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ON THE USE OF SIMULATION IN THE DESIGN AND INSTALLATION OF A POWER AND FREE CONVEYOR SYSTEM

George L. Good
GM Motors Consulting Center
803 W. Big Beaver Road
Troy, Michigan 48084

J. Thomas Bauner
GM Guide Division
2915 Pendleton Avenue
Anderson, Indiana 46011

INTRODUCTION

If the introduction of the first power and free conveyor system in a plant is a risky adventure, then the introduction of the second power and free conveyor system in a plant where the first one failed is an extremely hazardous undertaking. The people proposing this power and free conveyor system decided to decrease their risks by initiating a simulation study while the system was early in the design phase. The primary purpose of the proposed power and free system is to minimize the manual handling of parts between the two plating tanks compared to the system it replaced. The basic objective of this simulation study was to evaluate the feasibility of the proposed system to perform the required tasks while operating at specified production levels with efficient use of the planned number of workers.

This paper will begin by describing the power and free conveyor system which serves the two plating tanks. A discussion of the approach to model development and the problems encountered will be followed by a description of the problems encountered during model validation and the testing of alternatives.

A significant feature of this simulation study is the communications, involving problems, solutions, etc. which developed between the concerned parties during the time period from system proposal through final productionizing. The people involved in this study included the system proposers and production users in central Indiana, the conveyor equipment and programmable controller vendor in southeast Iowa and the simulation modeling activity on a computer in southeast Michigan.

DESCRIPTION OF THE PLATING SYSTEM

The system modeled is a large copper-nickel-chrome plastic plating operation at an automobile component manufacturing facility. The Plating Department has approximately forty different part numbers of which about twenty-five are simultaneously on the plating system. The parts range in size from small sidemarker bezels to large radiator grilles. Each part number has a quantity of distinctively designed plating racks which are dedicated to that part number. The quantity of racks used for each part number is dependent upon the schedule requirements for that part. The system may contain a maximum of 536 plating racks.

The power and free monorail system is used to convey plating racks to and from three basic facilities shown in Figure #1.

A. A Preplate Conveyor
B. A Final Plate Conveyor
C. An In-Line Rack Strip System

Molded plastic parts, of two different material types, are loaded to plating racks at five specific load stations. Each load station is capable of handling a maximum of seven different part numbers. The plating racks enter their respective load spurs sequentially by a logic control known as string loading. This method allows racks for only one part number to enter a specific load spur while the selected part is being loaded. Other racks bypass the entrance to their load spur and continue to move on a recirculation loop until all racks of the selected part have entered the load spur. Then a new part number is selected to be loaded.

Loaded racks are conveyed to the preplate conveyor on the power and free monorail. Prior to entry to the preplate tank, the racks are segregated according to material type. Racks of type "A" material (thirty percent of the total volume for the department) require special treatment in the preplate tank. Racks are transferred in pairs into and out of the preplate tank facility.

Racks are selectively stopped at the preplate inspection station to allow an audit of the plating quality and to replace defective copper preplate. Racks of type "B" material are next conveyed by the power and free monorail to the final plate tank. Type "A" preplate racks are conveyed to the re-rack area where parts are manually transferred to a matching type "A" final plate rack. The empty type "A" preplate racks move back to their respective load stations. The loaded type "A" final plate racks join the type "B" racks and proceed to the final plate tank, transfer of racks at the final plate conveyor is identical to that of the preplate transfer.

After the final plate process, the racks are conveyed to the off-loading station where plated parts are manually placed onto a conventional chain monorail. The empty racks are delivered to the in-line strip system where they are immersed in cleaning solutions while hanging from the power and free carriers. After several wash and rinse cycles, the racks move toward the load spurs. Type "A" final plate racks are diverted into the re-rack area. Type "B" racks move to their respective load stations.

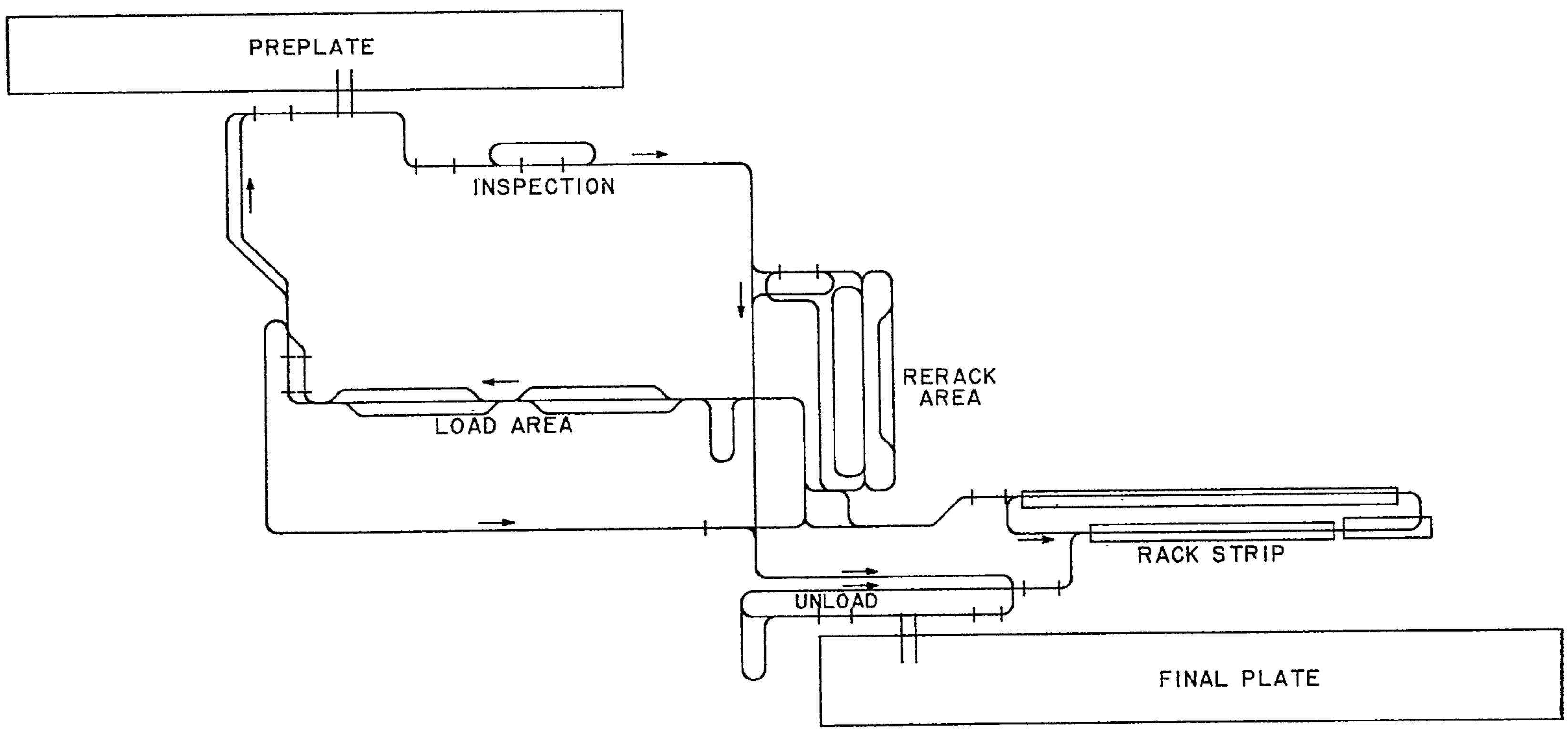

FIGURE 1: THE SYSTEM SCHEMATIC

MODEL DEVELOPMENT

Model development for this study was started while the system concept was still fairly fluid. A proposed system layout was available along with some probable rules for conveyor switch operation and the procedures to be used in a re-rack area, which included off-line equipment for minimal in-process inventory. These items of information were used to develop a logical word model of the proposed system. The iterative process involved in developing the word model was a very useful mechanism in communicating between the system proposer and the simulation modeler. During the development of the word model, some possible problems surfaced that resulted in some early design improvements.

The selection of the GPSS language for use in representing this system was based on the initial system description and the training and experience of the people involved in this project. When simulation becomes involved in the early stages of a project, the modeler may be frustrated by the fact that layouts and operating concepts may change faster than a model can be completed. The initial models of different concepts and layouts were developed in a modular fashion in so far as was practical. Although the early models were left incomplete, the time to complete a model of the selected concept was much less than would have been required if the modeler had started with a clean sheet.

The early communication between the simulation modelers and the users definitely influenced user-vendor interactions and had a minor influence on vendor selection. The selected system of individually powered carriers was new to the United States for this vendor. Model development preceded design proposals for the exact location of switch controls as well as the control logic used at many points in the system. These conditions made communication of system design details from vendor through user to modeler difficult, and the initial simulation model representations of some details were less than accurate and some proved to be rather optimistic. The initial workable control logic for the complex conditions in the re-rack area were developed independent of the vendor. This was necessary in order to complete the simulation project objectives in a timely manner.

MODEL VALIDATION AND VARIABLE TESTING

One method of validating a model of a non-existing system is to compare measured responses from the model to previously calculated expected average values. In some cases, when variability in the system is based on random occurrances from a known distribution, it is possible to check some conditional validity by substituting constant for variable values. Another complication when using simulation to design a system, is to determine the difference between a valid model of a bad system and an invalid model of a good system.

In this case, it was not practical to control the variability introduced by the combination of part loading times and the procedures for diverting racks to specific locations. A variety of schemes, such as interactive debugging and special reports, were used to ensure that the model was performing as designed. It is still recognized that what is considered a valid model may not exactly represent the final productionized version of the system. During productionizing, a time-scaled graphic histogram report of work content build-up approaching specific load stations was used to help production personnel understand some of the intracacies of this system which are not evident from floor observations. Floor observations often provide a picture of the problem, but no insight into the cause of the problem.

The types of tests conducted in different versions of the model included such items as the location of conveyor sections, conveyor switches and switch controls, the control logic and the number of carriers and racks in the system. The performance measures used to evaluate alternative tests included the total system throughput, individual part number throughput, worker idleness, and measures of potential congestion due to recirculating carrier traffic in specific sections of the system. Evaluation of simulated results contributed to layout changes for conveyor monorail sections and conveyor switches. Simulation test results were used during productionizing to direct changes in control hardware locations and operating procedures programmed into the programmable controller.

There was a considerable amount of testing concerning the optimum number of carriers and racks that should be used in the system. This question is complicated by the objective to reach desired levels of daily throughput for the individual parts as well as the total system. The original estimate was that 110 carriers would be required to meet the desired production level. Test results indicated that the system can operate at similar levels of performance for both individual part and total system throughput when the number of carriers is reduced to approximately one hundred two. Other tests indicated that the system could operate with no significant change in throughput with up to 135 carriers in the system.

VALUE OF SIMULATION DURING SYSTEM INSTALLATION AND PRODUCTIONIZING

Installation of the power and free monorail system for the plating system was accomplished in two phases. The phase one installation included the rack load and recirculating section, the final plate conveyor, the unload area, and the rack strip conveyor section. Phase two installation and debug was planned for approximately six months later. Phase two tied the entire system together, including the preplate conveyor, inspection area, and the re-rack section.

With the completed installation of phase one, numerous faults in the logical controls of the power and free monorail system were detected. The placement of some monorail controls unnecessarily limited the throughput of plating racks in specific areas, thereby causing the system to perform below standard. Steps were immediately taken to compare the location of hardware controls on the installed system with the locations represented in the simulation model. The reasons for the disparity in the simulation model's throughput and the actual plating system's throughput were recognized and steps were taken to relocate the controls on the monorail. With those changes made, the phase one system's throughput was increased significantly.

The disparity of location and logic used for the monorail system's controls indicated the need for better communications between the user and the monorail vendor. Information had been exchanged between the two parties, but closer follow-up on the part of the user during design and installation of phase one of the system could have greatly reduced or eliminated the above mentioned problems.

As a result of the problems encountered during phase one productionizing, communication between the vendor and user were much more intense while phase two was being designed. The simulation model was a constant source of reference and testing as to how control logic should be coded for the phase two programmable controller. The placement of monorail controls was closely scrutinized to assure that no problems with plating rack throughput would go undetected. Although separated by the programming language barrier, the GPSS model served as a source for logical flow charts which defined how the phase two system should behave. The conveyor system vendor was extremely receptive to the assistance which the analysis of the simulation model provided.

CONCLUSIONS

Simulation can be used as a tool in designing complex power and free material handling systems. Models should be modularized in so far as is practical to minimize the time required to keep the model current with the design. The simulation effort should be started early and time and resources should be provided in the project plan to permit adequate testing of alternatives and evaluation of results. There is a need for an improved method of communication between programmable controller logic programmers and simulators because they appear to be seeing complex material handling systems from different viewpoints.

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