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ROBOTIC PALLETIZING CELL FOR OPTIMUM 5L WATER BOTTLES PALLETIZING

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Abstract: *The paper presents the conceptual design, virtual prototype achievement and the real physically system implementation of a robotic palletizing cell. The system includes an own (original) designed robotic gripper and sorting system, both of them integrated with standard conveyors, used in a 5 litter water bottle palletizing application. The overall robotic palletizing cell and included sub-systems models were custom made designed following us the specification supplied by a water bottler Romanian client (“Bucovina”) and implemented in beneficiary's manufacturing facility as an "end of line" water bottles robotic palletizing cell for the existing manufacturing line of 5 liters plastic water bottles(PETs).*

Key words: *robotic palletizing cell, palletizing gripper, sorting system, water bottles.*

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1. INTRODUCTION

In Giurgiu (Romania), a new bottling plant "Bucovina" was opened. Here it was decided that one of the bottling lines will be dedicated to a new product range manufacturing - a variant for 5L water PETs. At the end of the bottling line, it was desired to integrate a robotic solution for palletizing these products. Initial data for the start of the project were provided related to: the height of the output conveyor at the end of the bottling line, the 2D drawing of the water PET, desired way of handling the PET (2 pieces once) and palletizing schema and the robot that intended to be used. The height of the end bottling line conveyor is 927 mm, imposing the height of the designed system's conveyors to be adjusted accordingly to this level. The dimensions of the bottles were provided in a D2 drawing (Fig. 1). Based on this 2D drawing, an approximated 3D model of the bottles was made (Fig. 2).

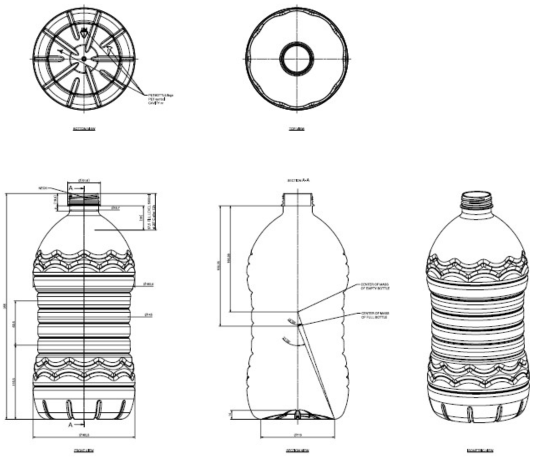

Fig. 1. Water bottle 2D drawing.

The bottles came at the end of the bottling line in a pack of 2 pieces packed in a plastic sheets (Fig. 3). This is important because it influences the possibility of bottles pack handling and their palletizing schema.

Regarding manipulation of PETs, first customer's requirement was that the robot should be equipped with a double end-effector (with two grasping zones) able to handle 2 packs of 2 bottles simultaneously. The initial manipulation scheme is shown in Fig. 4.

The robot specified by the customer to be implemented into the palletizing cell is ABB IRB 660 model (Fig. 5) having a maximum payload of 250 kg [1].

Fig. 2. 3D model of the bottle.

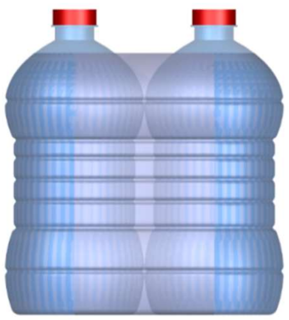

Fig. 3. 3D modes of two packed bottles.

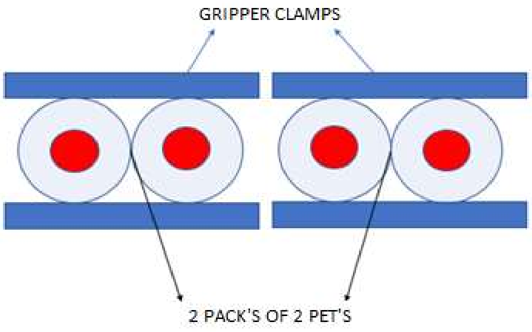

Fig. 4. Initial handling scheme.

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Fig. 5. Robot ABB IRB 660 [1].

In order to start designing the IR's end-effector and the overall robotic palletizing cell layout we first had to identify all the robot related information that may influence its further optimum integration and operation. From this point of view the most important IR's features that need to be identified from its technical data sheet, are: robot dimensions, maximum reach / operation radius and working space limits against IR's base, maximum payload and maximum speeds and accelerations correlated with IR's lifting capability, as well as the shape and dimensions of the robot flange for the end-effector assembly. During the further design steps performing, we need to keep in mind and respect all of these robot's information.

2. DESIGN OF THE EFFECTOR ACCORDGLY THE PALLETIZING SCHEME AND THE PETS PACKS INPUT ORIENTATION

Considering the above-mentioned initial data, in the technical study stage, a comparison between different 5 litters PETs robotic palletizing applications has been made in order to identify alternative FMC's appropriate structures. Similarly by mean of a comparative analysis of already existing technical solutions the best constructive model for IR's end-effector able to be used for bottles handling was identified. From this last point of view the most suitable reference models identified for the IR's end-effector waere the ABB clamp style effector having one area or two active areas (Fig. 6) [2].

Starting from the above initial data and reference model of the effector, the CAD part's design of the effector was started. In the starting point for design three elements were considered as being mandatory to be taken into account: the technical features of the already existing in the factory ABB IRB 660 robot model (having a maximum payload of 250 kg and a maximum reach radius of 3.15 m); the model and dimensions of the 4 PETs to be handled each time along palletizing operations, the predefined orientation of all 2 × 5 litter packs of PETs on the input conveyor from the robotic palletizing cell and the palletizing scheme requested by customer. From the point of view of end-effector design, the first elements that were configured as a CAD model were the 3D model of the PET set to be handled (the 2 x 5 litters PET package) and the 3D model of the effector flange, built in correspondence with the output flange of the robot in order to allow coupling between them by respecting IR's producer specification (Fig. 7).

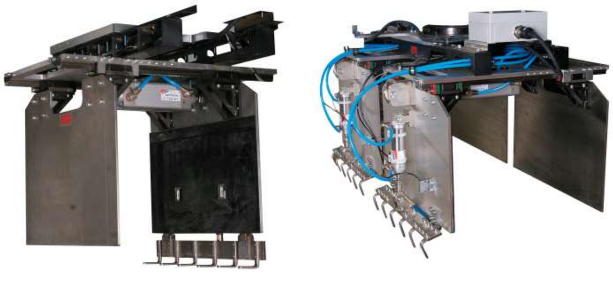


Fig. 6. Gripper reference models [2]

As concern the grasping mechanism, generally speaking, the effectors targeting this type of application include 2 clamping plates – one fixed and another one mobile. Respecting this main feature the first 3D model of the effector have been designed including the mobile plate powered by a linear Camozzi pneumatic linear motor and guided by two THK linear ball bearings (series HSR15). In this first approach, due to the longitudinal disposal (along the end-effector length) of the 2 grasped objects simultaneously handled (figure 4 and figure 8) a relatively limited / small transversal stroke of the mobile plate was necessary to be provided, and a reduced in wide preliminary 3D model of end-effector has been accordingly achieved (Fig. 8).

As it may see in Fig. 8, complementary to the just mentioned grasping mechanism, folding clamps mounted on articulated cushions (also power by linear pneumatic

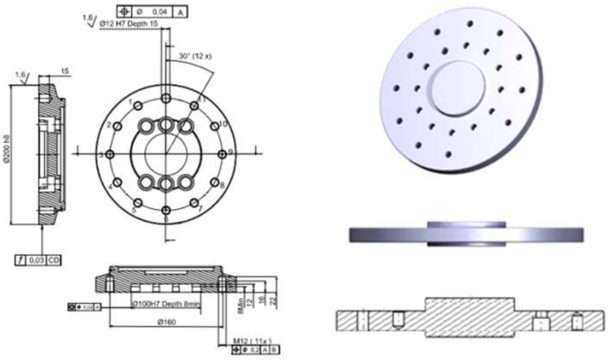


Fig. 7. Robot output flange drawing [1] and designed gripper's flange.

Fig. 8. Initial model of robotic gripper.

motors) have been included too, in order to supplementary sustain each of the 2 grasped bottles packs and provide a safety handling of both bottles packs even in case of their fast manipulation cycles.

Following the discussions with the beneficiary, a customer specific palletizing scheme was imposed including 2 rows of 8 bottles packs arranged transversally and 1 row of 8 bottles packs arranged longitudinally between the other 2 rows. However, the palletizing scheme subsequently imposed by the beneficiary was an "unpleasant surprise", because considering the initial model of the effector (Fig. 8), the imput orientation of the PETs packs on the input conveyor and the end-effector capability for placing the bottles packs on the pallet, the requested palletizing scheme leads to the longest duration of each layer building. That is due to the fact that the end-effector may work with only one half of its full grasping capacity in building the transversal rows layout (2 × 8 bottles × 2 rows) by handling individually each pack of 2 bottles. The imposed palletizing scheme may be seen in Fig. 9.

As result, with the initial model of the robot gripper (Fig. 8), for palletizing the bottles as the imposed scheme from Fig. 9 shows, it would be necessaries 16 handling cycles for the outer layer's rows building and another 2 handling cycles for the middle bottles row building (cumulating a total of 18 handling steps). Taking into account these aspects we have also analyzed two other alternative palletizing schemes and presented them to the customer including the involved advantages / disadvantages (Fig. 10).

Figure 10 presents in the left side the first alternative proposed palletizing scheme, allowing the minimal total palletizing time for one level of objects, because it facilitates the simultaneous manipulation of 4 bottles once with both grasping areas of the end-effector. This schema was the recommended option for the customer if he is targeting a minimum loading time for each layer and also for the fulfillment of the total pallet load. However special attention is required in this case for pallet load wrapping in order to secure the pallet load and maintain the stability of the full stack because all layers have the same layout of handled objects.

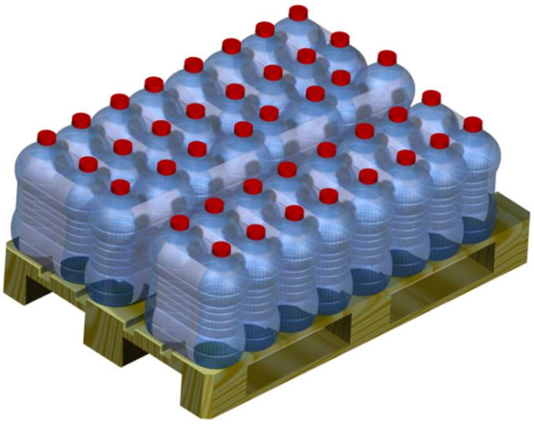


Fig. 9. Imposed palletizing scheme.

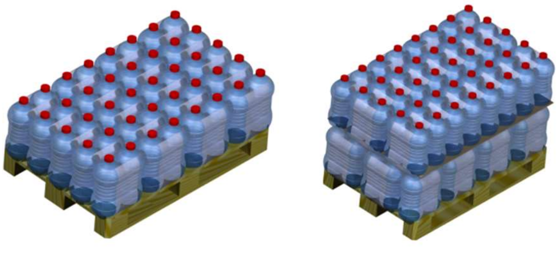


Fig. 10. Alternative palletizing schemes proposed.

In the right side of figure 9 is presented the second alternative palletizing scheme recommended to the customer as an optimal version of the stack structuring with asymmetrical layers arranged in the mirror, in pairs of 2 layers. The lower layer has the PET's arranged longitudinally on the first row and the second layer has the petals disposed longitudinally on the last row. For this schema it may be manipulated 4 PET items at a time for each object orientation.

However, besides all above recommendations regarding the benefits that may be reached in palletizing time reduction, the beneficiary insisted on maintaining the initial palletizing scheme, This led first to the necessity to reconsider the initial design of the effector (presented in figure 8) as follows and second to a more complicated design of the conveyors from which the bottles are to be taken by the robot.

As result, in this customer's imposed approach from the first point of view, the IR's end-effector requires a much larger grasping stroke (so the changing of the pneumatic cylinder and the guides have been involved) in order to allow it to grab 2 packs with longitudinal orientation at a time for building the middle stack layer (as previous figure 8 shows) and as well to be able to pick 4 packs with transversal orientation at a time for the outer layers building. In the mean time due to reduction in the contact surface size between effector's plates and PET's packs when transversal packs are picking, in order to avoid the increasing of the grasping force (limited by the low PET pack's stiffness) the shape of the plates were necessary to be redesigned by skipping from their initial flat surface design (figure 9) to a profiled one (Fig. 11) in order to allow an increased contact surface with the limited PET pack's frontal surface. For keeping in reasonable weight terms the effector plates and increasing also the friction coefficient between effector plates and the PETs packages supplementary rubber profiled plates have been attached to each plate (as presented for the left plate in figure 11). After making all necessary changes to respect the palletizing scheme imposed by the beneficiary, and PET packs group's manipulation the final model of the effector was achieved as figure 11 shows.

Following this, the overall robotic palletizing cell was necessary to be reconsidered too regarding the PET packages input conveyor design. From the second point of view, accordingly the imposed palletizing schema, the PET packs input conveyors configuration required 2 areas for picking bottles (a first area for longitudinally oriented PET packages accumulation and a second area for transversally oriented PET packages accumulation - as the packages arrive from the manufacturing area).

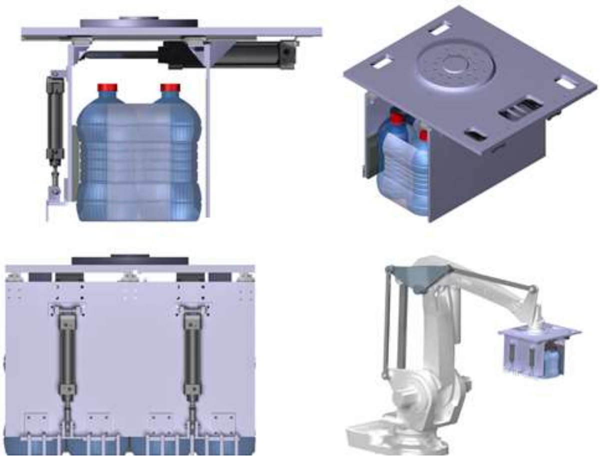


Fig. 11. Final form of the gripper.

3. DESIGN OF THE CONVEYOR

After the design of the effector has been completed, the focus has been moved on the designing of the conveyers system. Within the conveyor there are integrated standard components such as: ball bearing and ball bearing housings (SKF), wide leaf chains and chain wheels (Regina Italy), pneumatic cylinders (SMC) and gear motors (SEW). In designing it we took into account the possibility of distributing the packs of bottles in two (above mentioned) accumulation / picking zones with the possibility of selective distribution of the PET packs. Specific design features have been considered too for taking into account the possibility to pick up the PET packs by the clamp parallel gripper equipped with claws on the mobile plate (to ensure that the packages are caught underneath when they are handled).

In the first stage the CAD model of the first accumulation zone of the conveyor (where the packages are transversally oriented) was designed. At the end of this area, sets of 4 PET packs are accumulated to be retrieved by the effector and placed on the pallet on the outer layers (according to the palletizing scheme 1 – Fig. 9). The first designed part of the conveyor is presented in Fig. 12.

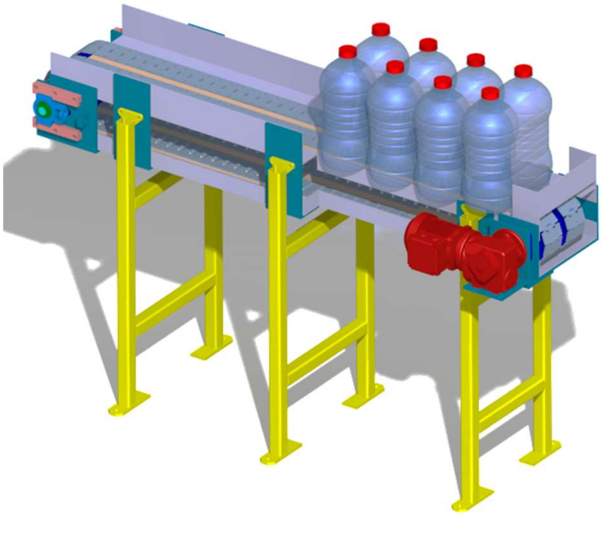


Fig. 12. First part designed of the conveyor.

This area of the conveyor is motorized and is fitted with a 2-row wide palette chain equally spaced to assure the transport of the packs of bottles. For economic reasons, it has been decided that the other accumulation area of the second conveyor, which assures the take-off of two packs of longitudinally oriented bottles, will be equipped with non-motorized rollers. To fulfill with necessary PET packages both take-off conveyor's areas a pneumatic gate and a pneumatic pushing system have been implemented. To fulfill both accumulation areas with PET packs, first a displacement of the transversally oriented 5 sets of PET packs is made by the motorized conveyor and afterwards their advancement the gate is closed. The 5-th PET pack is then deflected by pushing it by the pneumatic cylinder on the non-motorized conveyor, the PET pack's motion being further a natural (gravitational) one, assured by a slope arrangement of a first roller's set. The gate is open then again and another 6-th PET packs is advanced by the motorized conveyor then the gate is closed again. The 6-th PET pack is afterwards deflected by the same pneumatic pusher on the non-motorized conveyor. The 3D model of the final conveyors design is shown in Fig. 13.

Real system achievement and implementation on beneficiary's site is illustrated by the following figures, successively presenting:

- the overall conveyors system (Fig. 14) and specific details of the pneumatic vertical gate / stopper and pusher (Fig. 15);

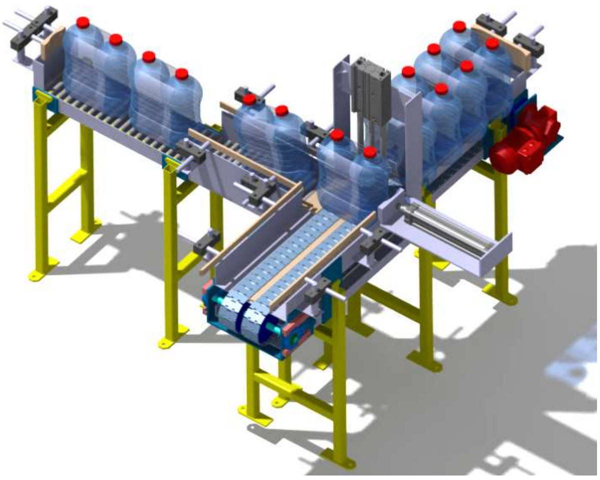


Fig. 13. The complete model of the conveyor.

Fig. 14. The conveyor at the end of the bottling line.

Fig. 15. The vertical gate / stopper and bottles pusher.

- the final designed gripper mounted on the IR in phase of longitudinal packs of bottles picking (Fig. 16) and in phase of preparing transversal packs of bottles picking (Fig. 17) and overall robotic palletizing cell programming.

Fig. 16. The gripper mounted on the robot in phase of picking longitudinally arranged 2 packs of bottles.

Fig. 17. Overall robotic cell programming and palletizing tests (the gripper mounted on the robot in phase of picking transversally arranged 4 bottles packs).

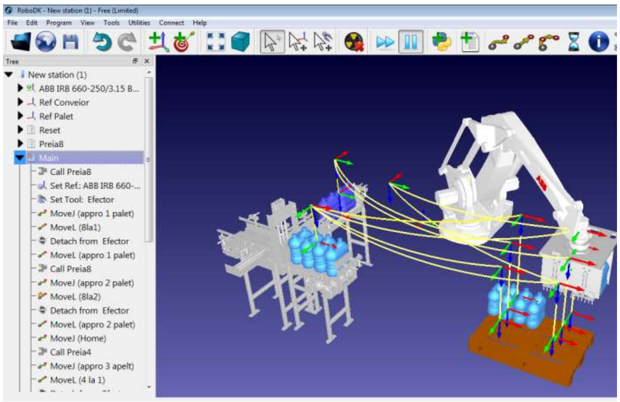
4. OFFLINE SIMULATION

Even though the palletizing scheme was set as beneficiary desired for each of the presented palletizing schemes an offline simulation was performed. The software used for the robotic simulation is RoboDK [3].

The graphic interface of the software during path planning is presented in Fig. 18.

For each of the simulation, the default speed settings were kept the same (500 mm/s being usually the maximum speed for operating similar palletizing robots in real palletizing applications). Even though those are not the real robot settings the same speed values were kept for all of the 3 palletizing schemes / configurations in order to obtain a proportional time difference for palletizing a full layer of each configuration. The first configuration that was simulated is the imposed palletizing configuration. The robot is palletizing a full layer in 6 steps as described in following Fig. 19.

For this first configuration, after simulation performing a total time of 1 minute and 50.4 seconds (110.4 seconds) for completing a full layer on the pallet was obtained.



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New station (1)
  ABB IRB 660-250/3.15 B...
  Ref Conveior
  Ref Palet
  Reset
  Preia8
  Main
    Call Preia8
    Set Ref.: ABB IRB 660-...
    Set Tool: Efector
    MoveJ (appro 1 palet)
    MoveL (8la1)
    Detach from Efector
    MoveL (appro 1 palet)
    Call Preia8
    MoveJ (appro 2 palet)
    MoveL (8la2)
    Detach from Efector
    MoveL (appro 2 palet)
    MoveJ (Home)
    Call Preia4
    MoveJ (appro 3 apelt)
    MoveL (4 la 1)
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Fig. 18. RoboDK interface and path programming.

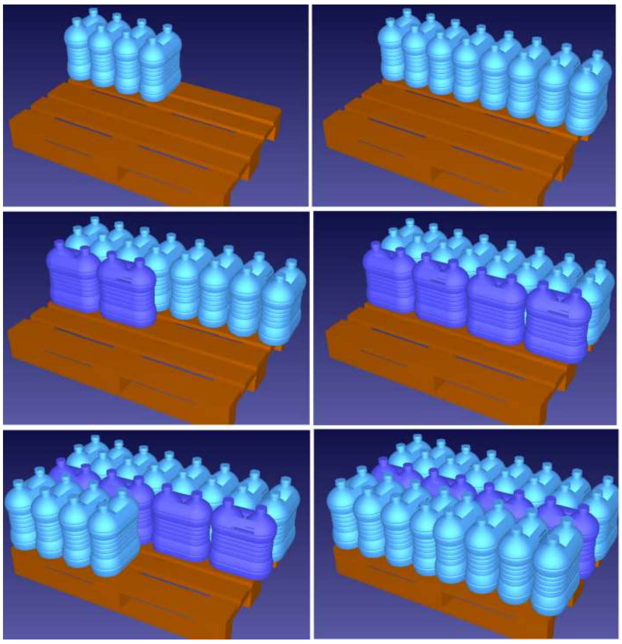

Fig. 19. Palletizing simulation steps for first configuration.

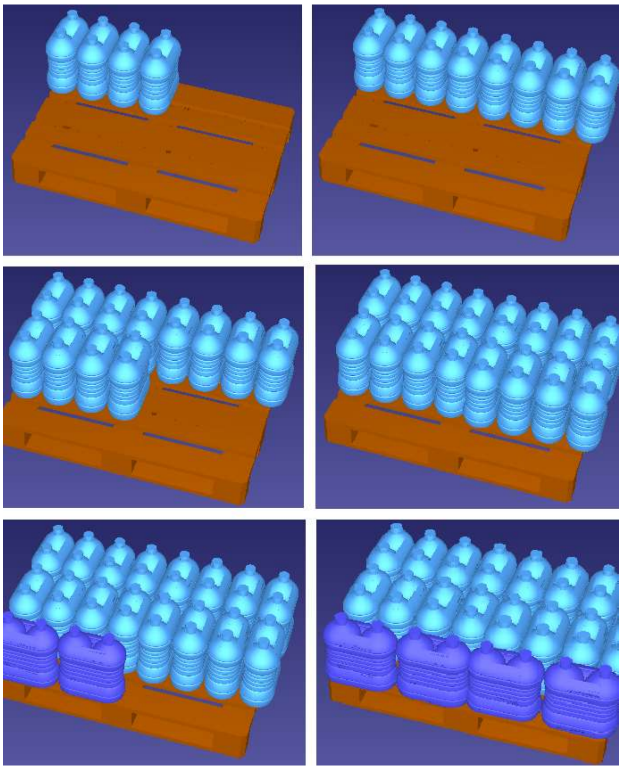

Fig. 20. Palletizing simulation steps for second configuration.

Table 1

Palletizing total duration and time difference

Config. nr.	**Simulation time [s]**	**Time difference [s]**	**Time difference [%]**
1	110.4	-	-
3	118.3	+7.9	+ 7.5 %
2	122.9	+12.5	+11.32 %

The second palletizing configuration also needs 6 steps in order to complete a full layer. The palletizing steps for the 2nd simulated configuration is presented in Fig. 20.

For this second configuration, the simulation was performed and the time to complete a full layer on the pallet is 2 minutes and 2.9 seconds (122.9 seconds).

After performing simulation for this third configuration (Fig, 21), the resulted time to complete a full layer on the pallet was of 1 minute and 58.3 seconds (118.3 seconds).

Comparing the time results we can observe that the first palletizing configuration needs the minimum time to complete a full layer on the pallet. The time results are resumed in Table 1 ordered from the fastest to the slowest result.

5. CONCLUSIONS

In this paper were presented some conceptual solutions for solving a real practical problem at the request of a beneficiary, regarding the design, manufacturing and implementing of a robotic gripper and a conveyor system for facilitating final achievement of a full robotic palletizing cell for PET packs (of 2 bottles x 5 litters packs).

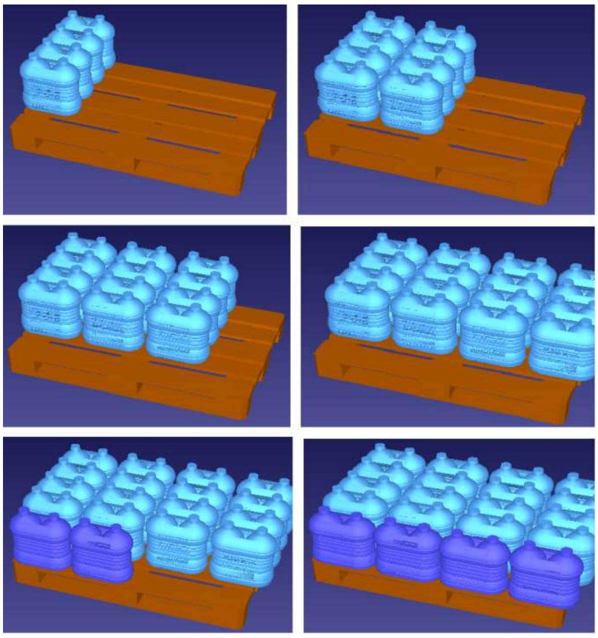

Fig. 21. Palletizing simulation steps for third configuration.

The design process for the two main subsystems (IR's end-effector and conveyors' systems) performed by taking into account all beneficiary specific requests has been presented. Specific design aspects and resulted integration aspects from changing the palletizing schema have been presented. Final design and manufacturing solutions provided have lead to the fulfillment of all beneficiary requests, the final palletizing robotic cell being implemented on the beneficiary site by respecting all beneficiary initial and latter specification.

In addition to the part of the paper describing the design works, from the last chapter, it can be seen how much important the offline programming and simulation phase of such an application is. For this particular case, using offline simulation, it was clear which of the palletizing configurations is the fastest. In this case, by adopting the optimal palletizing solution, it has been found that the palletizing time can be improved from 7% to 12% compared to the other variants. Overall, the constructive solutions presented and their integration with the simulation results not only did meet the imposed requirements but ultimately resulted in an optimal solution that was successfully adopted and implemented as a real application in beneficiary site.

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