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Balancing the manufacturing lines through modelling and simulation using Tecnomatix Plant Simulation

Florin Blaga[1,*], *Iulian* Stanăşel[1], *Voichița* Hule[2], and *Alin* Pop[1]

[1]University of Oradea, Industrial Engineering Department, Universității 1, Oradea, Romania
[2]University of Oradea, Mechanical Engineering and Automotive, Universității 1, Oradea, Romania

Abstract. A frequently problem found in case of serial production is the balancing of flow lines. This paper shows how using modelling and simulation procedures can put in evidence the bottleneck in the manufacturing flow. These situations occur to the case where the corresponding times of the technological operations differ very much. Using the program TECNOMATIX PLANT SIMULATION can be highlighted those dysfunctions that may appear during of the manufacturing system operation. It is also possible to identify the solutions to allow equilibration of the lines of the manufacturing process. The program TECNOMATIX PLANT SIMULATION offers a variety of information useful for/in the decision makers in the management of the manufacturing process.

1 Introduction

An objective of management activities characteristic manufacturing system organized as manufacturing flow is their balance, and the removal of the bottleneck [1, 2]. Also the *TECNOMATIX PLANT SIMULATION* software allows the modeling and simulation of manufacturing systems. The program is oriented object, allowing easily the change and the maintenance of complex models. The model is built from a collection of objects (block) which interact with each other [3, 4].

To each object it can be assigned initial information (default settings). During the simulation these information is processed and, ultimately, can be used as data in decision-making processes [3].

The efficiency of *TECNOMATIX PLANT SIMULATION* software was put in evidence in the flow lines applications [5].

The paper presents the use of *TECNOMATIX PLANT SIMULATION* software for functional optimization of the manufacturing line of the sliding gear part type. The arrivals in the system and processing times are considered random variables.

The paper highlights the way in which can be identified the bottleneck places using modelling and simulation techniques, and how they can be removed.

Also in the paper are presented solutions for increasing productivity.

[*]Corresponding author: 1. florin_blaga2000@yahoo.com

2 Overview of the product

The part for which will be designed the manufacturing line is a sliding gear whose drawing is presented in Figure 1.

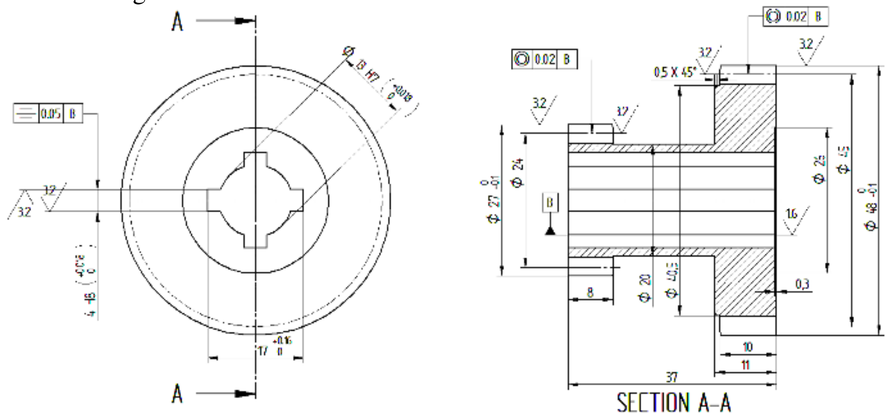


Fig. 1. The drawing of sliding gear part.

In Table 1 are presented the sequencing of operations for workpiece manufacturing

Table 1. The necessary operations of sliding gear manufacturing process.

Operation	Time (min)	Surface Speed (m/min)	Feed (mm/rot)	Workstation version 1	Workstation version 2
Face1 rough	21	40	0.25	F1_R	F1_R_v2
Face 1 finish	7	60	0.16	F1_F	F1_F
Center drill	1	15	0.12	CD	CD
Drill D11	7	15	012	D_11	D_11_v2
Finish ID 13	2	50	0.16	F_ID13	F_ID13
Rough OD_28	17	40	0.25	R_OD28	R_OD28_v2
Finish OD_27	6	60	0.16	F_OD27	F_OD27
Groove OD_20	14	30	0.1	GR_OD20	GR_OD20_v2
Cut Off	13	30	0.1	CUT	CUT_v2
Face2 rough	14	40	0.25	F2_R	F2_R_v2
Face 2 finish	4	60	0.16	F2_F	F2_F
Broaching straight sided spline	8	2	0.05 mm/tooth	BSSS	BSSS
Gear hobbing z30	40	40	3	GH_z30	GH_z30_v2
Gear shaping z16	28	4	0.07	GS_z16	GS_z16_v2
Gear teeth rounding z30	35	12	0.3	GTR_z30	GTR_z30_v2
Gear teeth rounding z30	30	12	0.3	GTR_z30p	GTR_z30p_v2
Gear shaving z30	32	35	0.2	GSv_z30	GSv_z30_v2
Gear shaving z16	26	35	0.2	GSv_z16	GSv_z16_v2
Gear running z30	25	-	-	GR_z30	GR_z30_v2
Gear running z16	25	-	-	GR_z16	GR_z16_v2
Gear control	26	-	-	GC	GC_v2
Grinding ID_13	20	-	-	G_ID13	G_ID13_v2
Final control	34	-	-	FC	FC_v2

process. To each operation it is associated the following technological parameters: name, time, surface speed, feed, workstation in the first model version, workstation in the second model version.

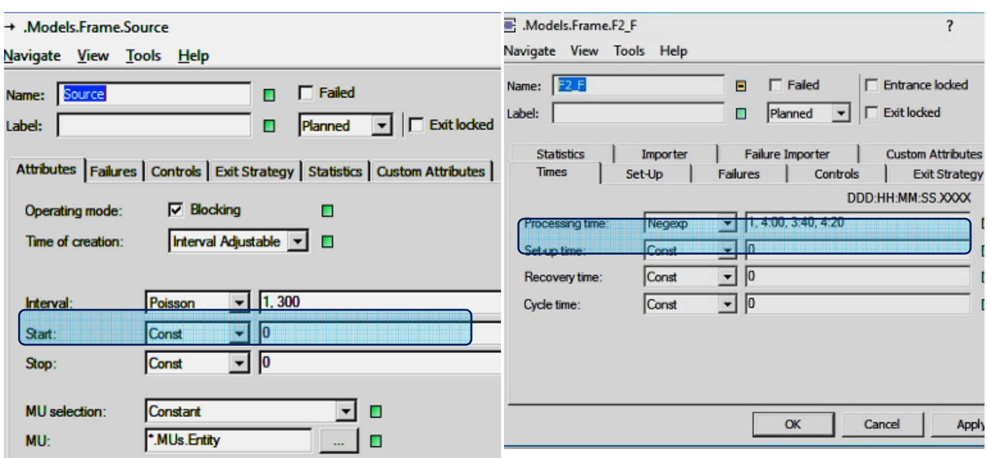
3 Modeling and simulation of manufacturing system activity

The model of manufacturing line of sliding gear is made by using the *TECNOMATIX PLANT SIMULATION* software. The first version of the model is characterized by the fact that to each operation of manufacturing process one block of *SingleProc* type. This is presented in Figure 2.

The arrival modeling of the blank in the system is realized through the type *Source* block (Figure 2). This block enables parameter setting the interval between two successive inputs (*Interval*). Considering this parameter a random variable, it will be associated a function of Poisson distribution [6]:

$$f(x) = \frac{\lambda^x}{x!} e^{-\lambda} \;; \quad x = 0,1,2,... \tag{1}$$

In our case x is a random variable (the time between two inputs) and λ is the medium value of the random variable. In the analyzed case Stream has the value 1 and λ=300 seconds (Figure 2.a).



(a) (b)

Fig. 2. Version 1 of manufacturing line model for the sliding gear production.

Regarding the workstation, the most important issue is the processing time change. When the processing time is a random variable, a density of probability will be associated to this one (probability function). In many cases the density of probability of processing time is negative exponential function [6] like this:

$$f(t) = \beta e^{-\beta t} \tag{2}$$

where, t is the random variable (processing time) and β is the average value of processing time. In the case of *Face 2 finish* (*F2_F*) operation, *Stream* has the value of 4 minutes, *Lower Boud* has value of 3 minutes and 40 seconds, *Upper Bound* has the value of 4 minutes and 20 seconds (Figure 2.b).

In the same way the processing times are defined in the other operations. Considering this manufacturing time like random variables is an approach much more closely to what is happening in the real manufacturing system.

After the model is made, for passing to the next step that is simulation, it has to be defining the simulation process parameters. This can be done thought the *EventController* block (Figure 3). So, the time interval in witch will be simulate the manufacturing system activity is 8 hours (Figure 3).

After the simulation is made, using the *BottleneckAnalyzer* option, it can be showed the status that every workstation and their weight related to the reference time of 8 hours. It can be seen the work period (green colour), the waiting period (gray colour). During the 8 hour interval, the workstations can be found in pause (blue colour), can be broken (red colour), or they are not provided in the working program (blue colour). Bottlenecks that may occur in the operation of workstations are represented with yellow colour.

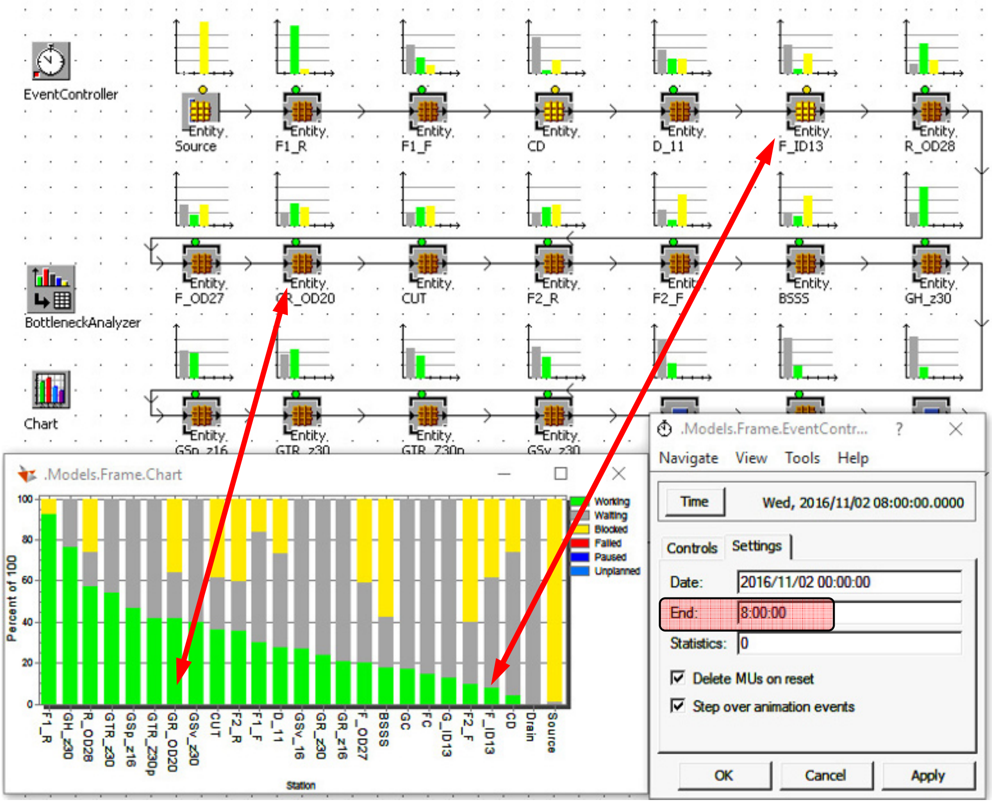


Fig. 3. The simulation system activity result. Version 1.

Through the *Chart* options it's generate a diagram (Figure 3) that shows the system components status during the simulation process (8 hours). In this case it can be seen the bottleneck frequency on the manufacturing flow. The reason of these bottlenecks is the difference between the processing times of different operations.

After the simulation, the performance indicators of every workstation can be analysed. In the case of *Frame block* associated to *Finish ID 13* (*F_ID13*) operation, by selecting the

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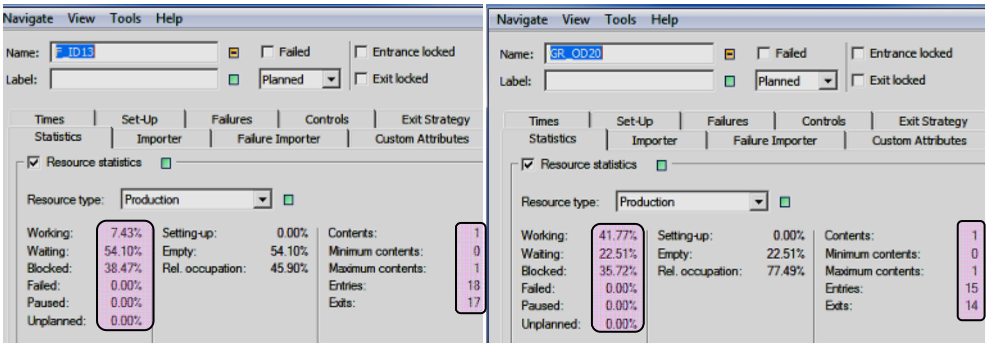


(a) (b)

Fig. 4. The system simulation results. Version 1: (a)- *F_ID13*; (b)- *GR_OD20*.

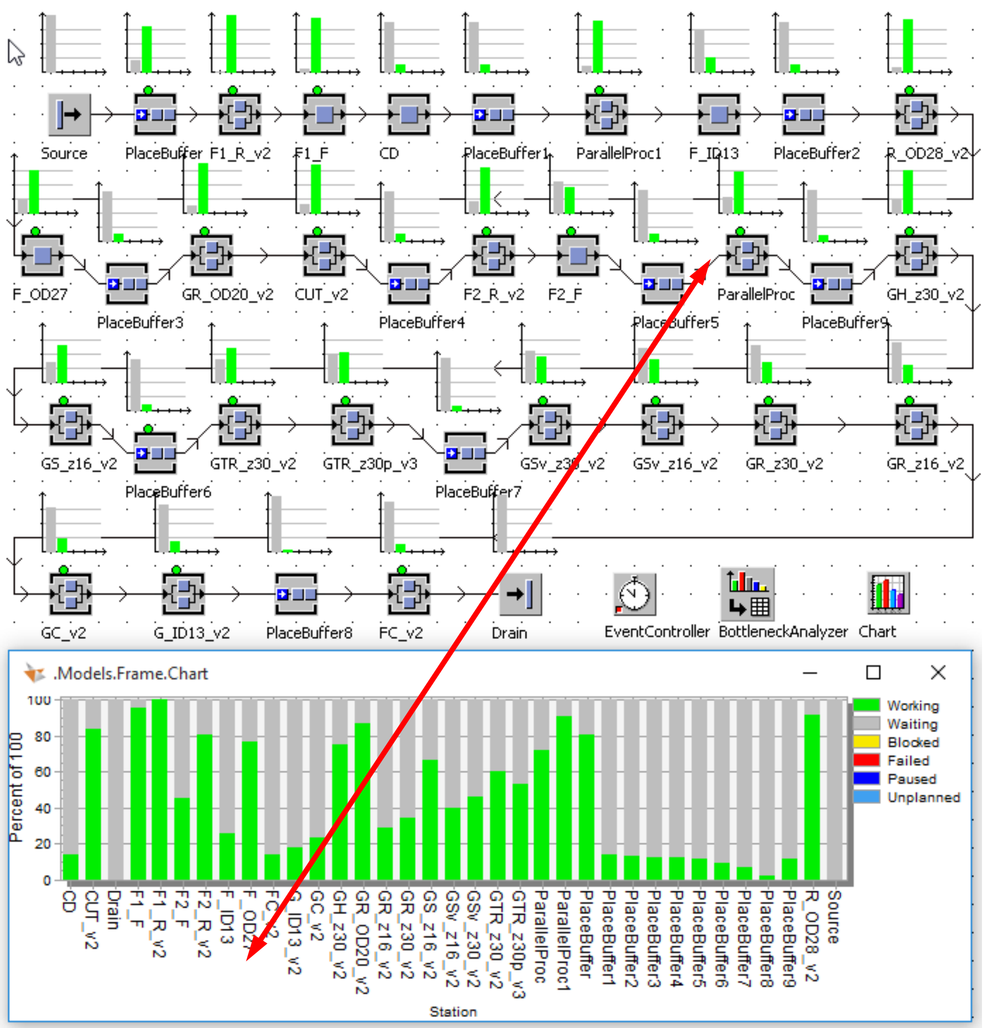
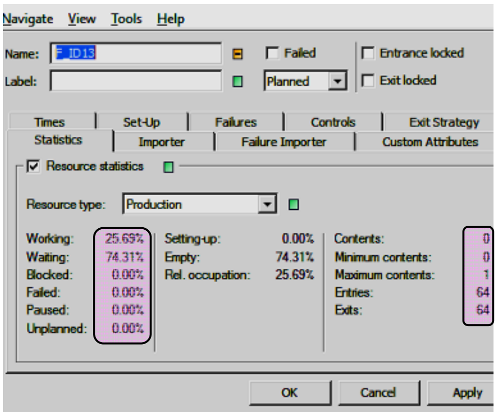
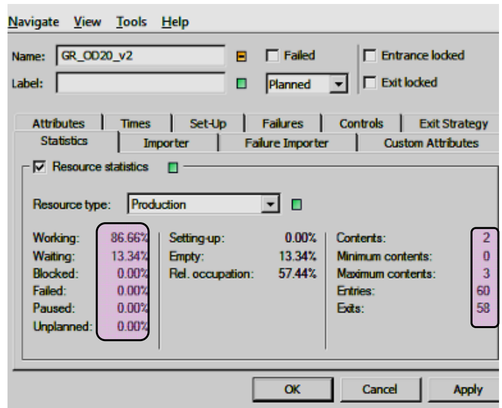


Fig. 5. The system simulation results. Version 2.



(a)



(b)

Fig. 6. Simulation results. Version 3: (a)- *F_ID13*; (b)- *GR_OD20_v3*.

Statistics button, it can be seen that during the 8 hours, the workstation is working 7.43% of total time, 54.10%it's waiting, 38.47% it's blocked (Figure 4.a).

In the case of *Groove OD_20* (*GR_OD20*) operation it can be seen that the workstation is working 41.77% from total time of 8 hours, 22.51% was waiting, 35.72 % is blocked (Figure 4.b).

To ensure a continuous manufacturing flow and increase in productivity it will adopt two solutions: involves buffers installation between the workstation with smaller processing time and those with processing time bigger and allocated more workstation for operations with processing time bigger than the operation time that precede them.

In the Table 1 are found the workstations name for the version 2 of model. In the version 2 of model it was used the *ParallelProc* type frame (Figure 5).

The second version of model highlights the significant increase in productivity. In this way on the *F_ID13* operation is made 64 parts (Figure 6.a), and the *GR_OD20_v2* operation are made 58 parts (Figure 6.b).

4 Conclusions

In the conditions of serial production can appear imbalances during manufacturing system operations, organize as flow lines. These imbalances are caused by differences in the duration of the various operations. In these conditions can occur bottlenecks and increase waiting times. Such disturbances can be highlighted through modeling and simulation.

Modelling and simulation of manufacturing systems using *TECNOMATIX PLANT SIMULATION*, offers the possibility to evaluate their performance for various production tasks (orders).

The different model versions that may be associated with a system that can provide useful information decision makers, responsible for management activities.

The case of study presented in the paper showed a gradual improvement of production system performances. Version 2 of model allowed bottlenecks removing and highlight a significant increase in productivity.

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