Using the Elements of Manufacturing Systems Management in the Calculation of the Implementation of a Serial-Modular Industrial Robot within a Flexible Work Cell Designed for Special Applications

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In this paper, the authors propose a basic design of a flexible work cell with a parallel organization, destined for the spot welding of AA V carcasses. The cell is serviced by three industrial TTR robots that perform spot welding operations on the carcasses flowing on the conveyor belt to each of the robots performing this operation. This paper presents economic issues on the value of the robots comprised by the system, the calculus of the entire FWC value, the determination of the FWC static configuration, and evaluates the overall profitability of the cell using elements pertaining to the mathematical game theory and the graph theory, as well.

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1 Introduction

Organizing the manufacturing activity with industrial robots is a design activity based on the synthetic analysis of the type of production, the type of equipments used and the products obtained within those processes. As part of the flexible work cell, the technological flow may maintain a certain feature dictated by the operations plan, a situation in which the part moves either successively from one piece of equipment to another, or randomly, depending on the type of parts processed within the cell. The flexibility of the work cell serviced by the robot is not given by the very presence of the robot within the work cell, but by the type of equipments within the cell. The flexible work cell stands as a developed manufacturing system, and not only because of the fact it is the most recent concept in the field of material goods manufacturing, but mostly because it triggers a significant improvement in the economy of the manufacturing process, given that it is focused on the needs for real and prevailing goods of the human society, that is, widely diversified goods in terms of typology which are produced in small quantities.

2 Determination of the TTR-Type Modular Serial Industrial Robot Workspace within the Flexible Cell with Parallel Organization. The Constructive Solution of the Cell

Given the kinematic diagram of the TTR serial industrial robot, presented in Figure 1a), we can determine, using the 3*3 rotation matrices method, and the algebraic one, respectively, the column vector of the operational coordinates and of coordinates on configuration space (relation 1), depending on which, by imposing numeric values to the geometric-constructive dimensions and their arresters, we can highlight the trajectory of the prehension device’s characteristic point (Fig. 2a)) on the horizontal robotic arm. The 2D constructive solution of the cell is also presented (Fig. 1b)). Hence, the following relations are obtained:

\[ \vec{X}_0 = [p_x, p_y, p_z, z, \beta_x, \gamma], \]
\[ q_1 = p_x - l_0 - r_{12}l_3, q_2 = p_z - (l_1 + l_2), q_3 = \arctan\left(\frac{l_0 + q_1 - p_x}{p_y}\right) \]

\[ q_1(t) = z(t) - 0.16 \]
\[ q_2(t) = y(t) - 0.20. \]
\[ q_3(t) = \frac{\pi t^2}{400} \]

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3 Aspects on the Calculus of the Flexible Work Cell Serviced by the TTR Robot

The flexible work cell proposed for implementation (Fig. 2 b) is composed of three TTR-type industrial robots (the first one performs the assembly operation, the second one is used in welding, while the third is introduced for AAV carcasses painting) and a conveyor belt necessary for the transportation of processing platforms. The conveyor belt consists of a roller bed, which is also an ideal solution due to the heavy-duty application, which is to be found in the Google Sketchup software menus with the Sketchy Physics plug-in, used in the modeling and animation of the cell serviced by the robot under study. At the moment when processing starts, the robot is positioned on the left, meaning that the translation module at the robotic base is at the beginning of the processing stroke. Before the horizontal translation movement begins, the robotic arm performs a vertical translation in order to position its gripper for the welding operation and by performing all the movements given by the execution program; the entire technological flow is performed. The economic study carried out on the cell, revealed the value of the robot included in the system, as well as that of the entire cell, the optimum size of the manufacturing batch and the supplementary benefit obtained using the robot within the cell (relation 2). The authors also calculated cell profitability by using graph theory elements in order to determine the minimum Hamiltonian path. The following values were, thus, obtained:

\[
\text{Price of robot} = 12882 \cdot \frac{\text{No.of points}}{2} = 23428[\text{EURO}], \text{Price of flexible cell} = \text{work units} + \text{cost of rendering modules compatible} + \text{transfer units} = 135454[\text{EURO}], Q_1 = N_1/k^* = 2040[\text{piece./batch}],
\]

\[
BS = \frac{\sum_{i=1}^{m} \sum_{j=1}^{n} S_i \cdot n_{ij}}{60 \cdot F_{tm}} \cdot W \cdot (1 - \frac{C_{1000m}}{1000}) = 4682[\text{EURO/year}].
\]

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References