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HYBRID PALLETIZING SYSTEM WITH GANTRY ROBOTS FOR ORIENTING THE OBJECTS AND ARTICULATED ROBOT FOR OVERALL LAYER HANDLING

Georgia-Cezara AVRAM [1], Florin-Adrian NICOLESCU[2, *], Andrei IVAN[3] and Mihai BOLDA[4]

[1)] Assistant Prof. PhD, Machines and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania
[2)] Prof., PhD, Machines and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania
[3)] Lecturer. PhD, Machines and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania
[4)] Eng., Msc. Student, Machines and Manufacturing Systems Department, University "Politehnica" of Bucharest, Romania

Abstract: *The paper presents works performed by the authors in the field of developing new concepts and virtual prototyping new model of hybrid palletizing system. Along development of the palletizing system virtual prototype in order for achieving system layout optimization new concepts have been implemented. From this point of view most important features have successively targeted development of: the modular design of the whole system and its specific subsystems / components, the implementation of two gantry robots for object orienting along layer forming conveyor, the modular layer compacting system integrated with the layer forming conveyor, the special end-effector for overall layer manipulation by a high payload articulated arm robot, the modular pallet stacking & dispensing system, the modular overall conveying system for objects and pallets, and the modular pallet stretching system.*

Key words: *Virtual prototyping, hybrid palletizing system, modular design, gantry robot, articulated robot, overall layer handling, palletizing system layout optimization.*

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1. INTRODUCTION

The hybrid palletizing system represents a new concept developed and presented as first achievements in international automation fairs starting from the second part of 2013 year [1, 2]. Such kind of palletizing systems have been developed targeting to find a new kind of system joining the main advantages of both "end of line conventional robotic palletizing systems" higher flexibility and "automated palletizing system" higher palletizing rates / productivity. As result actual existing hybrid palletizing systems have been conceptually diversified to adapt on specific necessaries demands of high speed infeed conveyors / high delivery rates for output conveyors [3]. From this point of view for the hybrid palletizing systems two main approaches / specific designs need to be considered: for mid-speed palletizing rates (systems operating from 25−30 up to 50−60 palletized objects per minute) and for high-speed palletizing rates (systems operating from 75 up to 125 palletized objects per minute) [3]. As result a first approach in development of this systems was to combine the "pattern forming subsystem" from a conventional automated palletizing system with a "full layer robotic palletizing subsystem" [4]. For this purpose the forming section of a conventional palletizer (usually a "sliding shoes sorter conveyor") was used to form the layer, and a large (heavy payload) robot (top mounted articulated arm or side mounted-cylindrical coordinates-column robot) was used to deposit the layer. However the approach offer practical advantages only in case of mid-speed palletizing rates, since the robot is a slowly device compared to the conventional automated palletizer (full layer manipulation rates by robots being inferior as automated system palletizing rates). However, a different second approach is used when targeting high-speed palletizing rates [3], the main idea being to combine robotic pattern forming area with conventional automated palletizers layer depositing subsystem. The concept really combines the best of both technologies for higher-rate applications, with robots being used to turn and position the objects precisely as required, while the conventional technology is used to square and deposit the layers of product [1, 2, and 3].

[*] Corresponding author: 313 Splaiul Independentei Bv, sector 6, Bucharest, Romania
Tel.: +40744923533;
Fax: +40212691332
E-mail addresses: *afnicolescu@yahoo.com* (A. Nicolescu)

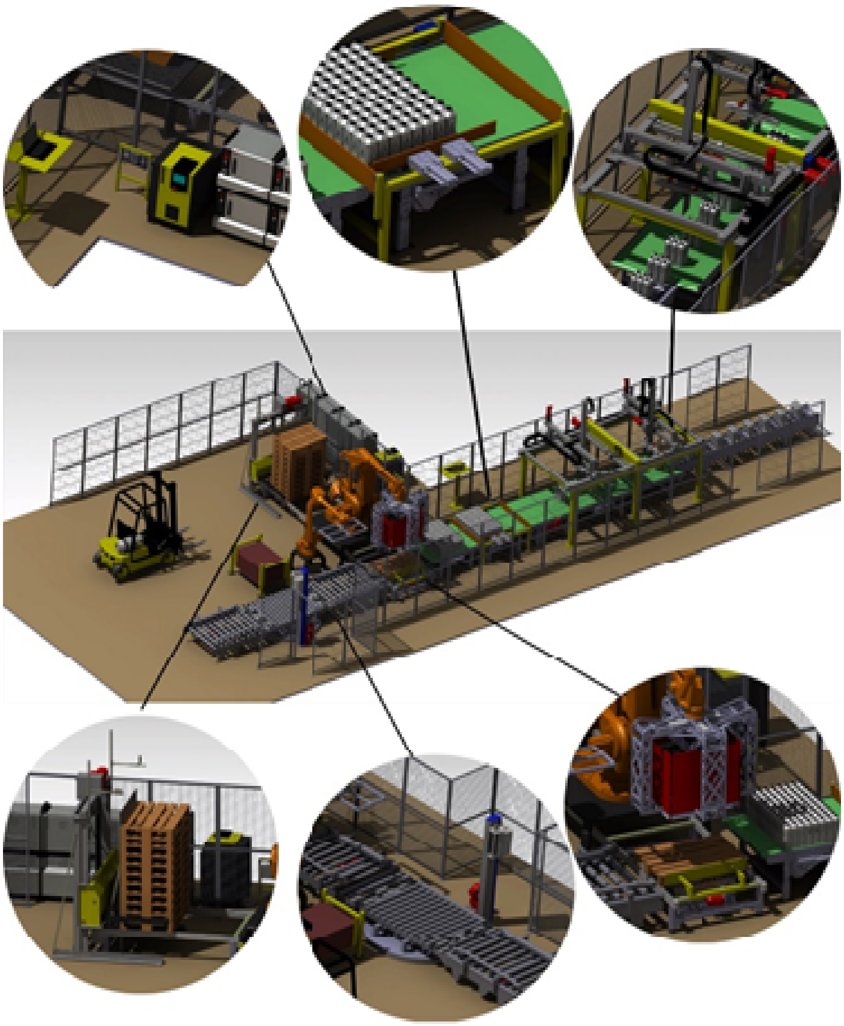
2. DESIGNED HYBRID PALLETIZING SYSTEM OVERALL VIEW.

2.1. Complete description of the application structure and robotized cell component identification

Designed hybrid palletizing system had as a reference model the Elettric80 robotized cell [4] (presented in Fig. 1,*a*), including four articulated arm robots (two of them for layer forming, one for full layer manipulation and one for separator manipulation), two roller conveyors, two chain conveyors, a system for layer compacting, and a system for automated pallet storage & dispensing.

From this point of view the system developed by authors (presented in Fig. 1,*b*) [5] has similar features but an improved design by including: the same input system for the manipulated objects (roller conveyor), two gantry robots for layer forming (because they have a more rigid structure and higher operating speed that performs better in handling applications and the overall structure of the hybrid palletizing system), an own designed layer compacting system integrated with accumulating conveyors, two articulated arm robots (one for full layer manipulation and one for separator manipulation)a different pallet storage-dispensing & transport system as well as a supplementary stretch-wrapping system for the formed pallet, previously to be removed from the cell by a forklift transporter, the overall structure of the system being completed by full set of necessary complementary equipment.

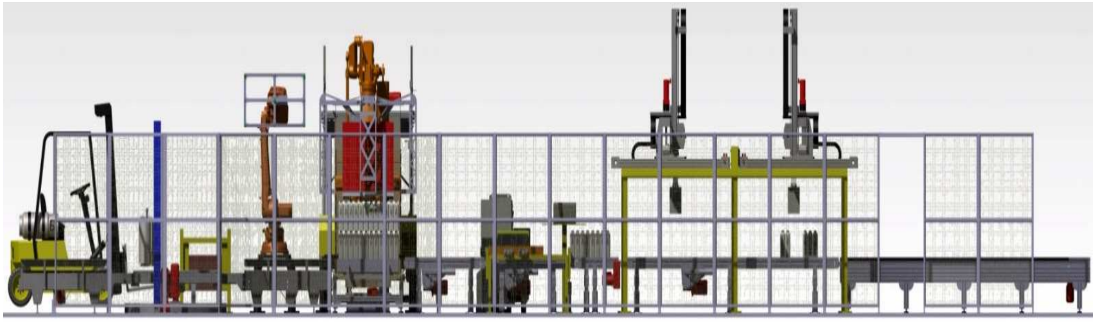
a



b

Fig. 1. Hybrid palletizing systems: *a* – overall view –robotized cell reference model [4]; *b* – virtual prototype of designed hybrid palletizing system and details on interest zones [5].

a



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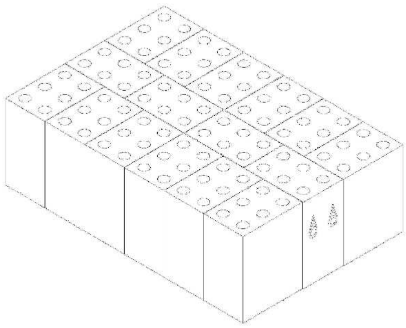

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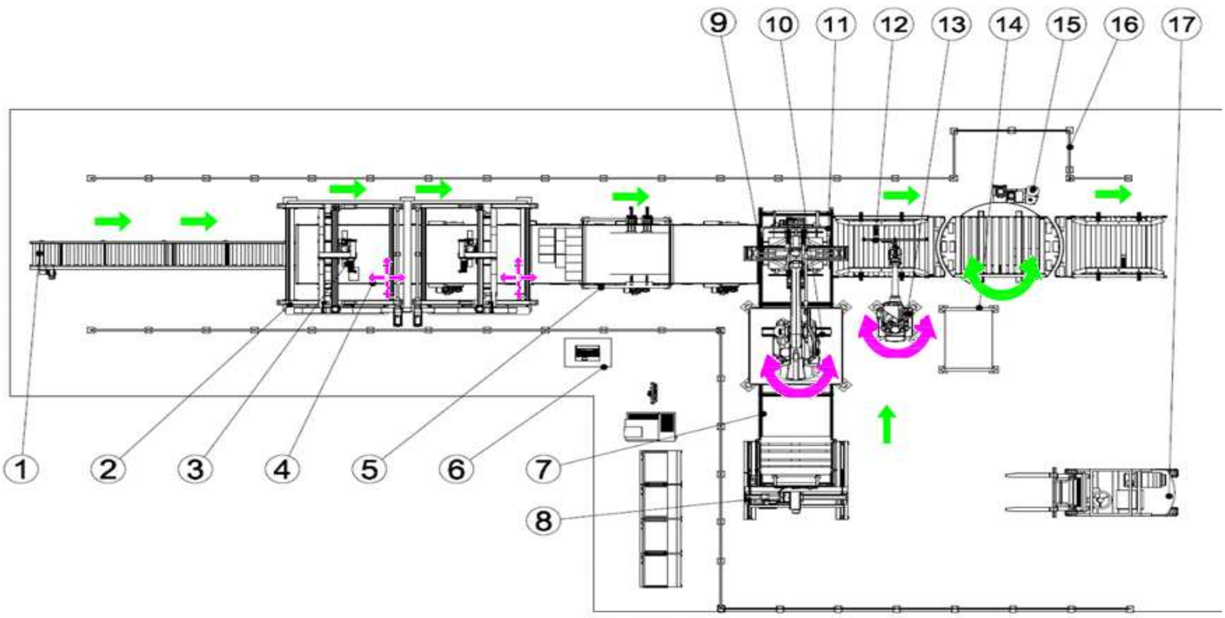

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Fig. 2. Orthogonal projection and the cyclorama for the application functioning [5]: *a* – orthogonal front view projection of the developed cell; *b* – orthogonal right side view projection of the developed cell; *c* – palletizing scheme; *d* – orthogonal top view projection of the developed cell.

2.2. The application structure

The application structure (detailed in above system's orthogonal views and specific layout presented in Fig. 2) may be summarized as follows: 1) Bosch-Rexroth transversal roller conveyor; 2) Schneider MAXR 43 modular designed gantry robot for layer forming (on the fly boxes orientation and positioning according to the palletizing scheme); 3) end-effector for boxes orientation and positioning; 4) Dorner 3200 conveyor; 5) system for layer's compacting; 6) command and control systems; 7) Bosch-Rexroth chain transversal conveyor; 8) Winkel system for pallets automated storage& dispensing; 9) Unigripper end-effector for overall layer handling; 10) ABB IRB 760 articulated arm robot (high speed full-layer palletizing robot); 11) Bosch-Rexroth lifting system; 12) Schmaltz vacuum end-effector for handling the separators; 13) ABB IRB 4600 articulated arm robot for handling the separators; 14) system for layer separators storage; 15) system for pallet stretch wrapping; 16) protection wall; 17) forklift transport system.

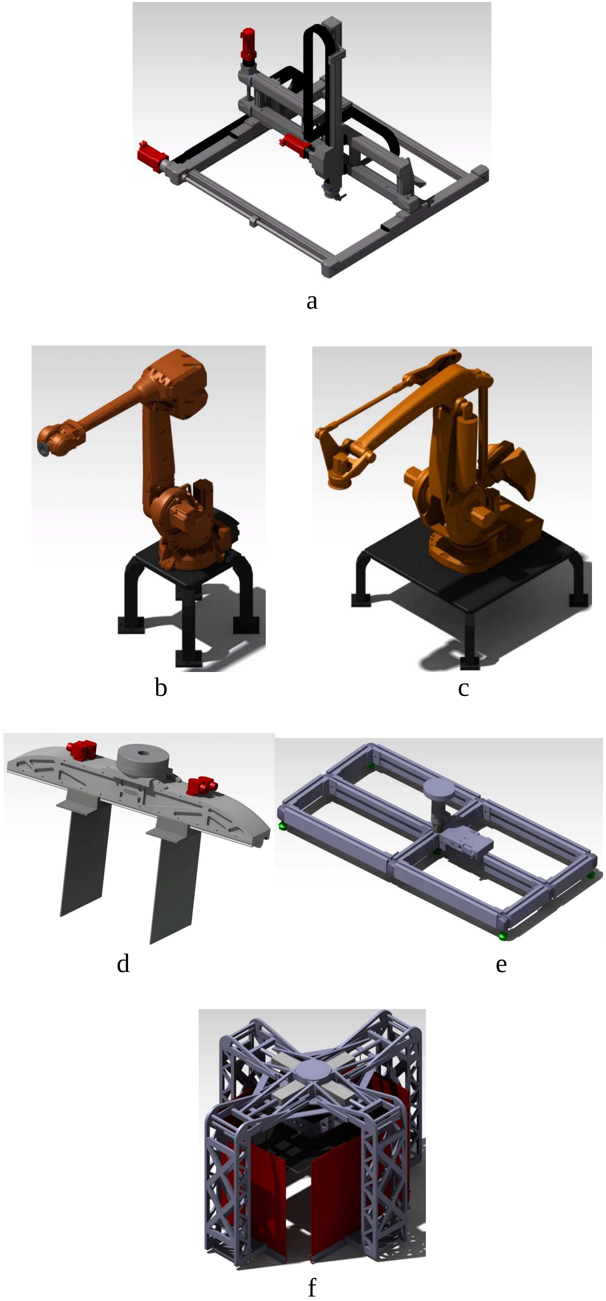

Fig. 3. Robotic end-effectors [5]: *a* – schneider gantry robot-MAXR 43 [6]; *b* – ABB Robot-IRB 4600 [7]; *c* – ABB Robot-IRB 760 [7]; *d* – 2-finger parallel gripper [8]; *e* – vacuum gripper [9]; *f* – UniGripper full layer manipulator [10].

2.3. The application general assembly operation specificity

The specificity of hybrid palletizing system's functioning of is depending from the objects to be palletized (in this case 2 liter water pets grouped by 6 pets in a plastic foil) and the developed model for the palletizing scheme (presented in Fig. 2,*c*). Flexible palletizing cell operates continuously, every move being well determined to minimize and optimize working cycle time. In Fig 2,*d* is shown the working cyclorama and the direction of travel defined by the conveyor, and the types of rotational or translational movement carried out by the handling system. It is symbolized with green color those defining the direction of movement and are symbolized with pink color those interacting with the direction of movement.

After carrying out a comparative analysis of robots that can be used in such an application, the authors chose for integration into the hybrid palletizing system two gantry robots (Fig. 3,*a*) selected from Schneider constructive model [6]. The reason for this selection is the payload fulfilling (the minimum payload criteria of 38 kg is accomplished) and increased values for numerically controlled axe's acceleration, that for such kind of palletizing application is a very important criterion to be accomplished too. The robots are designed to grab, orient and position the palletized objects according to the palletizing scheme. They are equipped with a Schunk 2-Finger Parallel gripper [10] (Fig. 3,*d*) so designed that the jaws are sufficiently large to cover at least 50% of the lateral surface of the object to be manipulated and the clamping force to be greater than 120 N (which is the minimum force that must be developed to manipulate the object). Their specific lightweight allows reaching of a speed slide arm of 270 mm/s and acceleration of 1.5 m/s^2**.**

The ABB IRB 4600 articulated robot [7] (Fig. 3,*b*) equipped with a Schmalz Vacuum effector [9] (Fig. 3,*e*) is designed for handling the separators – the layer separators being take over and placed on the formed vertical stack. The ABB IRB 760 articulated robot (Fig. 3,*c*) [7] is equipped with an Unigripper effector [10] (Fig. 3,*f*) specially designed for high speed full-layer palletizing allowing taking over of the full formed layer and deposit it on the pallet.

2.4. Overall hybrid palletizing cell operation principles and assisted functioning simulation

After achieving the virtual prototype of the overall hybrid palletizing system and fulfillment of detailed shapes design for each of its subsystems as well as specific geometric and dimensional constraints checking, a full set of functioning procedures have been implemented and the assisted simulation of the whole system has been performed. For this purpose, taking into account the specific design features of each subsystem,

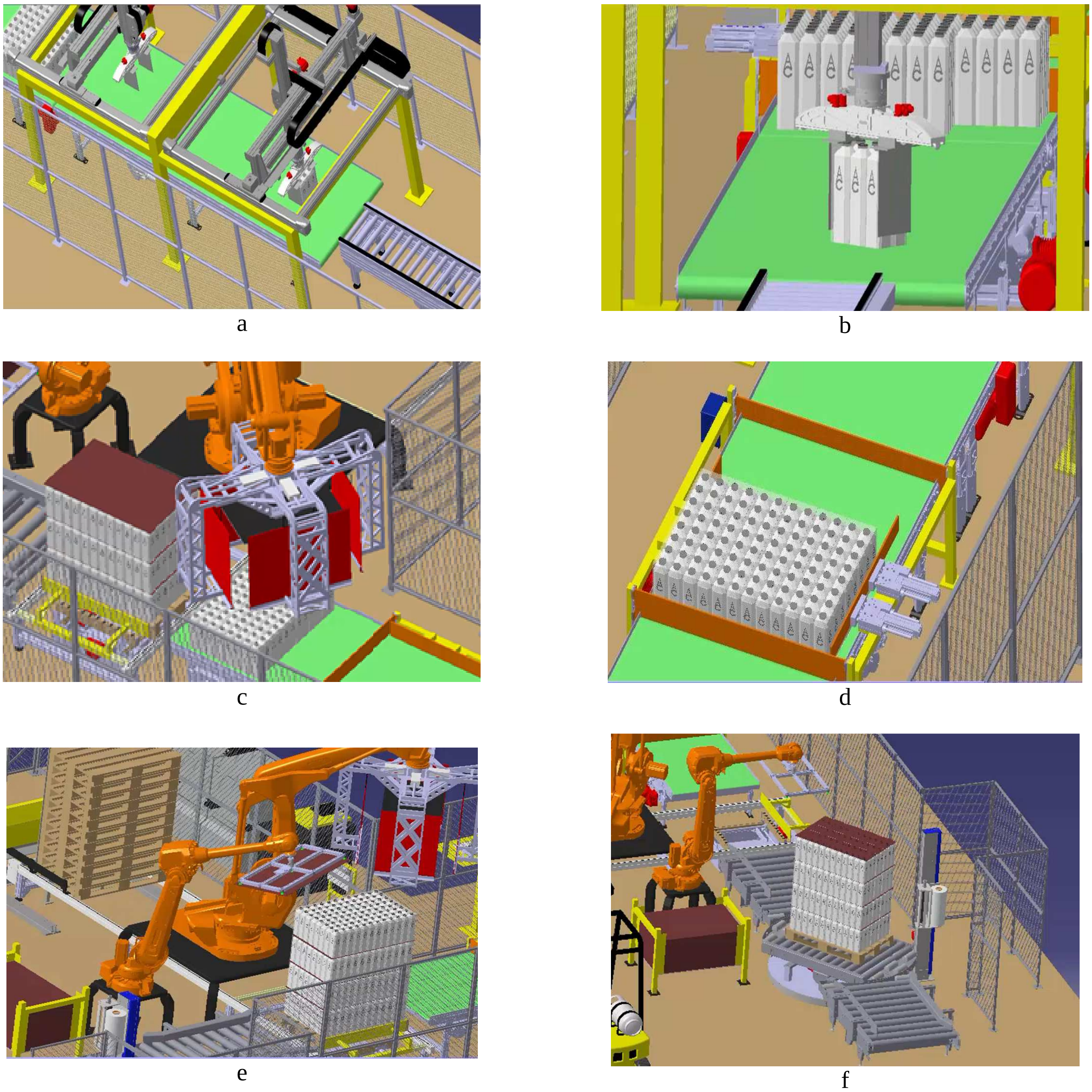

Fig. 4. Screen captures from hybrid palletizing system functioning simulation [5]: *a* – retrieve the manipulated object by the gantry robot; *b* – positioning and orientation of the manipulated object according to the palletizing scheme; *c* –. retrieving the formed layer and its vertical placing; *d* – layer compacting; *e* – placing the layer separator; *f* – wrapping process.

first of all it were defined all sets of translational and rotational joints characteristic to each subsystem by using DMU Kinematics Catia V5 CAD environment. For exemplifying parts of the overall functioning procedures of the whole system, Fig. 4 presents some relevant screen captures from overall system's functioning simulation.

From the point of view of implemented functioning procedures main issues are referring to following aspects: 1) the hybrid palletizing system has been designed for high-speed palletizing rates allowing maximum inputs of up to 60 objects per minute. From conceptual point of view the overall hybrid palletizing system represents an in-line hybrid palletizing system incorporating two gantry robots for object pattern forming and a single layer accumulation zone. In the accumulation area it was integrated too an originally designed layer compacting system; 2) as general purpose the palletizing system may be used for mixed loads palletizing arranged by groups of two anti-symmetrical consecutive layers of different objects types. However the system obviously allows palletizing of a single objects type; 3) for the exemplified case a single palletized object type was considered (2 liter water pets grouped by 6 pets in a plastic foil); 4) the system input (for palletized objects income) is represented by a high rate continuously flow roller conveyor; 5) the palletized objects are automatically passing from the input conveyor to the belt pattern forming conveyor where two gantry robots (tandem operating for palletizing flexibility and speed increasing) manipulate them for precise and repeatable pattern layer preliminary forming (by modifying on the fly object orientation and position accordingly specific palletizing layer features. For this purpose each gantry robot is equipped by a parallel (translational jaws) gripper (Schunk reference model) and specifically operates only on odd / even palletizing objects and has the capability to automatically adapt to different object's size in length / wide; 6) specific arranged rows and columns of palletized objects are thus continuously directed up to the first accumulation gate integrated on the accumulating conveyor front end. By this operation mode longitudinal compacting of the layer is made back to this first accumulating gate; 7) after the full set of palletized objects have been completed for the current formed layer the first gate is descending simultaneously with the activation of a second gate integrated in the front side of the compacting area and the palletizing object layer is transfer by the same belt conveyor into the final compacting area where the transverse compacting is performed by a special dedicated system. After achieving of the bidirectional compacting the second front gate is retracted and the formed layer is advancing to the full layer manipulation area; 8) the compacted layer advancing on the last belt conveyor is stopped into a determined position in order to prepare the full layer manipulation; 9) after final targeted position reaching the (heavy payload) articulated arm (Fig. 3,*c*; Fig. 4,*c*) starts manipulation cycle for picking-up and deposing the full layer on the pallet located in the pallet's loading post. For this purpose a special dedicated end-effector for full layer manipulation has been designed. It includes four translational jaws (bidirectional simultaneously acting) for safe and firmly gripping the full set of layer's palletizing objects; 10) after each palletized layer a separator is picked up and deposed on it in order to materialize a new perfect flat surface for next layer stable palletizing, this action being performed by a second (low payload) articulated arm robot equipped with a vacuum gripper. The separator storage system is located near this robot;11) the pallets supplying system includes a pallet storage & dispenser subsystem and a dedicated chain transversal conveyor for pallet transport up to the pallet loading post. Whole pallet circulation is made to an inferior level in order to allow an easily loading of the pallet by the high payload articulated arm robot. The pallet's loading post includes a short roller conveyor and also a lifting system too for full loaded pallet's positioning up to the transfer level of the pallet's evacuation roller conveyor; 12) the full loaded pallet is afterward transferred to a stretch wrapping machine post which perform this operation in order to secure the pallet load during it further manipulation and transport; 13) finally the stretch wrapped pallet is evacuated on exit roller conveyor up to the picking-up post by forklift AGV / forklift transporters served by human operators.

7. CONCLUSIONS

The article presents virtual prototyping of a new concept of mid-speed hybrid palletizing system including gantry robots for orienting the objects along layer forming and heavy payload articulated robot for full layer palletizing. The article presents the full virtual prototype of the optimized design of hybrid palletizing system as well as some screen-captures from the assisted functioning simulation of the whole system's operation. Compared to the reference model offered by the Elettric80, the new designed hybrid palletizing system has some similar features but also includes consistent improvements in design by including: two modular design gantry robots for layer forming (replacing the two articulated arm robots, due to a much more rigid structure and higher operating speed allowing their better performing in handling applications and inside overall structure of the hybrid palletizing system- for layer forming), an own (new) designed layer's compacting system integrated with accumulating conveyors, a different (new) pallet storage-dispensing & transport system as well as a supplementary (new) stretch-wrapping system for the formed pallet, previously to be removed from the system by a forklift transporter, the overall structure of the system being completed by all necessary set of complementary equipment.

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