VIRTUAL PROTOTYPING, PROGRAMMING AND FUNCTIONING SIMULATION OF MODULAR DESIGNED FLEXIBLE MANUFACTURING CELL

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Abstract: *The paper presents works performed by the authors in the field of flexible machining cell design, virtual prototyping as well as programming and functioning simulation. The project includes virtual prototyping a real scale flexible manufacturing cell considering workspace and components distribution validation, followed by developing part's manipulation and manufacturing programming and finally both manipulation and manufacturing subsystems simulation using MachSIM dedicated software.*

Key words: *flexible manufacturing cell, virtual prototyping, CNC modular machine tool, gantry robot, manipulation and machining simulation*

1. INTRODUCTION

Last decades researches regarding CNC machines tools and industrial robots development have reached a maturity stage. Manufacturing automation has dramatically increased the productivity and flexibility of manufacturing processes by implementation of industrial robots and modern CNC machine tools having facilities for high speed and high accuracy processing. Beside of these, the standardization provided by the G codes leads to more rapid and easy application configuration setting and implementation. Taking into account these aspects, more and more researches in this area focuses on new applications development (especially in the field of modular flexible manufacturing systems virtual prototyping and functioning simulation) as well as digital manufacturing and process control optimization by new informatics technologies implementing (Enciu et al., 2009 and Nicolescu et al., 2009).

2. THE FLEXIBLE MANUFACTURING CELL VIRTUAL PROTOTYPING

The flexible manufacturing cell (see Fig. 1), has been developed using Catia V5 virtual prototyping environment.

The manufacturing cell includes following elements:

- a modular 4 axis gantry robot for part manipulation (see Fig. 1), having three ISEL standardized modules for the X, Y, Z linear positioning axis, a FIBRO standardized module
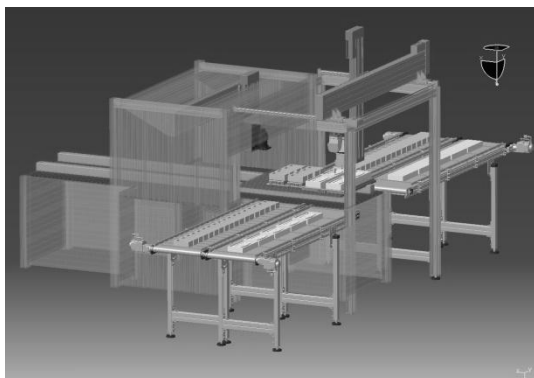
for the C rotation axis, and a PHD pneumatic standardized gripper (***, 2009a and ***, 2009c);
- a modular 3 axis CNC machine tool for part manufacturing, having three ISEL standardized modules for the X,Y,Z linear positioning axis, a standardized electrical inline tool-head driving system and a standardized (modular) part fixing vacuum system;
- complementary structural elements for the modular CNC machine tool configured using ISEL standardized mechanical elements too for supporting beams, pillars, angular reinforcing supports, connecting plates, covers etc.
- four standardized linear conveyor modules for two different part families income / outcome in / from the flexible manufacturing cell, as shown in Fig. 1 (***, 2009a).

3. MANUFACTURING CELL PROGRAMING AND SIMULATION USING MACHSIM SOFTWARE

After all flexible manufacturing cell's components have been reciprocally constrained and the workspace / components distribution were validated using specific functions, the modular CNC machine tool, the gantry robot and the conveyors were exported using the Machining menu (STL Rapid Prototyping option) from the CATIA software interface. All solid bodies were converted to simple surfaces using the Tessellation option. Thus, each component has been separately saved as a STL file. The zero (origin) point of the machine tool's coordinate system $O_M(0_M,0_M,0_M)$ has been defined in the geometric center of the X axis machine's table, supporting the manufactured part. The machine tool characteristic end-point $O_T(0_T,0_T,0_T)$ has been set as tool's characteristic contact point in machining. These setting have been done too in CATIA environment by defining the compass manipulation parameters.

For manufacturing cell programming and functioning simulation, specialized software "MachSIM" was used (Fig. 2).

In order to develop above mentioned application in MachSIM (***, 2009b), first, a new project was created by
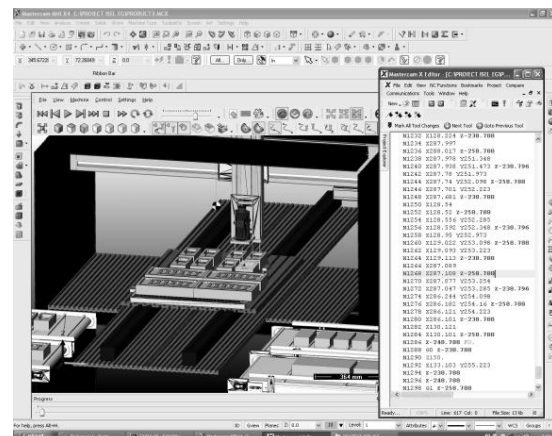

Fig. 1. Flexible manufacturing cell virtual model

Fig. 2. The machining phase programming, including G code generated by the MachSIM software

accessing the "New Machine" option. Then, flexible manufacturing cell was configured and further machine tool / gantry robot programming and their functioning simulation were performed following below detailed procedure:

- importing in MachSIM previously created STL files for the structural elements included in the modular machine-tool, the gantry industrial robot and as well complementary components (conveyors support, etc.) and machine-tool's X axis, Y axis and Z axis sets of components respectively gantry industrial robot's X axis, Y axis, Z axis, C axis and end-effector's sets of components;
- setting the zero (origin) point $O_A(0_A,0_A,0_A)$ of the overall application;
- setting the zero (origin) point of the modular CNC machine-tool's coordinate system $O_M(0_M,0_M,0_M)$ in the geometric center of the X axis machine's table, supporting the manufactured part, as well as specific transformation values for reporting O_M system versus O_A reference systems
- setting the machine tool characteristic end-point as origin of the tool's coordinate system $O_T(0_T,0_T,0_T)$, considering machine-tool's main spindle end-point $O_S(0_S,0_S,0_S)$ as well as specific transformation values for the origin of this system accordingly tool parameters and configuration (tool type, tool length, tool diameter, etc.) and specific transformation values for reporting O_T versus O_M reference system (accordingly machine tool's configuration);
- setting the zero (origin) point of the modular gantry robot's coordinate system $O_R(0_R,0_R,0_R)$ in the geometric center of the front-left pillar's rectangular base, as well as specific transformation values for reporting O_R versus O_A reference system;
- setting the modular gantry robot's characteristic end-point as origin of the end-effector's coordinate system $O_E(0_E,0_E,0_E)$, considering modular gantry robot's orientation system's end-point $O_O(0_O,0_O,0_O)$ as well as specific transformation values for reporting the origin of O_E system versus O_O and O_R reference systems (accordingly end-effector's respectively gantry robot's configuration);
- setting the origin point of each income/outcome modular conveyor's coordinate system $O_{C1i/j}(0_{C1i/j},0_{C1i/j},0_{C1i/j})$ respectively $O_{C2i/j}(0_{C2i/j},0_{C2i/j},0_{C2i/j})$ as well as specific transformation values for reporting $O_{C1i/j}$ / $O_{C2i/j}$ versus O_A reference system;
- setting the origin of each individual part's coordinate systems $O_{Pi}(0_{Pi},0_{Pi},0_{Pi})$ for i part family respectively $O_{Pj}(0_{Pj},0_{Pj},0_{Pj})$ for j part family, as well as specific

transformation values for defining each i/j part's characteristic location and orientation on the income / outcome corresponding conveyor as well as specific transformation values for reporting O_{Pi} / O_{Pj} versus $O_{C1i/j}$ and $O_{C2i/j}$ reference systems and O_R reference systems;
- setting the individual part's coordinate systems as well as specific transformation values for defining each part's characteristic location and orientation in machine-tool's coordinate system as well as specific transformation values for reporting O_{Pi} / O_{Pj} versus O_M and O_R reference systems;
- developing of first stage part's manipulation programming (uploading sequences of all part's manipulation by gantry robot from income conveyors on the machine tool table);
- developing part's machining programming including G code generating for each group of (same type) parts (different machining programs for i/j part families);
- developing of second stage part's manipulation programming (unloading sequences of all part's manipulation by gantry robot from the machine tool table on the outcome conveyors);
- performing overall collision checking (automate collision detection between machine/robot/part's elements) in order to prevent such events during part machining/manipulation;
- performing first stage simulation for i type part's uploading from C_{1i} conveyor on the machine-tool's table, second stage simulation for j type part's uploading from C_{1j} conveyor on the machine-tool's table, third stage simulation for i type part's machining (Fig.3a), fourth stage simulation for j type part's machining, fifth stage simulation for i type part's unloading from the machine-tool's table on C_{2i} conveyor (Fig.3b) and sixth stage simulation for j type part's unloading from the machine-tool's table on C_{2i} conveyor, using "Start Post Run" command from Sample Integration module of MachSIM software (***, 2009b), sets of (maximum 5) NC selected axis per simulation stage, as well as appropriate control options from the NC control area.

4. CONCLUSION

Present paper presents authors' contributions in the field of: 100% modular design of flexible manufacturing cells mostly based on ISEL standardized components, virtual prototyping of flexible manufacturing cells using Catia software as well as CNC machine-tool's / gantry robot's programming and their functioning simulation using MachSIM software. Future works will be focused on future development of using MachSim software for modular machine-tool units included in flexible manufacturing lines programming and functioning simulation.
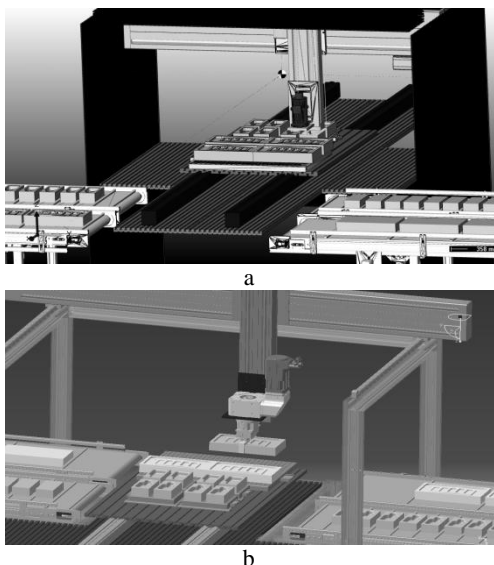

a

b

Fig. 3. Sequences from the simulation phases using the MachSIM: (a) machining, (b) manipulation (unloading)

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