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VIRTUAL PROTOTYPING ROBOTIC CELL FOR MUSHROOM CULTIVATION IN CONTROLLED ATMOSPHERE

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Abstract: *Continuing previously developed works, the modular robotic manufacturing cell presented in this paper refers to a second fully automated subsystem dedicated for mushrooms cultivation in controlled atmosphere conditions. The modular robotic cell designed by authors is part of a completely new robotic subsystem allowing septic cultivation condition and respecting food safety standards by completely excluding human operators involvement in the production cycles and allowing controllable and repeatable production cycles by continuously monitoring and adapting of the environment parameters to different production phases.*
Key words: *mushrooms growing, robotic system, virtual prototyping*

1. INTRODUCTION

Mushrooms cultivation common processes are not benefiting from fully septic conditions, mostly due to non sterile cultivation mediums (composts) using, as well as human operators' necessary involvement in the specific not-continuous production cycles. The more, frequently the productivity and quality of mushroom crops are not exactly predictable because cultivation processes are not benefiting too of controllable and repeatable environment parameters as well as these parameters' continuously monitoring and adapting to different production phases (as incubation and fructification are). In order to avoid above mentioned disadvantages a fully automated facility for mushroom's cultivation and harvesting has been developed as a completely new (already patented) system (Petre et al., 2008a and Petre et al., 2008b). The conceptual model of the overall above mentioned fully automated facility as well as the virtual prototype of the first robotic manufacturing cell included in the system (for compost sterilization and inoculation) have been already presented in previously 20th DAAAM Symposium (Nicolescu et al., 2009a and Nicolescu et al., 2009b).

The modular robotic manufacturing cell presented in this paper represent a second fully automated subsystem dedicated for mushrooms cultivation in controlled atmosphere conditions, designed by authors as a completely new robotic subsystem allowing septic cultivation condition and respecting food safety standards by completely excluding human operators involvement in the production cycles and allowing controllable and repeatable production cycles by continuously monitoring and adapting of the environment parameters to different cultivation phases (as incubation and fructification are). The system is able to supply best environmental conditions for cultivation of a large variety of edible mushrooms (Ganoderma lucidum, Grifola frondosa, Hericium erinaceus, Lentinus edodes, Pleurotus eryngii, Pleurotus ostreatus), for better results, in the incubation / fructification room the atmosphere parameters being continuously monitored and set accordingly each variety of mushroom and cultivation phase.

As growing support for mushrooms are used specially designed bags filled with sterilized and inoculated compost, those are transported thru the production facility using custom built pallets loaded with three compost bags (Fig. 1).

Fig. 1. Special designed pallet and support for bags transport / stocking in cultivation rooms

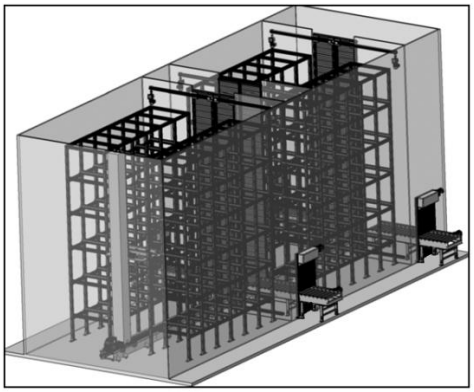

Fig.2 .Virtual prototype of the one robotic cell unit (AS-RS system) for edible mushrooms cultivation

2. VIRTUAL PROTOTYPE FOR MUSHROOMS CULTIVATION ROBOTIC CELL UNIT

As previously mentioned, after the compost bags were sterilized and automated inoculated with liquid mycelium in the first modular robotic cell (Nicolescu et al., 2009b), the bags loaded on pallets, are transferred into a video inspection area (for bags integrity checking before loading into the cultivation rooms) and afterwards transported by roller conveyors to the cultivation (incubation/fructification) area.

The cultivation area is divided in four distinct incubation / fructification rooms, grouped in two robotic cell units (Fig. 2), each robotic cell unit including a set of two "face-to-face" incubation/fructification rooms served by same column robot equipped with a bilateral telescopic fork system (Fig. 3), allowing both pallet's transfer (pallet's pick-up from / to conveyors), as well as pallet's manipulation and staking in the two automated storage-retrieval systems (AS-RS) belonging to the same robotic cell unit.

However, in order to allow cultivation of multiple varieties of mushrooms at the same time, or as well extending (when necessary) production capacity for a specific mushroom type (on two, three or four rooms), each incubation / fructification

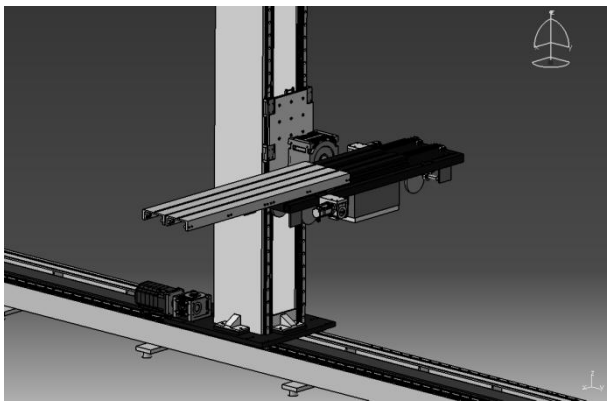

Fig. 3. Column robot having bilateral telescopic fork system

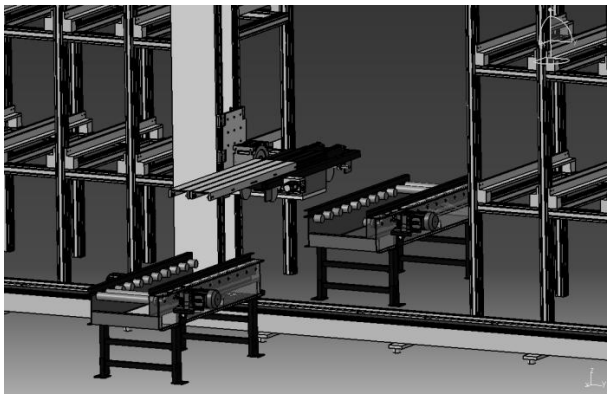

Fig. 4. Column robot in automated pallet's transfer working cycle

rooms may be used independently, being equipped with own sealing (horizontally sliding) doors system (Fig.2) and including own system for climate parameter's monitoring and adjusting able to be set in correspondence with specific mushroom's variety / cultivation phases specificity. In the same time, to allow maintaining the sterile climate in the cultivation area the conveyor's access gates are designed as sealing (vertically sliding) doors too (Fig. 2).

In order for interconnecting two similar robotic cell units and both of them to the overall mushroom's automatic cultivation and harvesting system each column robot equipped with the bilateral telescopic fork system is programmed to perform a first working cycle allowing exclusive pallet's transfer (pick-up from / to the in-line transport conveyors, as figure 4 is detailing). However, for each pallet's manipulation and staking in the two incubation/fructification rooms belonging to the same AS-RS unit the column robot has the facility to automatically load different (specific type) working cycles programs allowing pallet's loading / unloading on both-sides (front/rear robot's sides) of the storage systems included in each incubation/fructification room (a total set of 30 stations - 15 stations distributed in two storage systems, each station supporting up to 200 kg nominal load - being included in each room). To allow pallet's loading / unloading in each storage station the maximum robot payload is 300 kg, column robot's telescopic forks extending strokes are 1400 mm (in front and respectively back side direction) the vertical fork's stroke is 6 m and the ground column's traveling stroke is 12 m (Fig 3), (Nicolescu, 2005 and Nicolescu, 2010).

3. CONCLUSION

The modular robotic system presented in this paper is component of an already patent protected fully automated facility for mushrooms cultivation and conditioning system.

The modular robotic above detailed cell is dedicated for mushroom cultivation in controlled atmosphere.

The overall modular robotic facility has following advantages (as a sum of the involved advantages induced by each modular robotic section specific design): the facility guarantees the alimentary and therapeutic safety of the products by respecting all standard conditions of workspace purity in the sterile zones and also by totally excluding human operators presence in the whole facility (biotechnological safety ensuring); it uses an efficient method of sterilizing the cultivation substrate by total decontamination, accomplished in a shorter time (70% time less) and reducing by 40% the energy consumption costs compared to classic procedures; it fully ensures the total sterile conditions imposed by appropriate biological material cultivation, eliminating any hazards regarding human contamination of the production areas; it prevents human access in the sterile zones, allowing 100% automatic pallet's / bag's sterilization, handling, transport, transfer, compost thermo-regulation and inoculation, pallet's / bag's manipulation and storage, 100% incubation and fructification controlled process performing, as well as automated mushrooms harvesting, all operations being performed by modular robotic equipments; the installation functions are controlled by a central command system which also controls the system parameters for the sterilizing system, the thermo regulation areas, the robotic inoculation system, the pallets identification, bags visual inspection, pallet's / bag's handling, transfer, transport and storage systems, the environment parameters control of the incubation / fructification areas, the robotic harvesting system and the final product packing equipment (Petre 2008b and Nicolescu A., 2009a).

Real scale production system will be fully operational starting by June 2011. By the time, virtual prototyping for individual units and overall system, functioning simulation, detailed design phases, have been already performed and system's sections building up and testing, as well as overall system programming and real functioning adjusting will be performed. A following paper directed related to the present one illustrates the virtual prototype of the last automatic subsystem achievement: mushroom's robotic harvesting cell.

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