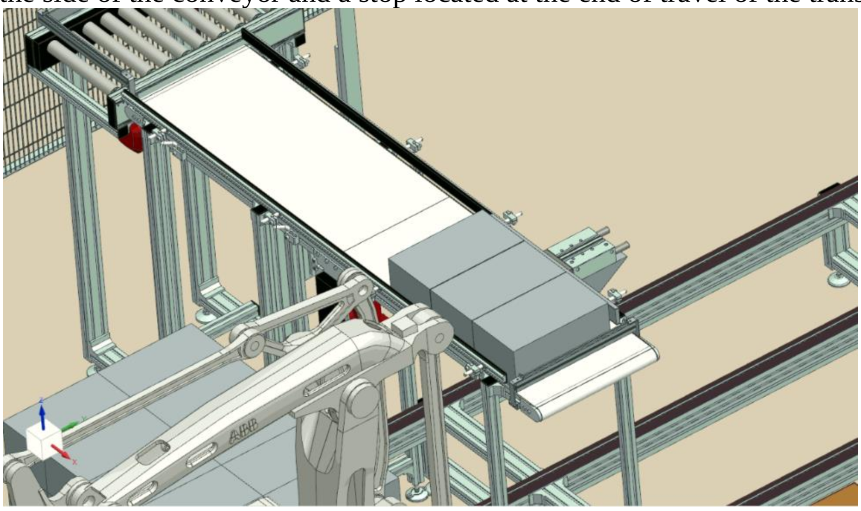


Fig. 19 3D model of the alignment system

In the first stage we exported as STEP file from NX all the components of the assembly to be analyzed: the belt conveyor, the 3 boxes to be taken by the robot, the piston that will push the boxes and the end-stopper mounted at the end of the conveyor.

After importing the file into Ansys, I started the operation of "cleaning" the model, which aims to simplify the geometric model, eliminate insignificant details in terms of simulation and thus reduce computation time, but also to use as much as possible few types of material.
"Cleaning" a model refers to the elimination of all elements that will not be included in the analysis and therefore will not affect the simulation.

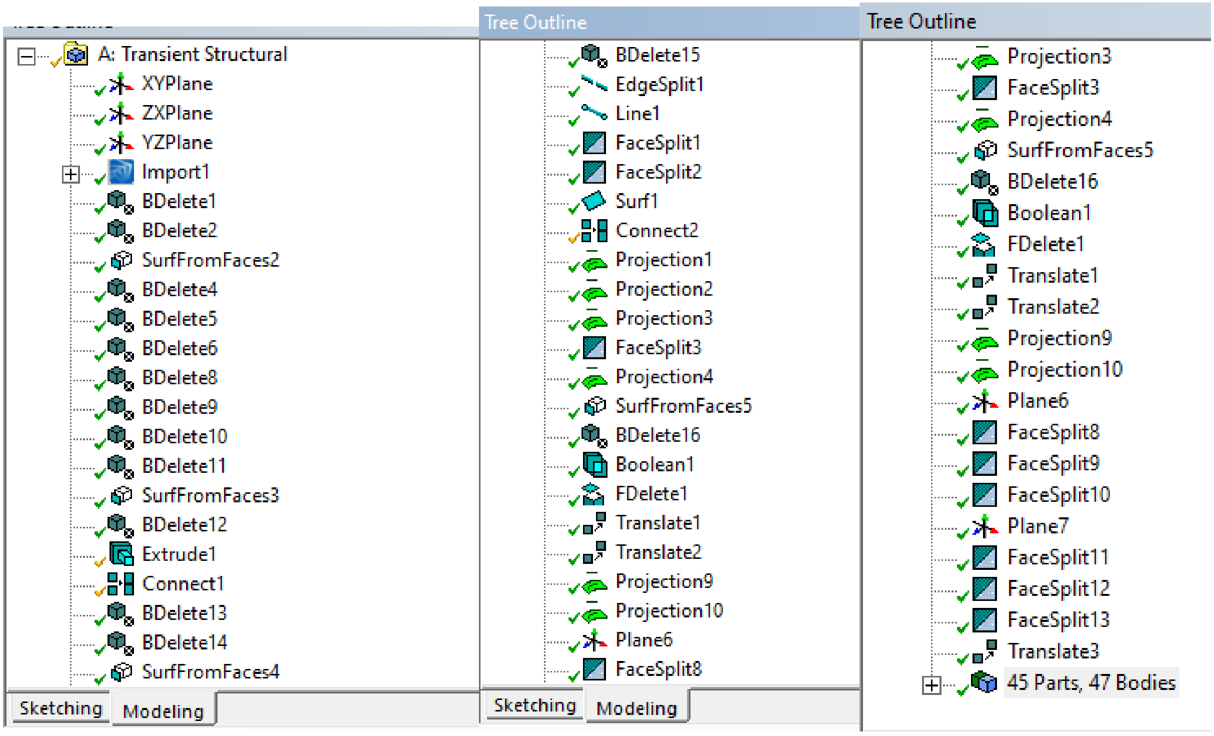


Fig.20: List of orders used for cleaning

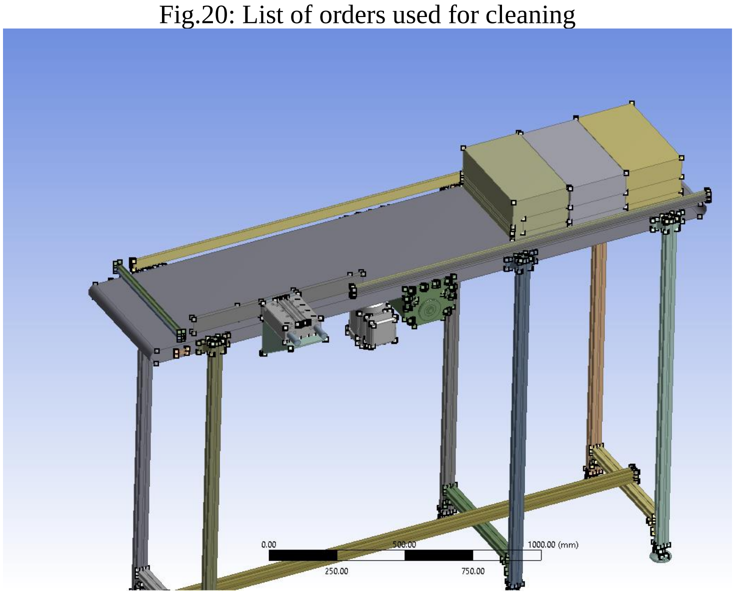


Fig.21 Geometric pattern after cleaning

Transient analysis (Structural Transient) determines the dynamic response of the structure to a time-varying force (response in time) through an implicit calculation of the equations of motion. The results are: displacements, specific deformations, stresses, reactions, contact forces, etc. - all results illustrating the variation over time of these response quantities.

The initial data that we entered as parameters of the transient regime were calculated following the simulation performed in the Process Simulate program, which were centralized in an excel file (Fig. 3.2):

Pozitia	Cursa	Timp	Comentariu
1	1400	5	cutii vin pe pozitia din capat
2	56.6198		cursa piston pana la cutii
3	10.307		cutia 1 din marginea conv
4	15.315		cutia 2 mijloc
5	5.3303		cutia 3 spre opritor
6	1408.7	1.66667	cursa cutia 3 inspre opritor
7	1411.7	1.66667	cursa cutie 2 spre capat
8	1411.7	1.66667	cursa cutie 3 spre capat

Fig.21 : Centralized data in excel

Also, the solution settings influence the convergence of the results and because it is a transient analysis, the number of steps in which the simulation is performed must be set:

Step Controls	
Number Of Steps	2.
Current Step Number	1.
Step End Time	5. s
Auto Time Stepping	Off
Define By	Substeps
Number Of Substeps	20.
Time Integration	On
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Large Deflection	On
Restart Controls	

Fig.22: Number of simulation steps

In the dynamic analysis, contact types and kinematic torques must also be defined.

Therefore, we defined several types of contacts as follows: 3 “Frictional” contacts with a coefficient of friction μ = 0.4, 3 “Frictionless” contacts and other “Frictional” contacts with μ = 0.42.

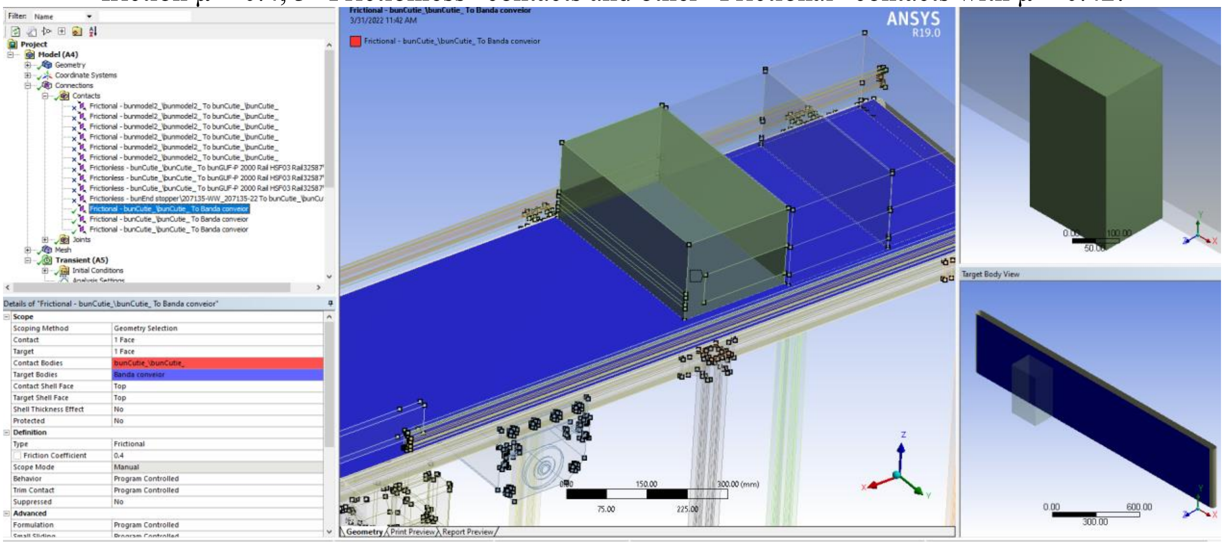


Fig.23 : Contact cu frecare de tip “face to face”, între banda conveiorului și fața cutiei.

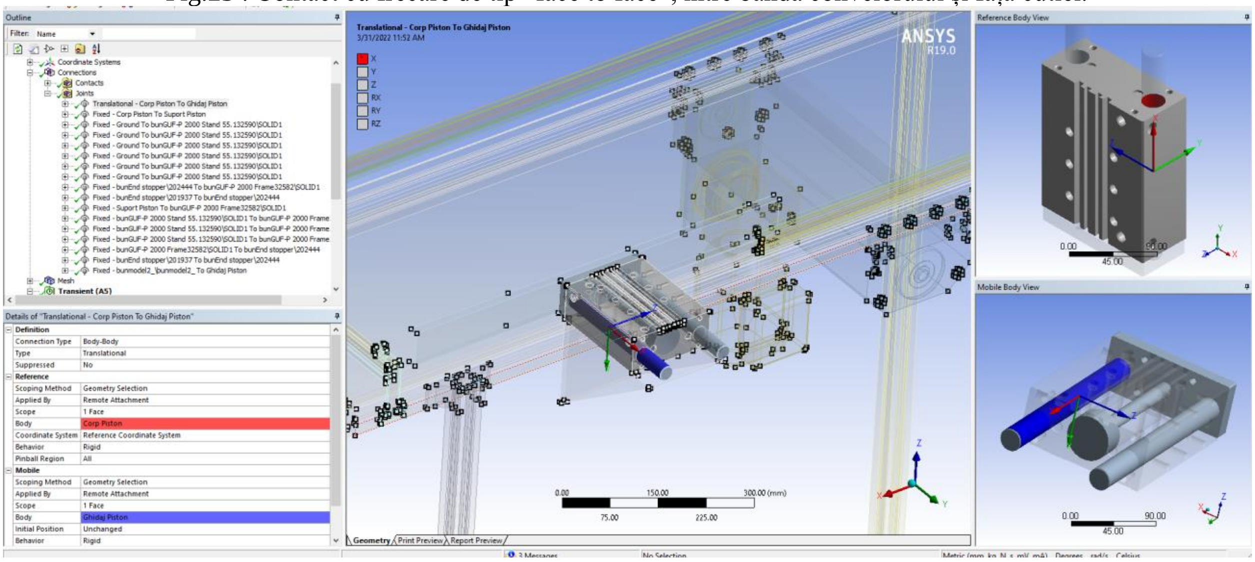


Fig.24“Translational” kinematic coupling, “body to body”, between the piston body and the rod body to which the piston “blade” is connected.

The next step is to discretize the geometric pattern.

Discretization is the approximation of the geometric model through a network with a large but finite number of elements with a simple geometric configuration.

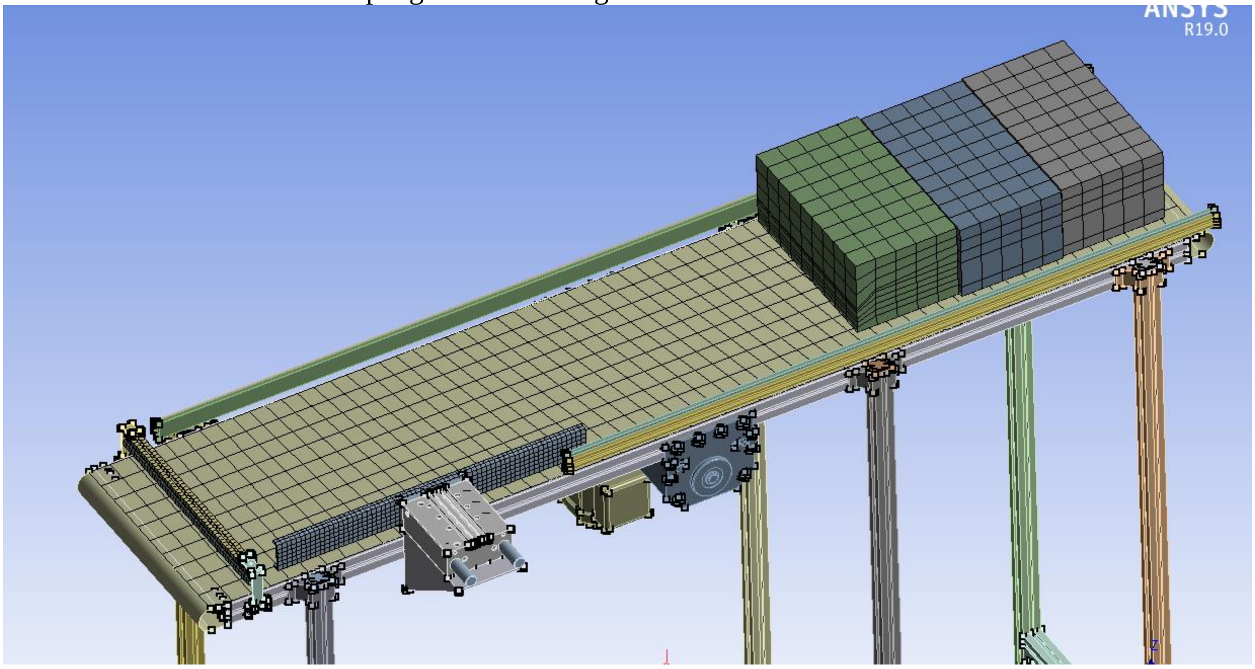


Fig.25. Discretized components of the assembly

Once the discretization is completed, we can start the dynamic analysis in transient mode.

Each box will have its own stroke, because their alignment will be done when the electric piston is actuated.

Only three types of materials were used: Structural steel (general purpose steel) for piston and stopper, Carton - separately defined material for boxes and rubber - separately defined material for the conveyor belt.

At that point the piston will start operating, so the boxes must move along the Y axis at the distance corresponding to each at that time:

• Box 1 moves 5.33 mm at the time of 7.8 seconds;
• Box 2 moves 15,315 mm at the time of the second 7.3;
• Box 3 moves 10,307 mm at a time of 7.5 seconds;

After performing the dynamic analysis in transient mode and obtaining some results, in the graphical interface of Workbench we could process the displacements, specific deformations, but also the stresses that appear on the chosen components in the form of a color gradient where: blue areas are the least required areas. and the red ones represent the areas with the most demands.

Following this analysis, the following results were obtained:

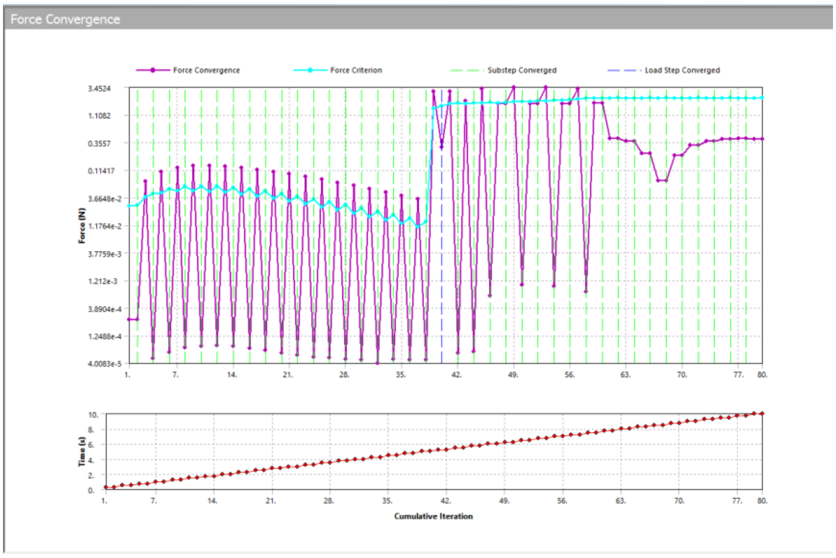


Fig.26: Monitoring the solution according to the criterion of convergence of forces

The bisections represent strong discontinuities in the model during the simulation that the program tries to solve forcibly. They often occur due to poor discretization. The fact that the number of iterations is low and the result of the simulation does not show bisects, is an indicator that the analysis performed is correct: it means that the discretization is correct and the geometric model is good, valid.

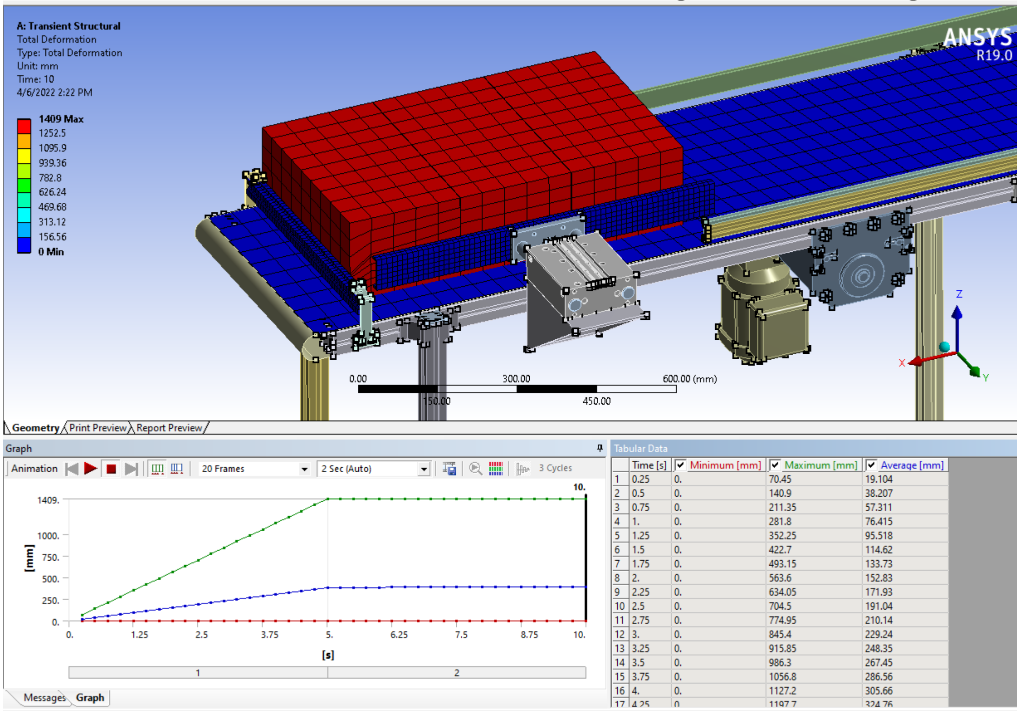


Fig.27: Total displacements for all objects

The total displacement reaches a value of 1409 mm in an interval of 10 seconds, the average being 397.4 mm.

6. 3D modeling of the robotic cell

3D modeling of the cell was performed in the Siemens NX software, where various components were imported as native STEP files, and other components were modeled in this software.

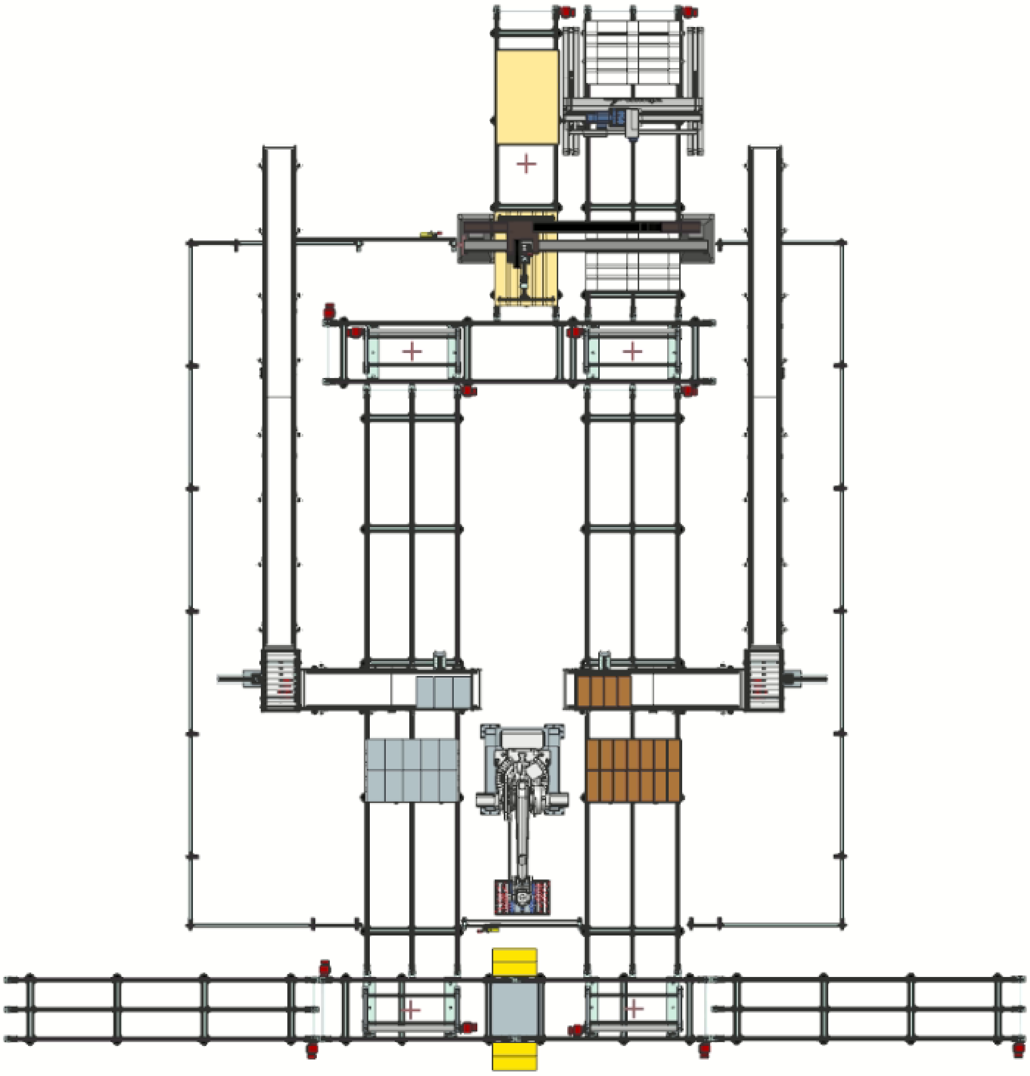


Fig. 28 Top view of 3D modeled cell in NX

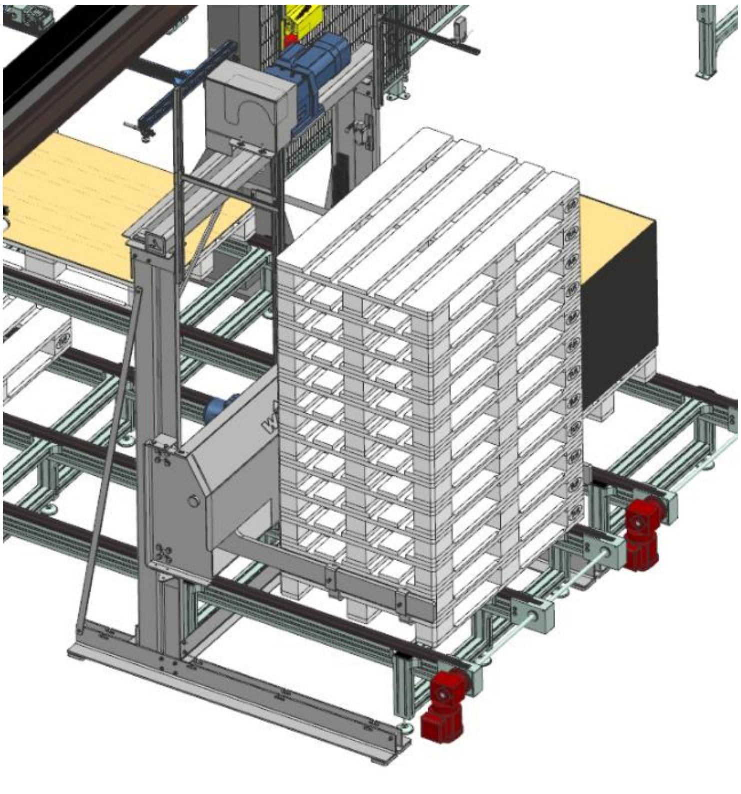


Fig. 29 Isometric view of pallet dispenser

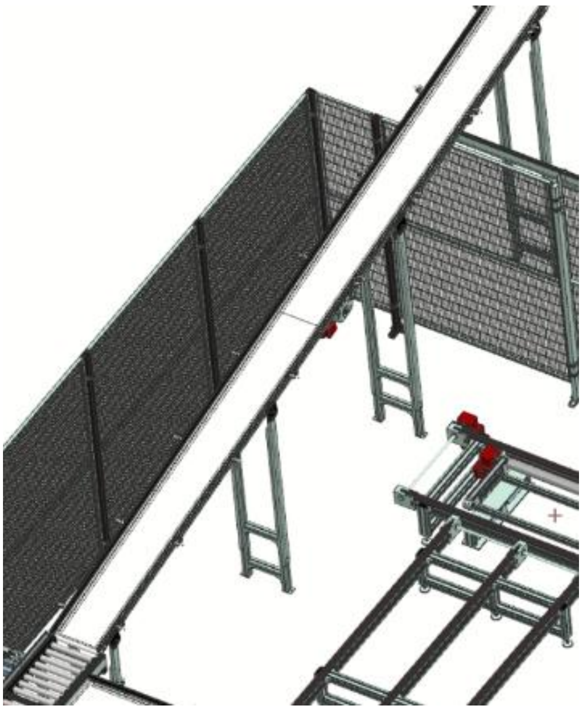


Fig. 30 Isometric view of the input conveyor

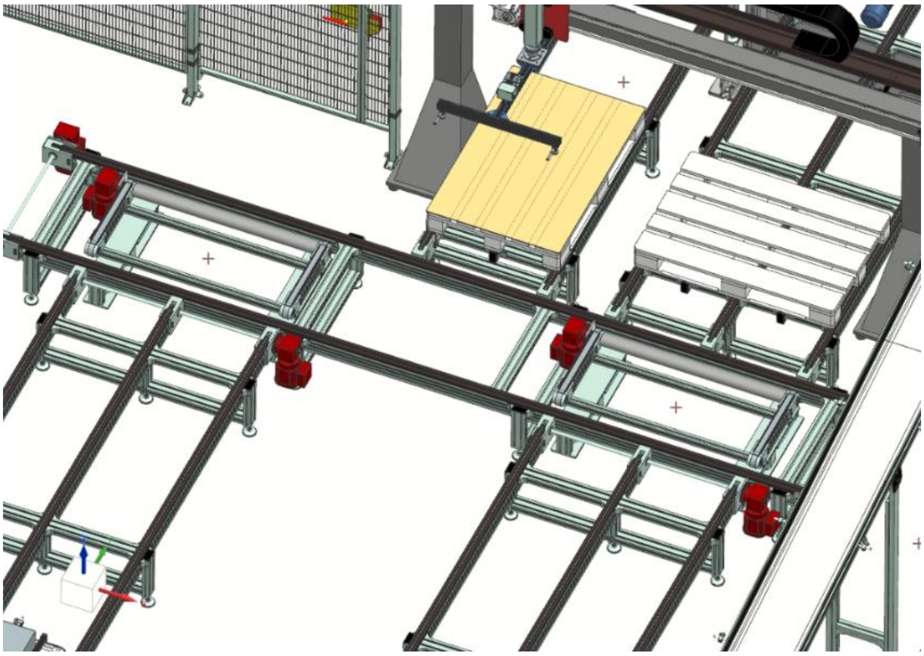


Fig.31 Isometric view of the distribution area of separators and pallets

6. 3D modeling of the effector

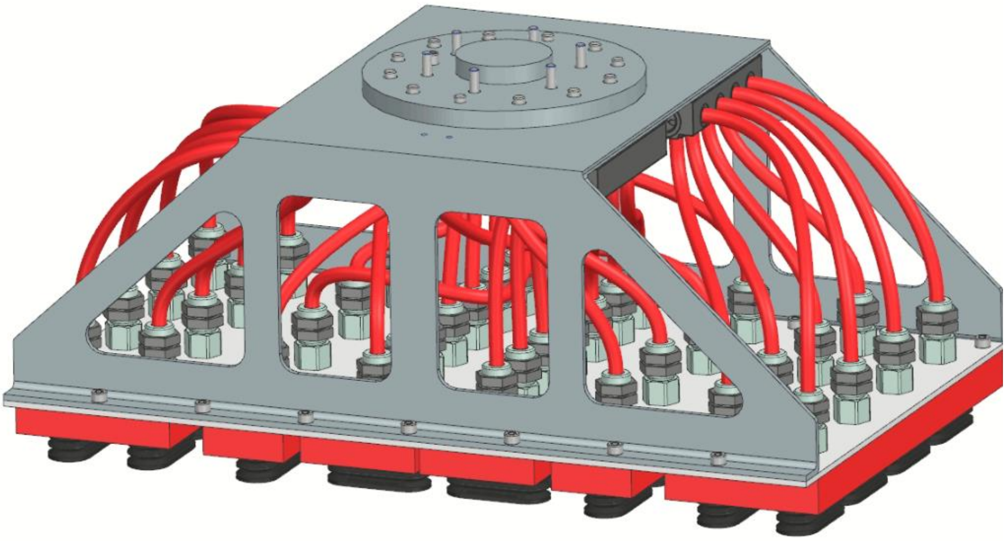


Fig. 32 Isometric view of the pneumatic effector

The body of the effector is made of Aluminum A356, weighing about 9 kg. The effector has 6 housings with a number between 10 and 15 suction cups, each group of suction cups being operated separately to be able to handle one box individually, depending on the type of box.

Fig.33. Picture with the arrangement of the suction cups

Fig. 34 View of the effector present in the application for the diploma project

7. Conclusions

In conclusion, the realization of a robotic cell is a process that requires a lot of attention, from the choice of components, to their location in the cell.

Also, some elements, such as the box alignment system because no 3D models were found from the manufacturer, had to be modeled based on the documentation provided.

Another contribution is the found documentation of the robot, without which it would not have been possible to make the execution drawings with the internal structure of the robot. The supplier only specified the components used, but assembling them in the execution drawing was his own contribution.

8. Bibliography

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