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INTEGRATING CAPACITY SIMULATION INTO PROCESS PLANNING

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ABSTRACT

Process planning in the automotive industry is referred to as advance manufacturing engineering, because it is done in advance of production — before the facilities are created. When developing these processes, simulation is typically done by service groups, not the process planner, resulting in communication errors and unnecessary iterations. Software applications are now becoming available that not only simulate the production throughput objective of process planning, but other planning considerations such as process capability, material flow, ergonomics, and interferences. The impact of these simulation tools is put into perspective when considering the powertrain manufacturing engineering environment: process development time in years, cycle time accuracy in seconds, cost of the facility in hundreds of millions, and expected duration of the process in years. That is, a single expensive opportunity to implement a long-term investment, with verification done by "simulation" experts not intimately involved with the process. The future of simulation for me seems obvious!

1 INTRODUCTION

Process planning is the selection of methods and equipment for production of a product at a specific rate. The selected process is based on the volume required, such as flexible manufacturing for small batches, or transfer lines for throughput typical in the automotive industry. When planning for automotive production rates, emphasis is placed on optimizing cycle time (units in seconds). Automotive process planning is therefore concerned with minutiae about facility layout and manufacturing events. This process planning is typically done in advance – referred to as advanced manufacturing engineering – when there is no hardware (normally new facilities). Facility layout is not easily "modeled" or "simulated" because it is typically done with drawings (2D layouts) and the mix of disciplines involved. Manufacturing events include estimates of setup time, cycle time, downtime, and mean time to repair etc. It is evident then that process planning (simulation of the facility and its performance) has to be done in a virtual world. How can this be done by process planners, and what other benefits can be realized by virtual modeling? This paper proposes that this capability is emerging for automotive process planners, based on a study in advanced manufacturing engineering for power-train at DaimlerChrysler in Auburn Hills, in collaboration with UGS/EAI.

2 PROCESS PLANNING

Even though product engineering is credited with the most influence on cost, process planners are the source of how that cost is incurred (manufacturability). Process planning is therefore not only concerned with preparing the manufacturing instructions, but also the coordination of the "knowledge" of the product development community, that is, product functionality, facility capability or process preferences, and production equipment suppliers. By function then, process planning is the integrating activity for product and process cost estimating, plant and tool engineering (geometry simulation), methods and ergonomics (human-machine-interface/ergonomics simulation) and proof of production capability (throughput simulation). Manufacturability analysis is essentially time (hence cost) estimating based on the facilities needed for a specific rate or capacity. Plant engineering addresses the "layout" of the production equipment, that is, the ordering of events and material flow. Tool engineering, determines the performance of the specific tasks, or production cycle time. Internal or external specialists that know simulation tools, but not necessarily process planning, typically do simulation of the proposed plant and tools.

Advance manufacturing engineering coordinates the information of functional specification/manufacturability, plant layout, tooling, and suppliers, as follows:

- **Simultaneous engineering:** manufacturability analysis, estimates or of cost, time and other production metrics such as process capability.

- **Process planning:** process selection for feature types (machine tools), setup planning for feature grouping (fixtures), and line balancing by feature decomposition (tooling and process geometry).
- **Equipment procurement:** tooling/human interface, and equipment specifications (tools, fixtures, gauges) and simulation studies to verify the applications.
- **Runoff:** proof of manufacturing plan and production rate (process capability and throughput).

As can be seen from the above phases of product and process development, manufacturing engineers need simulation tools, from cost estimating/cycle time simulation, to process verification/tooling simulation, to human-machine (HMI/ergonomics) simulation, to process variation simulation, to throughput simulation.

3 COST ESTIMATING AND PROCESS DESIGN

Cost is based on the equipment cost and the respective processing time. Equipment cost can be associated to the items in the layout. Process costs can be based on the manufacturing features per piece of equipment. The production rate, based on cycle time, hence cost, can be quantified using feature information, such as when determining processes by feature type, fixtures by feature grouping and rate by feature decomposition. The common terms of reference in product and process development, as well as production, are these features and the associated information, for instance, a hole feature with a diameter and location tolerance produced by specific tooling with planned parameters.

These features, or the decomposed elements thereof, can be associated to machine tools (stations in automotive terminology), as are other performance data when creating a virtual factory. For instance, the FactoryCad software application allows process planners to embed simulation data such as time–to–fail, time–to–repair, tool–change–time, and scrap–rate into the machine tool elements of the virtual factory. This virtual process (models and information) then not only enables communication, but also serves as a simulation model, for cost, layout, ergonomics, and throughput etc.

4 PLANT LAYOUT

The virtual factory can be created, or "simulated visually" in FactoryCAD, an object oriented factory modeling capability on top of AutoCad, enabling designers to work at a higher level of abstraction, that is, working with library objects such as turntables and conveyors rather than lines and circles. This is obviously much more efficient. These objects are parametric, allowing customized configurations. Objects can be general such as a standard set, or domain specific such as for automotive, or unique such as for DaimlerChrysler powertrain, and could include objects such as machine tool bases, columns, heads, etc. This layout capability can be 2D, 3D, or both at the same time - thus a very comfortable transition for process planners – an easy way to introduce the digital factory concept without severe technology shock. The efficiency of working with objects is best described by the sales slogan that "3D fly-through representations are virtually free". The objects are "smart", that is, inherent interactions between objects, as well as design rules within a single object. The virtual factory file size is kept manageable by using a "visual shell" rather than solids.

Material flow analysis available in FactoryFlow can be used to quantify material flow distance and frequency, thereby optimizing floor space and other layout concerns. This consists of establishing a work-piece "flow model" to identify the critical path and potential process problems. Inputs include the above layout and planned volume (from process planning). The analysis shows both visual (simulated) concerns (bottlenecks) and quantitative measures (time and cost).

5 ERGONOMICS

The virtual factory could now analyze the human interface, through "visual simulation" in VisJack. Specific DaimlerChrysler ergonomic rules can be imbedded into visual simulation tools that show the human-machine interface. For example, reach and height can be represented as a "working envelope" showing the human interface with a part, mounted on a fixture, being assembled (with tools), at a machine or conveyor. More thorough analysis such as lifting and fatigue should still be analyzed quantitatively, but this could result in a small percentage of the analysis if the visual simulation capability is available.

6 CAPACITY

The virtual factory, containing the layout and associated process parameters, could be the basis for capacity simulation. Because the simulation model is essentially built by the process planner, it is a logical step to automated through-put analysis by submitting the virtual factory objects through a link, or simulation data exchange (SDX), to a simulation application that will generate "first cut" analysis for process planners.

The SDX process can be summarized as follows:

- create a 3-D model of the layout,
- embed simulation relevant data into the equipment "smart objects",
- use the SDX Route Editor to create the routing of the parts in the plant,
- generate a formatted ASCII flat file (SDX file) describing the manufacturing data and layout,
- translate the SDX file into a simulation model,
- simulate throughput, using the preferred simulation software.

Integration with simulation software vendors was part of the study, and is best explained by the representative from AutoSimulations, Dan Doss, as follows: "Phase I consists of being able to generate a 1st pass AutoMod simulation analysis directly from FactoryCAD. This is done by the plant engineer from inside FactoryCAD, by selecting an AutoMod simulation activate menu button. All design analysis is done from the FactoryCAD environment. There is no need for the plant engineer to interact with AutoMod directly. The plant engineer can change data from within the FactoryCAD environment and can run as many simulation analyses as needed until the desired plant throughput performance results are obtained. Each simulation takes only minutes to perform versus days for each run under the current process. Plant design results can be dramatically improved and custom simulation time significantly reduced.

The plant engineer can provide input for a detailed simulation analysis to a simulation specialist for further analysis if desired. A base AutoMod model will have already been created by the plant engineer and can be given to the simulation specialist, significantly reducing the simulation specialists time and effort to analyze a plant design in detail. The AutoMod capabilities that are provided in Phase I include support for version 4.2 of Simulation Data Exchange (SDX) format. All routing capabilities for version 4.2 of SDX will also be supported. AutoMod will be provided as a seamless integration into FactoryCAD. It will function essentially as a FactoryCAD add-in. This will support discrete event simulation build, run, and performance statistics generation from within FactoryCAD.

Phase II will continue to build on and support the implementation of an integrated FactoryCAD / AutoMod design and simulation environment. The major focus of Phase II will be to support bi-directional SDX data flow, to enhance design change management by allowing AutoMod models to be updated with selective data from new SDX files and to allow export of AutoMod models to the FactoryView 3D virtual factory viewing environment."

AUTHOR BIOGRAPHY

VAUGHAN HETEM is responsible for systems used in process development for powertrain at DaimlerChrysler in Auburn Hills. This involves integration of "best in class" solutions not only within DaimlerChrysler but also in the supplier community. He is an experienced process planner and has a Ph.D. from the University of Illinois.