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# INITIAL DESIGN, DESCRIPTION AND ANALYSIS OF THE MATERIAL FLOW AT AN INTELLIGENT MANUFACTURING CELL – PROPOSAL OF SOME PRINCIPLES FOR A SUCCESSFUL FUNCTIONING

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**ABSTRACT:** *The Institute of Production Systems and Applied Mechanics has been working for some years in the design, development and improvement of a Flexible Manufacturing Cell. Due to the scope of new projects and the need of turning this cell into a more flexible, autonomous and intelligent one, i.e.: Intelligent Manufacturing Cell, the present paper emerges with the main aim of offering an initial design, description and analysis of the material flow of such a cell under the new "intelligent" denomination, as well as some principles to take into account for a successful functioning. For the sake of a better comprehension, all these elements are supported by the proposal of a detailed layout of the cell as well as by another illustration. At the end of the paper the authors state further research ideas and upcoming works.*
**KEYWORDS:** *Flexible/Intelligent Manufacturing Cell (F/IMC), material flow design, layout, reverse and direct flows, palletization, storage*

## INTRODUCTION

*The last decades have witnessed a significant migration from traditional production systems to a more flexible and intelligent manufacturing; it is happening as a way of looking forward to better satisfy the new and changing requests of the clients and overcome all those gaps from the quite rigid, traditional but at the same time quite cost effective mass productions. These still rather emerging FMS are capable of processing different types of products in an arbitrary sequence with insignificant setup delays between operations, and are mainly distinguished from other types of manufacturing systems by the following characteristics: high degree of functional integration, complex tool management and complex control software. Such systems as well all their most modern fellows, e.g.: Intelligent, Holonic and Agent-Based Manufacturing Systems are relatively expensive and thus and even when it is becoming better over the years, just a few companies can get to their implementation. As for solving these cost matters, a growing tendency to develop and use just smaller versions, e.g. I/FMC, is taking place both with real life production intentions or as research projects helping to evolve the field, [1, 2, 3 and 4].*

*Conscious of all this, the Institute of Production System and Applied Mechanics consists of a FMC. This cell is composed of several subsystems, i.e. Cartesian robot (CR) and Shelf-storage system (SS), and in a very close future of others like a small robot for the transportation of the parts and finished pieces inside the cell (Robotino), and another one dedicated to the palletization and despalletization (ABB robot). At present this FMC is still subject for further improvements and under a constant changing process towards a more intelligent, evolved and autonomous cell, i.e.: IMC. Changes related to such migration already encompassed the design and acquisition of new needed devices, and are currently being focused in the design, analysis and projection of its material flow, hence from this point on; it will be referred to as the IMC.*

*The rest of this paper will be organized in section II: Initial design, description and analysis of the material flow at the IMC, section III: Some basic principles to consider during the material flow design and section IV: Conclusions and further research issues.*

## INITIAL DESIGN, DESCRIPTION AND ANALYSIS OF THE MATERIAL FLOW AT THE IMC

*The future material flow is intended to function as described below, useful analysis and viewpoints related to this section could be found in [5, 6, and 7]. For the sake of comprehension in Fig. 1 the detailed design of the IMC layout is shown.*

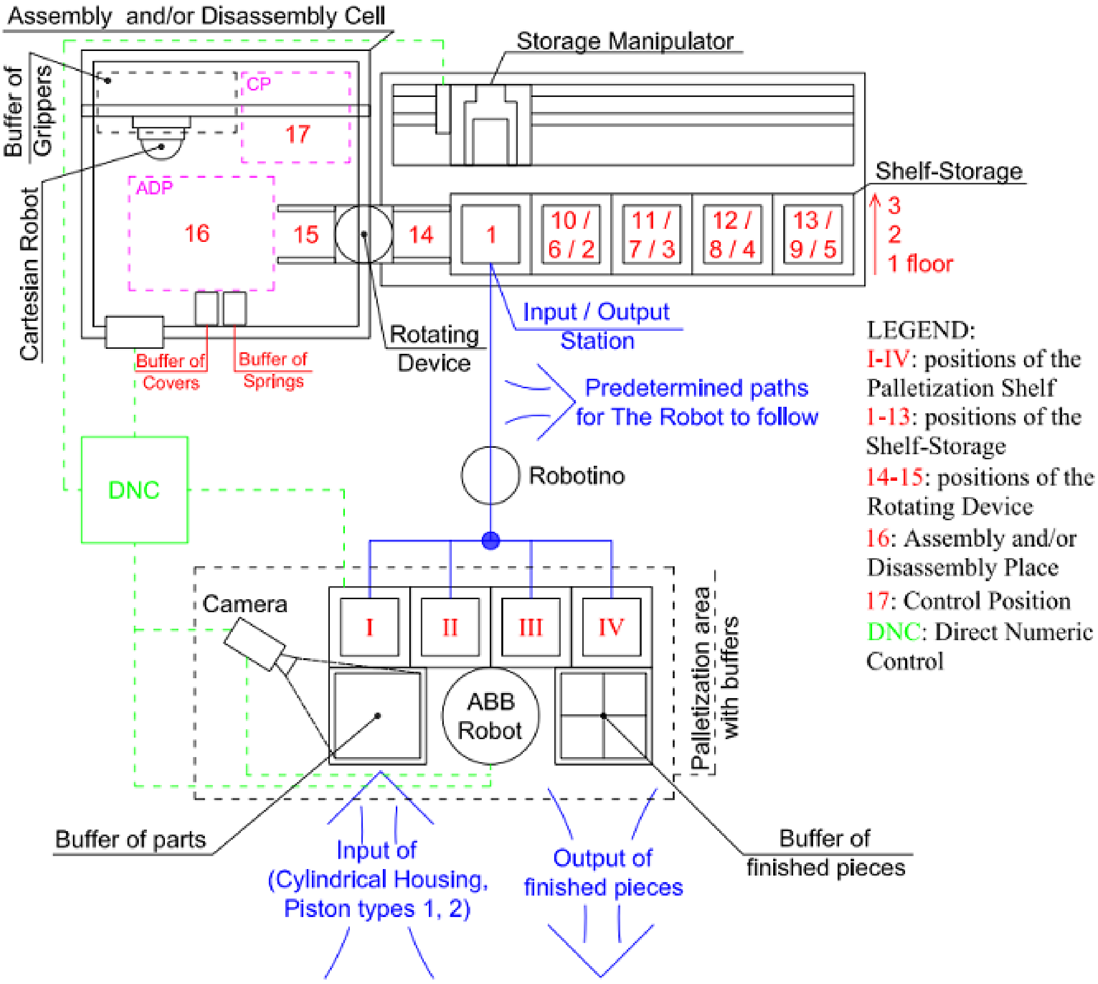


*Fig.1. Detailed layout intended for the IMC*

*The material flow begins at the Palletization area with buffers (PAB), where unsorted parts, i.e.: pistons and cylindrical housings wait to be manipulated. An ABB robot inside the area will select and place the right parts in the right position on the pallets as well as the assembled pieces in the boxes during the reverse flow. Such robot is intended to collaborate in a close future with camera so as to make possible these tasks. Such camera will identify the 3 types of cylindrical housings and 2 types of pistons, it will be located in the same PAB consisting on a high quality source of light, so as to unequivocally enable the identification of the colors of such housings, and then select the right one according to need of the batch being produced as commanded by the computer controller; colors of the cylindrical housings are silver, black and red. In a future such camera is also supposed to be making some surface quality control either of the parts or the assembled pieces, as well as to be helping in the selection of specific parts needed for a certain batch, when being these spread and mixed with different ones all over the area. The camera will be effectively located (inclined) so as to visualize the parts in 3 dimensions. Fig. 2 shows some pictures of the parts intended to be assembled in principle inside the IMC:*

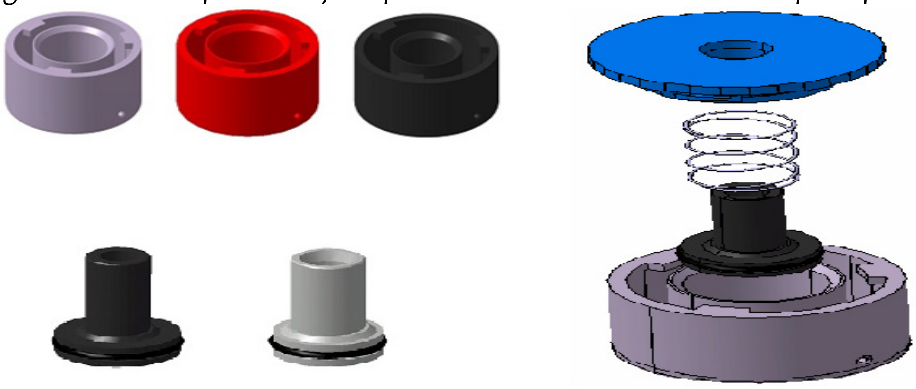

*Figure. 2. Set of parts integrating the piece intended to be flowing through the IMC*

*The shelf at the PAB where the pallets will be located consists of 4 positions that will be used either for the direct flow of parts or the reverse flow of the pieces. Once the pallets and their parts are ready, each pallet having one and only one part, these are handled by another smallest robot (Robotino), which moves between such PAB and the SS. This second storage area consists of 12 positions and an input/output one (I/O) where in a simple and first approximation, all parts must be placed when coming from the PAB, and pieces or empty pallets when going either from SS to the PAB or directly from the Rotating Device (RD) to the PAB, in case these are not stored in the SS before being transported. The SS is supposed to have in principle 2 available positions so as to avoid any kind of collision, this number could vary in dependence of the operating scenario and once the cell starts running, time standards must be determined so as to more mathematically justify such number of needed empty positions for which it could be useful the use of Simulation.*

*Parts being placed by Robotino at the I/O can either be moved into SS having to wait, or directly moved by a Manipulator (M) to the RD, for which the M must have stored the previous pallet(s) from the RD into SS first (it could be a pallet with an assembled piece, a piston's pallet or both of them). The selection of one of the 2 previous alternatives, besides having to do with the importance of the order being processed or simply the will of prioritizing the direct flow of parts or the reverse flow of pieces, could be better justified in future work when having the time standards of Robotino and its combination the ABB robot to take parts towards the SS, and the time standards of the M, RD and the assembly process; this and the possible combination of all these time standards at their different operative speeds which are at present unknown, could differentiate other working scenarios.*

*The RD either takes parts into the Assembly place (AP) or takes the pieces out from it when assembled. Once the parts are in the AP, first the cylindrical housing and then the piston which is also transported by Robotino, different grippers from the 3 existing ones are taken for the realization of the assembly process. The assembly process begins with arrival of the cylindrical housing which is fixed, then the piston is introduced, right after the spring, and finally the cover, the last 2 ones are in buffers located in the same AP. Assembled pieces just like any empty pallet, can either remain in the RD waiting till the incoming part being transported by Robotino from the PAB is stored in the SS, or be directly moved into the SS while the incoming part takes its place in the RD, the course of action decided will lie on the elements explained in the last paragraph. In any of the cases, pieces and empty pallets taken by Robotino when coming back to the PAB are placed in the 4 places shelf, and then pieces are taken by the same ABB robot into the proper boxes as it can be seen in Fig. 1.*

## SOME BASIC PRINCIPLES TO CONSIDER DURING THE MATERIAL FLOW DESIGN

1. *There must be predetermined paths for Robotino to follow between the PAB and the SS (optimized paths), such paths could depend on the decided operating scenario. In principle and in the most simple of the cases, there must be predetermined paths for Robotino between each of the 4 positions of the shelf in the PAB and the I/O*
2. *The PAB and the SS must be as close as possible*
3. *The I/O position should be always kept available for any Robotino ingoing movement (RIMj) from PAB*
4. *It must be a priority not to unnecessarily keep pieces in the SS and that Robotino never comes back empty*
5. *Manipulations of the M and rotations of the RD should be optimized to a minimum so that less energy and time are used as well as less complexity added to the system*
6. *Robotino should not wait for a part being still assembled to come back when having stored ready to return pallets in the SS*
7. *The M should never wait for the a part coming with Robotino to assemble a piece if having available parts in SS*
8. *The speed of the devices in the cell should tend to the maximum always that the quality keeps being as desired, this would increase the throughput. The combination of all possible operative speeds could yield a hard combinatorial problem that could be better analyzed in further research*
9. *The material flow must be as simple and linear as possible*
10. *The computer controller and the pallet identification system software must collaborate so as avoid unnecessary movements and anticipate some actions, e.g.: a. Robotino should not load a piece and take it towards the I/O when there will be a collision and it would have to take it back, b. every time*

*Robotino is coming back from the I/O at least 1 position must be available, why to place a pallet and mount a part if it would create a collision and would have to be removed back from the shelf. Elements of intelligence like these are intended to be added to the cell.*

*Even when most of the principles stated here are proper from this paper, it was also useful to analyze some rules, see 8 and 9 as well as the whole paper itself, from [6].*

## CONCLUSIONS AND FURTHER RESEARCH

*Through this paper the authors offered, described and analyzed in a first approximation, an initial design of the material flow at the IMC of the Institute of Production Systems and Applied Mechanics. As for helping comprehending some of the descriptions and situations, both a figure and a detailed layout of the IMC accompanied the sections. The paper creates a basis for a broader research project which includes the complete migration till the phase of practical functioning, to more autonomous, intelligent and flexible manufacturing cell. Further research ideas are related but not limited to the improvement of the material flow described herein, and more specifically to the analysis of most of its complexities, to the development of its flows diagrams as a basis for the future programming of the ideas, to the proposal of a more complete set of principles for a successful functioning of the cell, to the definition and delimitation of the states of the cell, to the definition of priorities, and to the analysis of possible events and their corresponding courses of actions.*

## ACKNOWLEDGMENTS

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## REFERENCES

*[1]. Gausemeier, J. and Gehnen, G. (1998). Intelligent material flow by decentralized control networks. Journal of Intelligent Manufacturing. Volume 9, Number 2, 141-146, DOI: 10.1023/A: 1008815928799*

*[2]. Kosturiak, J. & Gregor, M. (1998). FMS Simulation: Some Experience and Recommendations, Simulation Practice and Theory, Vol. 6, Issue 5, July 15, 1998, 423-442.*

*[3]. Mudriková, A., Delgado Sobrino, D. R. and Košťál, P. (2010). Planning of material flow in flexible production systems. In: Annals of DAAAM and Proceedings of DAAAM Symposium. - ISSN 1726-9679. - Vol. 21, No 1. Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium "Intelligent Manufacturing & Automation: Focus on Interdisciplinary Solutions" 20-23rd October 2010, Zadar, Croatia. – Vienna: DAAAM International Vienna, 2010. – ISBN 978-3-901509-73-5, pp. 0247-0248*

*[4]. Mudriková, A., Košťál, P. and Velíšek, K. (2007). Material and information flow in flexible manufacturing cell. In: Annals of DAAAM and Proceedings of DAAAM Symposium. - ISSN 1726-9679. - Vol. 18, No. 1. Annals of DAAAM for 2007 & Proceedings of the 18th International DAAAM Symposium "Intelligent Manufacturing & Automation: Focus on Creativity, Responsibility, and Ethics of Engineers": Croatia, Zadar 24-27th October 2007 (2007). - Vienna: DAAAM International Vienna. - ISBN 978-3-901509-58-2, s. 485-486.*

*[5]. Velíšek, K., Košťál, P. and Švrček, D. (2008). Flexible manufacturing cell and material flow planning. In COMEC 2008: V Conferencia Científica International de Ingeniería Mecánica. Del 4 al 6 de Noviembre de 2008, Cuba. Santa Clara: Facultad de Ingeniería Mecánica Universidad Central "Marta Abreu" de Las Villas, 2008, ISBN 978-959-250-404-2*

*[6]. Velíšek, K., Šebeňová, S., Ružarovský, R. (2010). Transport systems in flexible manufacturing. In I. Central European Conference on Logistics: 26 November 2010, Miskolc, Hungary. Miskolc: University of Miskolc, 2010, s. 5. ISBN 978-963-661-946-6.*

*[7]. Xu, D. (2001). Hardware-based Parallel Simulation of Flexible Manufacturing Systems. Dissertation submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfill the requirement for the degree of Doctor of Philosophy in Industrial and Systems Engineering, Blacksburg, Virginia.*