Measuring the industrial processes performance by simulation

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Abstract**—** This paper describe the development of a reliable product that enable to measuring the industrial processes performance by framework management methods. It briefly describes the Witness simulation system and three Excel tools built and used to modeling and simulating a complex assembly line known as AML (Assembly Main Line). Also, it describes typical problems that call for use of modeling and simulation process and then explains how the relevant data are collected. Validation of the AML model is carried out through a significant case study that describes and analyzes the impact and effect of rejection rate (measured by first time through, FTT) on throughput of the assembly line, and the use of simulation as a method and supporting tool used to improve the industrial processes performance. By validating the AML model, it's confirming that it was properly built, provided that the input data are correct and correspond with reality.

Keywords**—**assembly line; overall throughput; performance evaluation; rejection rate

I. INTRODUCTION

Many papers in the specialty literature highlights the fact that, to succeed with high-quality products in today's highly competitive world markets, companies have a great demand to highly adaptive management and plays a significant role in improving their industrial processes performance in order to fulfill the customers' needs and sustain their competitive advantage [1, 2]. Due to the customer's needs and expectations, the modern companies are facing a higher pressure to identify and implement management methods to improve their responsiveness in 21st century market dynamics [3]. One of the most important advances of implemented management methods in industrial processes have opened up the research possibility of optimizing the modeling and simulation process [4]. The global trends on software development allow processes to be developed in a large area which require several changes and reliable software's [5-7].

Due to the emergence and improvement of electronic computers, simulation is now widely used in scientific research and design. The simulation process is a technique that involves the use of mathematical and logical models that describe the behavior of a real system over a period of time and requires the use of electronic computer. Modeling complex systems such as industrial process is a difficult task and as such, requires a simple and effective way to facilitate the simulation process [6]. Simulation has an important role in guiding the processes understanding and development without requiring costly manufacturing trials [8] and accordingly, the computer-aided techniques are found mainly in modeling and simulation process [9].

To characterize the impact of changing the values and parameters to measuring the industrial processes performance, simulation has been widely used as a support decision in modeling and analysis the processes. Thus, when the direct measurement of parameters isn't easy and trusted, modeling and simulation process provides efficient methods of observing the behavior over time of a process [6], [10]. Simulation is a rewarding tool for industrial processes performance, especially in the system design and launching phases and a model is a conceptual or mathematical representation of a system or process [11]. Mainly, the modeling and simulation process includes specific techniques and methods of computer-aided applications [9].

II. THE ASSEMBLY MAIN LINE (AML) MODEL AND SIMULATION TOOLS

An assembly line has different sub assembly lines or process flows, defining a process flow as any set of operations that feed another line that would stop the line from working, because of slow or varying cycles, breakdowns, quality issues etc. Simulation is one of the techniques available to study large and complex systems, is a collection of methods and applications designed to mimic the actual behavior of industrial processes. Today, there are many simulation tools available that can model all kinds of systems, regardless of their complexity [6].

To build the AML model as a complex line composed by eleven production zones (areas) was used the Witness simulation system. Although Witness is quite efficient and allows modeling and simulation of complex production systems, however, in certain circumstances, it cannot cover their versatility. In this case, to simplify and ease the simulation experiments of the AML model was developed three Excel tools (Fig. 1), named as Database Centralization (DC), Orders Generator (OG) and Collector of Results (CR):

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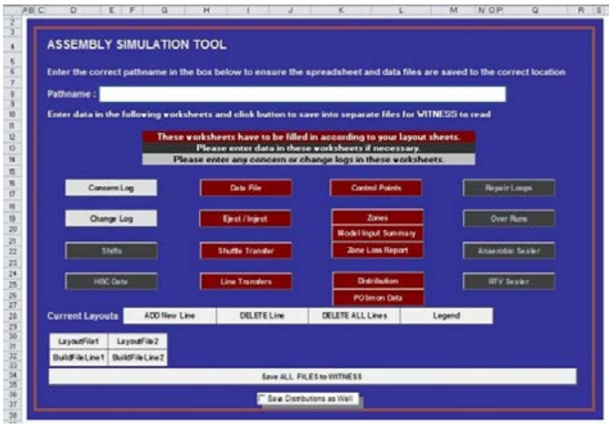
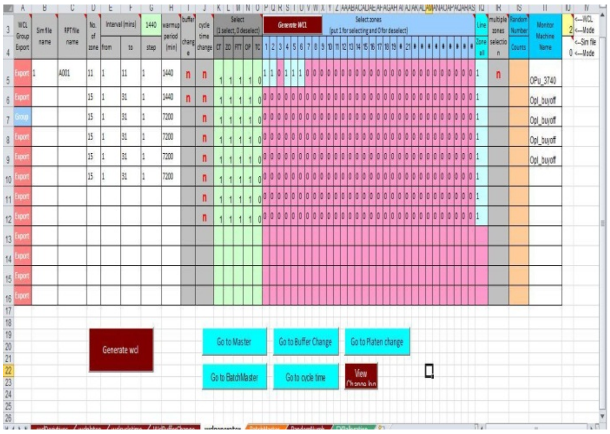
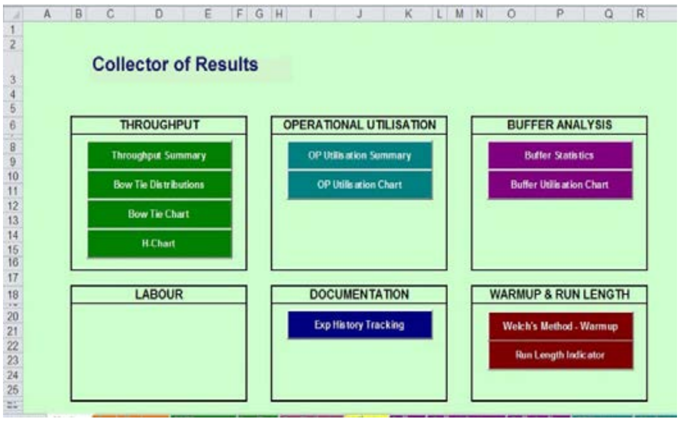


a. The Database Centralization



b. The Orders Generator



c. The Collector of Results

Fig. 1. Tools used to simulate the AML Line [12]

- Database Centralization (DC) – contains all the needed data and worksheets with information on the functioning line, input and output data, areas description of that make up the assembly line, transport means used in the production process, processed parts, the check points, data on the production capacity of machines, their cycle time, areas of repairs or improve parts, data on quality rules and standards, storage areas, waiting times etc. (Fig.1.a);
- Orders Generator (OG) – allow the possibility to generate a number of „n” simulation experiments and sets up the experimental scenarios using the Witness command lines (Fig.1.b);
- Collector of Results (CR) – is responsible to display and analyze the simulation experiments results (Fig.1.c).

The AML model built and simulated in Witness system and a detail of its operation and components, are shown in Fig. 2. Studies and data presented are part of the PhD experimental research performed by the first author of this paper.

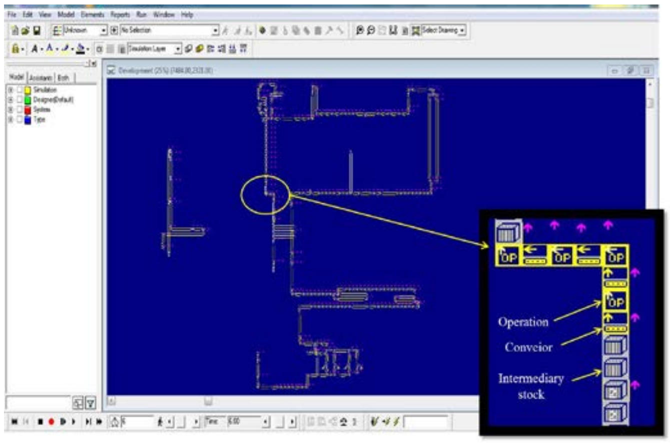


Fig. 2. The AML modeled in Witness

Connection between tools created in Excel and Witness simulation system is possible because, inside of Excel were created macros which automatically generated the „simulation codes” of assembly line (Fig. 3). These codes make the connection with a so-called „library modules” designed for Witness and this library is made up of elements and existing equipment in an automated assembly line (manual or automated workstations, output materials, data quality, conveyors, inventory etc.).

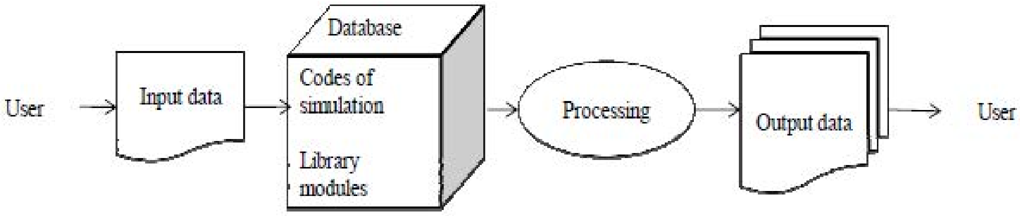


Fig. 3. Connection between DC and Witness [12]

III. Validation of the AML Model

The issue of testing and validation of a model is an essential element of all credible modeling and simulation processes [13-15]. The AML model built using the Excel tools (DC, OG and CR) and Witness simulation system, is accurately represented provided that the input data from Excel are accurate and the conversion is carried out automatically with help of the verified modules. Any building error can also be visually identified from the way that the elements are constructed in Witness.

The main verification and validation process, therefore, is the running of the AML model for a specified period of time (plus the warming up time) and checking that the simulation throughput is consistent with the expected cyclic throughput. This is done by first disabling all causes of losses including breakdowns, over cycles and first time through (FTT) prior to running. The simulation is then run and the output in JPH compared with the cyclic JPH which is calculated as 60 divided by the longest cycle time (in minutes) of the AML line operations. If the two values are the same, then it can safely be said that there are no logical errors in the model. If the result between theoretical JPH and real JPH is the same, the model is valid. Otherwise, the model is check. In this case, the theoretical JPH is equal to real JPH.

Once the model has been verified, it is reset to include all the relevant data (including the losses) and is it rerun. The simulation output is then compared with the real data from the manufacturing floor. The acceptable variation to validate the model is generally 1 JPH or 5% on the average JPH.

The simulation outputs are discussed with manufacturing personnel and experimenting decisions set out. The fundamental consideration is how the causes of the bottleneck could be alleviated. The normalized average JPH profile analysis is valid only for a model with at least 100 data points. By data points is understood the provided data by a single transfer (change) in one day.

IV. The AML Simulation and Rejection Rate Analysis

For the AML model a lot of experiments have been done on production losses caused by machine breakdown, overcome, lack of balancing, but not much attention was given to the quality issues (rejection rate) that directly affect the first time through (FTT) and the job per hour (JPH). The effect of FTT (rejection rate) on individual, zonal and overall throughput is more obvious when rework is involved and the rework items have different entry points, as in the assembly line this case study is based on. The experiments consist in performing a number of „n” different simulations of the AML model by making several changes on the values of product quality, in order to determine the JPH percentage in order to achieve the rejects rate analysis.

For the first experiment, in the Database Centralization (DC) were made changes on the rejection percentage of operations from zones 1, 2 and 4. After saving the changes and running the model in Witness, it opens the Orders Generator (OG) program and it activates with „1” the input factor of the quality problems FTT (first time trough or quality). After conducting the first simulation experiments of AML model, it has found that the most significant differences on the rejection rate, is recorded at the operation 1000 (OP1000) from zone 4 (Z4), the largest cycle time is recorded to the operation 860 (OP860) from zone 4 (Z4) and the bottleneck is recorded also in zone 4 (Z4). Based on these first results, was insisted on making changes in zones 1, 2 and 4, zone 3 is outside of the line.

Another experiments consisted in making changes on the rejection rate of OP1000 and OP860 from Z4, by activating in OG all the input factors: CT, FTT, ZO, OP and TC. Based on the simulation results, was done another experiment where were made changes on the rejection rate of OP1000 only, by activating again all the input factors: CT, FTT, ZO, OP and TC.

Another set of simulation experiments was consisted in making changes on the rejection rate of OP1000 and OP860 from Z4. After making changes in DC and running the AML model in Witness simulation system, is activated in OG the CT only. The last simulation experiments consist in changing the rejection rate of OP1000 and OP860 from Z4 and activation in OG the input factors CT and FTT.

As the first step to analyses the effect of FTT, the AML model has already been verified and validated. Variation of the FTT values of OP1000 from the existing 2.68% to as low as 0.5% and as high as 4.0% has the results shown in Fig. 4. The throughput improved when the rejection rate was reduced from 2.68% to 0.5%, and when the rejection rate deteriorates to 4.0% the throughput dropped.

Experiments were also carried out with changes on the FTT of OP860, combinations of OP860 and OP1000, and changes in zone 3 and zone 5. The results did not significantly improve the overall throughput when compared to the output of FTT changes on OP1000. For instance, a combined reduction on FTT of OP860 from 1.3% to 0.5% and that of

OP1000 from 2.68% to 1.5% resulted in an overall throughput of 106 JPH. This is the same as the throughput obtained by changing the FTT of OP1000 only (Fig. 4).

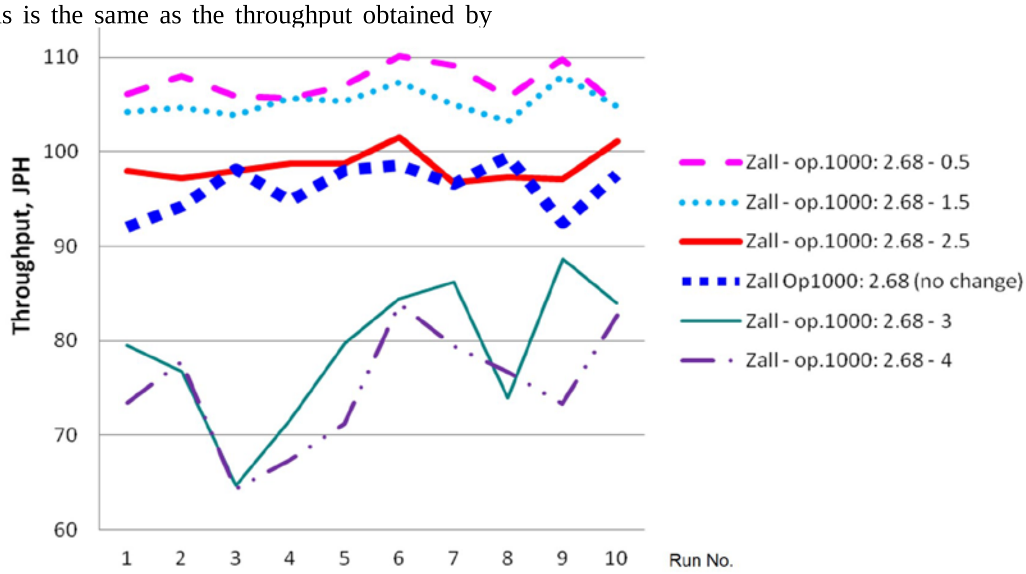


Fig. 4. Effect of the rejection rate on the overall throughput [12]

V. Conclusion

To describing and observing the behavior of a real assembly line in a certain period of time, is resorted to computer-aided simulation which allows identifying, analyzing and implementing the management methods to industrial processes performance. The main objective followed by modeling an assembly line submissive to the simulation experiments, is to actually restore and reproduce the essential elements and basic activities of its. A model subjected to the simulation process is able to cope with a system containing more than one hundred sequential operations and adopt the philosophy of continuous improvement and change after each improved version. These models help managers in making decisions on improving and extending the existing lines or to build new assembly lines.

In any simulation process, the quality of provided data has a paramount importance. For the AML simulation process, data to model building are mainly gathered from the assembly line layout plan (layout drawing), the work standard, and the real-time computer monitoring system. The layout gives a scaled drawing of the assembly plant layout and includes information such as loading/ unloading area, operation numbers, relative sizes of stations, repair areas, team sections and, in some cases, line cycle times.

Modeling and simulation of the AML assembly lines was carried out by using the Database Centralization (DC) which is an Excel based on front-end user interface to the Witness simulation system, outputs are generated using the Orders Generator (OG), and the results analysis is carried out by using the Collector of Results (CR) tool. The AML model building was also enhanced by the use of specialized sub modules (Witness modules). The DC is a component-based simulation system that enables engineers and non-simulation experts to develop models easily and quickly. It is designed to make model construction of assembly lines easier, with an interface that is readily understood by end users. The OG is used to setup experimental scenarios, run the model based on the scenarios and generate results. The CR tool then collects the simulation outputs and generated tables and charts, as appropriate.

The simulation experiments of the AML model led to following results:

- Development the Excel tools used to simulation process of the AML assembly line;
- Verification that the AML model is correctly built and corresponds with reality;
- Generate the simulation experiments of AML model;
- Identify the bottleneck and the largest cycle time of assembly line;
- Change the rejection rate (FTT) in certain zones of AML model;
- Analysis the experimental results of AML model simulation in order to identify and implement management methods to increasing the overall throughput (JPH) of assembly line;
- Determination and selection of the most relevant reported data of AML model simulation experiments;
- Analyzing of the data reports regarding the rejection rate (FTT) on the overall throughput (JPH);
- Validation of the AML model.

The results from the study performed in this paper, have led to identification and analysis of the rejection rate influence, also known as first time through (FTT) on the throughput rate, termed as jobs per hour (JPH) of assembled parts. To investigate the effect of rejection rate on throughput, the bottleneck zone (zone 4) and the zones feeding to and receiving from the bottleneck zone were identified and experiments carried out by varying the FTT values of selected operations. The OP1000 and OP860 were identified as those with the highest and the next highest rejection rates in Z4.

The impact of quality issues especially focused to FTT has been demonstrated to show that its effect on throughput could be significant. As complete as the simulation process is, it also has areas where improvement could be made such as in the debugging process where the user has to be familiar with the error messages to understand where the causes of the problem could be.

On the whole, the Witness simulation system and the Excel tools have proven to be effective in building the AML model and do the simulation experiments, and in collecting and analysis the relevant results of rejection rate on overall throughput. These tools are used not only in the simulation experiments of the AML model, but it can be used to simulate any real industrial process in order to measuring its performance. The component-based nature of the simulation system has made building of accurate assembly line models very easy even to end users with limited simulation expertise. This helps managers to concentrate more in analysis and evaluation of simulation results on implementing the framework management methods. It is hardly surprising therefore that modeling and simulation is used by managers to take the risk out of business change.

The future research directions imply analysis the possibilities of developing a informatics product that can facilitate the linking mechanism and access between the Excel tools and Witness simulation system, in order to simplify selection of managerial decisions on AML line performance. Analysis of a model is the key of any simulation study and the models are built in order to meet the experiments requirements. Accurate modeling but an improper analyze, can lead to incorrect decisions and may even be harmful, especially when financial investments are involved.

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