

Increasing manufacturing systems performances by process and discrete material flow synchronized simulation

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Abstract: This paper will focus on the possibility of increasing manufacturing systems productivity by integrating the process simulation results in the material flow simulation. In our proposed algorithm we can improve manufacturing system performances using an optimized architecture by eliminating material flow concentrators on a simulation model. In order to assign the necessary parameters of this model we have used the results of process simulations describing each work point activity.

1. INTEGRATED MODEL LEADING ACTORS & HOW THEY ACT

In order to describe and illustrate our increasing productivity algorithm we need to define first the leading actors of that integrated synchronized simulation.

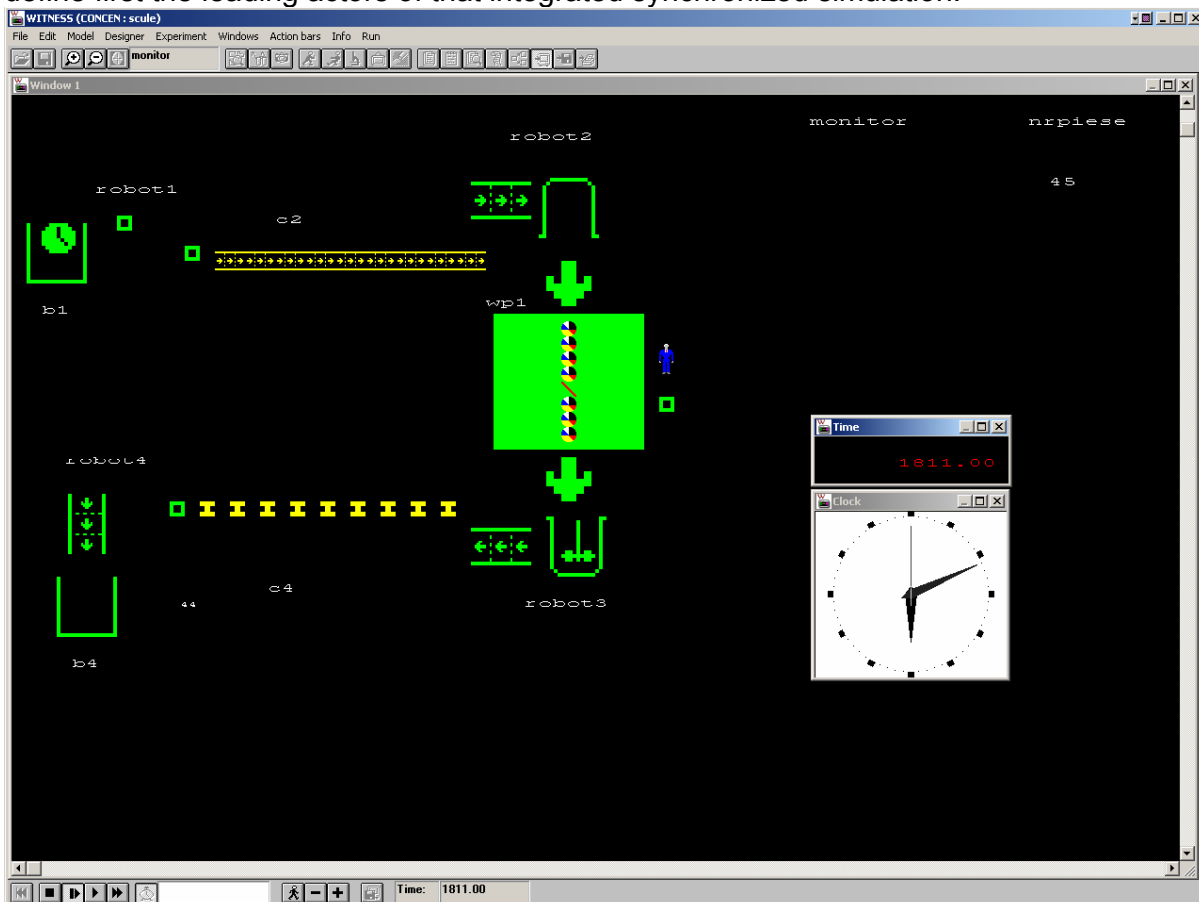


Figure 1 Witness model for a concentrate manufacturing system during simulation

We start with the material flow defined as the totality of parts & tools circulating during the manufacturing process from the first to the last work point of the manufacturing system. We define then concentrate manufacturing systems as architectures based on a single work point surrounded & assisted by transport, transfer & deposit facilities. One can see in figure 1 a Witness software model for a concentrate manufacturing system. In order to cover the entire material flow modeling area diffused manufacturing systems are also defined here as architectures with more than two work points connected by transport & transfer systems and using deposits at local or system level. In figure 2 we present a Witness software model for a diffused manufacturing system with 2 work points.

For a designed manufacturing architecture it is always useful to simulate the material flow conduct before applying our design into practice in order to avoid potential flow concentrators generating low productivity or even blockage. The leading actor able to manage this area will be the flow simulator. We agree here with the thesis that within the class of stochastic simulation models, one further distinction is necessary: simulations can be either terminating (sometimes called finite) or nonterminating in nature, with specific algorithms for each category [1]. We consider that due to the complexity of the mean time between failure (MTBF) and mean time to repair (MTTR) modeling for various machines and manufacturing systems one can provide the best solutions for such productivity improvement based on stochastic distribution laws and not on fixed values [2]. However fixed values for these parameters would be used for some particular finite short simulations. The algorithm proposed in this paper is based on a set of simulation techniques used to optimize manufacturing systems productivity via optimizing manufacturing systems architecture [3].

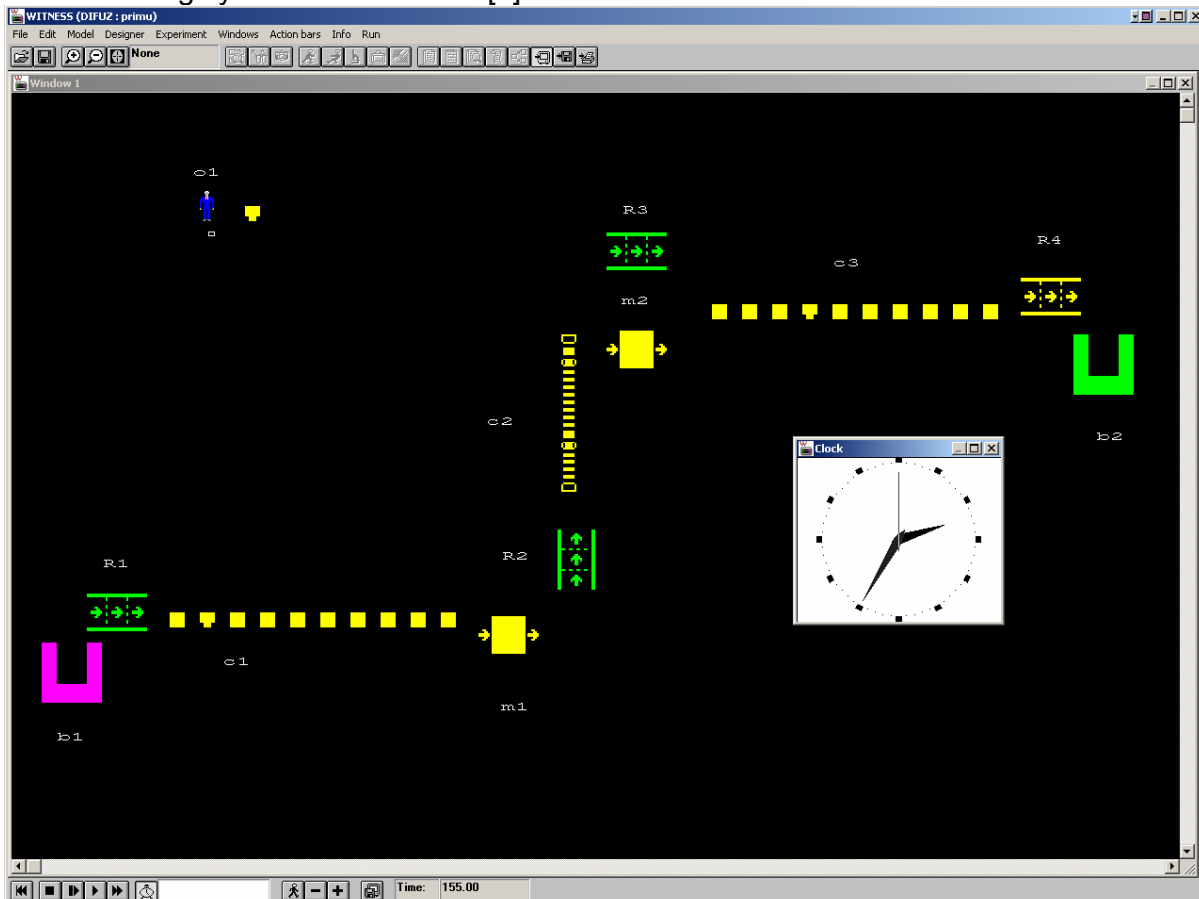


Figure 2 Witness model for a diffused manufacturing system with 2 work points during simulation

2. INTEGRATING PROCESS & MATERIAL FLOW SIMULATION

The main goal of our algorithm was to increase the productivity by improving the discrete material flow management using the process simulation as a preliminary data. We had analyzed the results of the material flow simulation and we had identified the flow concentrator for a preliminary manufacturing architecture based on process simulation results [4]. We had proposed an architecture modification as a solution for eliminating flow concentrators. We had performed a second simulation to validate the optimized manufacturing architecture by obtaining an increased productivity.

In our algorithm some of the necessary data for the material flow simulation like cycle times for the work points defined in our models are provided from CAM simulations describing each work point manufacturing process. The material flow simulator is integrating the process simulation results at the level at each work point in order to provide a complete model of the manufacturing system.

So in order to realize this integrated simulation model of the manufacturing system using Witness software we started with the process simulation using CATIA NC Manufacturing Solutions. That kind of software solution enabled us to define and manage NC programs dedicated to machining parts designed in 3D wire frame or solids geometry using 2.5 to 5-axis machining techniques corresponding with the work points in the Witness model. An integrated Post Processor engine allows the product to cover the whole manufacturing process from tool trajectory (APT source or Clfile) to NC data.

Let's illustrate the steps to be done for a lathe machining work point. The Machining simulation process can then be used by the Witness software model for overall manufacturing process integration, simulation and optimization.

Step 1. Preparing the 3D model.

The main element of the Lathe Machine application from CATIA is a ".CatPart" file that must contain the geometry of the work piece and the finite product. This file must also contain the geometric profiles needed for defining the work surfaces. This file is associated in Lathe Manufacturing application command tree with the part operation entry and as a result a new instance of the file is inserted into command tree. This entry can be edited using the Mechanical Design application; all the modifications are then updated automatically in NC Manufacturing application. Another ".CatPart" file is needed for storing complementary geometrical elements like the 3D model of the work piece after each part operation.

This 3D model is generated automatically after part operation simulation by activating the "compute stock part" command. Both ".CatPart" files can be accessed from the command tree. The user can also edit them by using the "Mechanical Design" module. Several ".CatPart" files can be used to store the geometry of the fixing part or the geometry of different tools that were used, if the tools were not selected from the CATIA tools catalog. The user can always check the link between individual 3D models, stored in ".CatPart" files, and the main work file ".CatProcess" by activating the "links" command from the "Edit" menu.

Step 2. Defining the part operations.

After opening the 3D model of the workpiece, it is necessary to specify the type of the machine tools from the CATIA V5R16 build-in types (3-axis Machine, 3-axis Machine with rotary table, 5-axis Machine, Horizontal Lathe Machine, Vertical Lathe Machine, Multi Slide Lathe Machine). This can be done using the "Machine editor" dialog box.

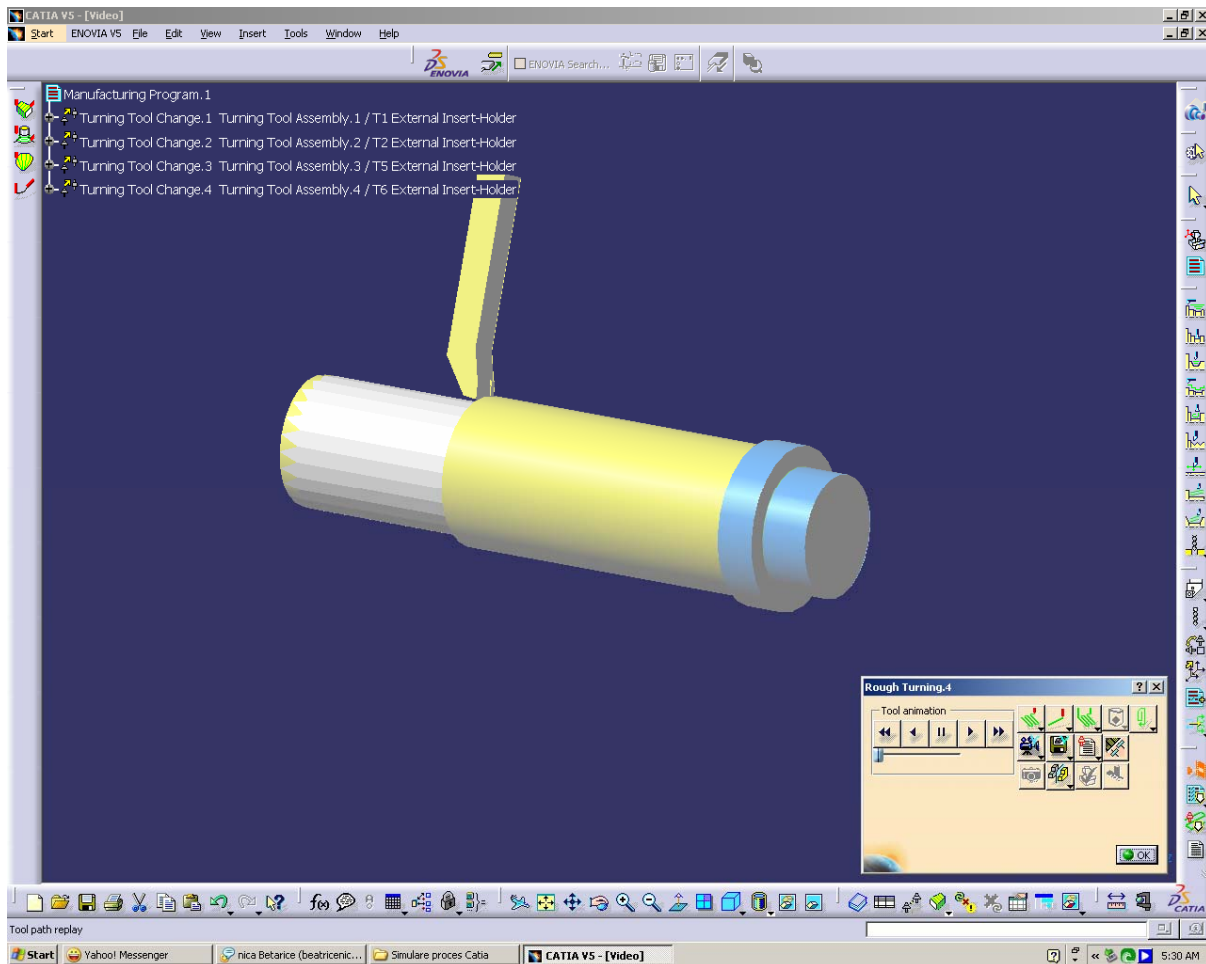


Figure 3 Catia Process simulation (rough turning operation)

By using this dialog box the user is able to customize some major aspects of the machine tools like Spindle axis, radial axis, tool change, numerical control. It is necessary to define working profile and the workpiece profile in Part Operation dialog box; those profiles are used by the program to compute tool paths.

Part operations are inserted into manufacturing program hierarchically regarding the technological program. This is also the order in which the manufacturing program is simulated. After choosing the right tool – insert assembly needed for manufacturing program a cutting profile must be selected. It is necessary that that after each operation a compute of the stock to be performed. The tools needed for process simulation can be choosed from CATIA's tools catalog, The user can chose from a large variety of shapes and dimension the right tool's insert. Geometrical characteristics of choosed tools inserts can be then modified in order to match the real tools.

The cutting parameters are automatically calculated by the program considering the machining program (finishing, roughing) and the tool characteristics. Those parameters can be changed by disable the "Automatic compute from tooling Feeds" option.

Step 3. Simulating the manufacturing program

After defining the manufacturing program a simulation can be performed in order to visually analyze of the entire program. The purpose of this analyze is to ensure that tool path are compute correctly and there are no clashes during the manufacturing process. This step must be performed before testing the NC program on the machine-tool.

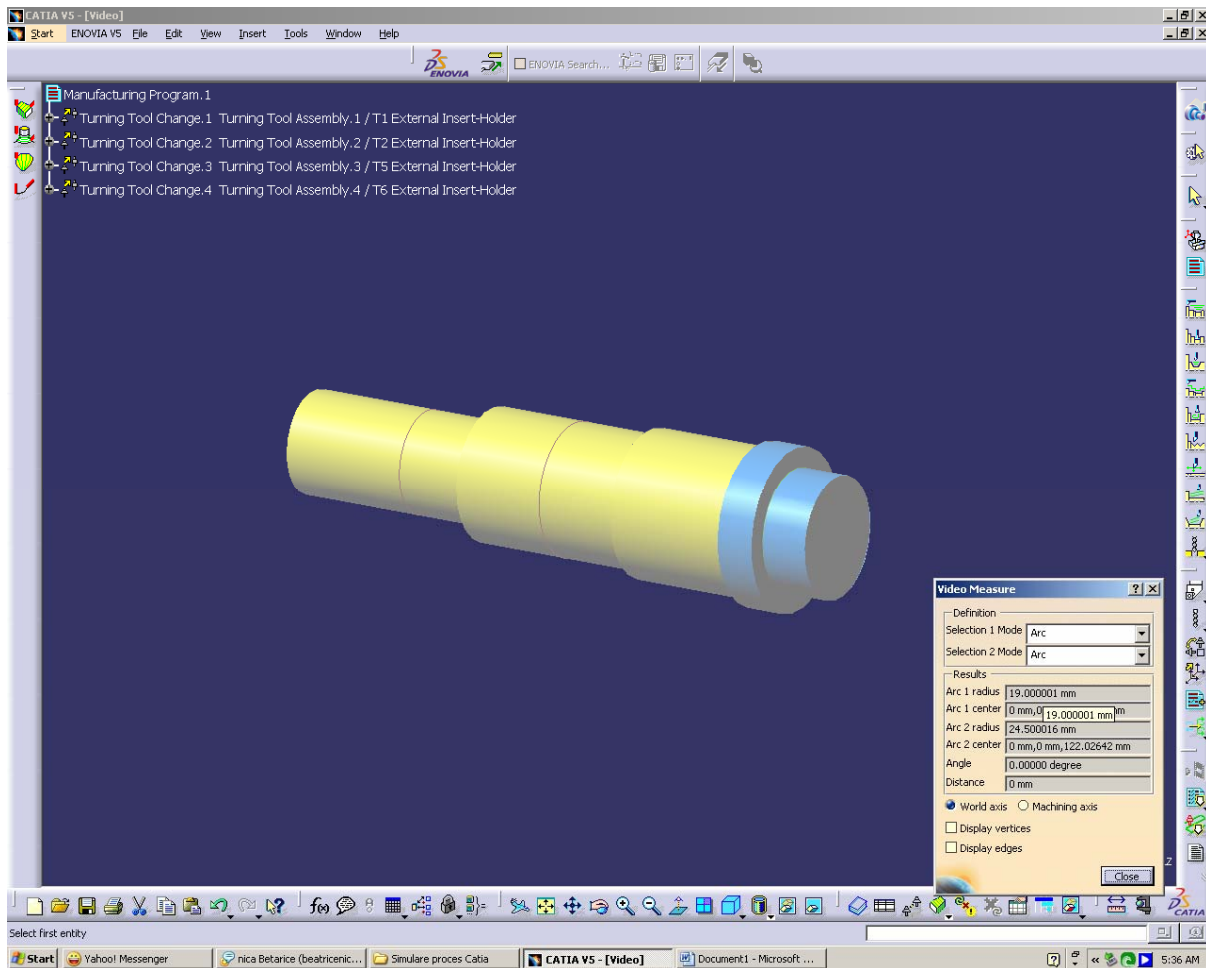


Figure 4 Graphical analyze of the simulation (Video measure tools)

To briefly illustrate those steps in figure 3 a sequence from the rough turning manufacturing process simulation is presented as well as one can see in figure 4 the video measure tools used for the graphical analyze of the simulation.

Step 4. Configuring models for discrete material flow simulation

Using the results of the process simulation this step allowed one to establish the parametric configuration of the manufacturing system model. We use Witness software to realize the preliminary parametric model of the manufacturing system and to simulate the material flow in the system in order to identify the flow concentrator. Different algorithms are used for the diffused and concentrate manufacturing systems, for terminating or non terminating simulations according with the specific constraints characteristic for each case. A Witness concentrate manufacturing model and a Witness diffused manufacturing model for terminating simulations (using fixed values for MTBF and MTR) are presented in figure 1 and 2. In both cases each work point parameters were established based on process simulation results using Catia.

Step 5. Optimizing the manufacturing system architecture

Using the Witness reports one can identify the flow concentrators and according with manufacturing planning constraints can propose technological solutions or modifying manufacturing architecture based solutions to eliminate those concentrators. In order to validate the increased productivity obtained on the optimized manufacturing system

architecture, a new simulation is necessary. If one weighs the productivity for the preliminary and optimized architecture the increasing productivity due to the optimization can be quantified.

Step 6. Quantifying the economic gain of the optimized manufacturing architecture

A very important issue of this algorithm is to evaluate if the optimized architecture supplementary costs are or not covered by the productivity gain. This financial analysis is based on a NPV algorithm and validates the financial profitability of the optimization.

3. CONCLUSION

We focus in this paper on several simulation techniques of increasing manufacturing systems performances. In order to evaluate the manufacturing system preliminary architecture we had used material flow and cutting process simulation models based on Witness and Catia software. This simulation project was undertaken with the goals of demonstrating and confirming production rates of a manufacturing process based on a proposed design layout and operational data and of identifying ways of improving the design of the system in order to increase those production rates. We had applied in this paper a set of synchronized simulation techniques used to optimize concentrate & diffused manufacturing systems illustrated by two Witness models acting together with corresponding Catia CAM models in virtual manufacturing architectures. The main goal was to propose an algorithm able to increase the productivity by improving the discrete material flow management based on the results of cutting process simulation as parameters for each machine-tool work point. According with this algorithm one can analyze the results of the material flow simulation and identify the flow concentrator for each one of the manufacturing systems integrated in the two virtual simulation models. If an architecture modification is proposed as a solution for this problem. a second simulation to validate the optimized architecture and the obtained increase of productivity is necessary. Last but not least a financial analysis must confirm the profitability of the manufacturing optimized architecture.

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