WORK ANALYSIS OF PLATE BENDING WORKSHOP IN SHIPBUILDING INDUSTRY

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SUMMARY

Plate bending is one of the major processes in shipbuilding. The plates which are cut in specific dimensions are sent to plate bending work shop and they are curved by using various methods. These curved plates constitute bilge turn plates of a vessel which are curvilinear. In this study, plate bending work shop was considered and its simulation model was created by using SIMIO software. The aim of the study is to see the effects of some alterations on available situation of plate bending work shop and present some recommendations in order for the plate bending work shop to operate effectively. In this work, there are number of four alterations including the changing of bending processing time, number of cranes and bending machine. At the end of the study, the values of the most suitable crane number, bending machine number, and the bending operation processing time were recommended. It is believed that the plate bending work shop will operate in effective way if the shipyard administration implement the recommendations presented in this study.

1. INTRODUCTION

Plate bending process is one of the most important procedures in shipbuilding activities. Curved plates comprise curvature plates of a vessel. In shipbuilding, each curved shell plate is produced out of flat and thick steel plates by using the mechanical and thermal forming techniques [1]. In mechanical technique, flat plates are located on the table of press machine and a specific weight is pressed on the surface of the plate and the inclination is checked at the same time. This pressure is continued until the desired inclination is reached. At the point that the desired inclination is achieved, the pressure is stopped and the curving operation of the plate ends. In this way, plates are bended. As for thermal forming technique, the line heating or flame bending method is one of the major processes carried out by workers to form the plates into desired shapes [2]. In this method, the operation of plate bending is performed with heating effect and controlled heating and cooling operations are carried out through the lines predefined on the surface of flat plates. As a result of controlled heating and cooling, curved plates are fabricated. Figure 1 and 2 show plates before and after bending operation.

In literature, the works on plate bending in shipbuilding are concerned with structural effects of heating at the operation of plate bending. Yu et al [3] developed a finite element model for estimating the amount of heat flux in the process of metal plate forming by laser line heating. Kuo and Wu [4] found that the factors affecting heat bending are the intensity of the heat source, the temperature variation, and the speed of the source of the heat. Yu et al [5] presented a simplified thermo-mechanical model for estimating angular deformations of metal plates due to line heating. Hwang and Lee [6] investigated spring back deformation and also the degree of adjustment of the stroke of pistons in multi-press forming process by using Finite Element Analysis. Liwen et al [7] used Finite Element Model in order to calculate the temperature, stress, and strain fields on steel plate during laser forming process. Hemmati and Shin [8] investigated heat transfer during flame plate bending and evaluated temperature distribution on the surface of the plate. Therefore, no detailed simulation model of plate bending work shop is found in literature.

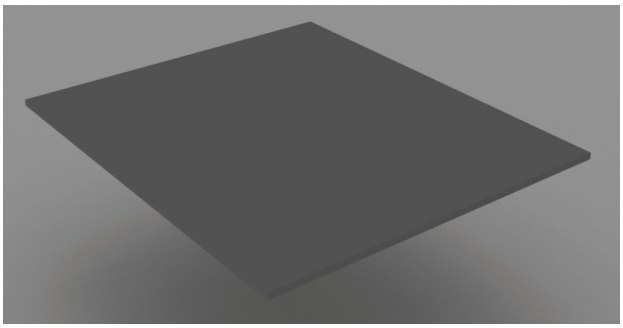

Figure 1: Flat plate before bending operation.

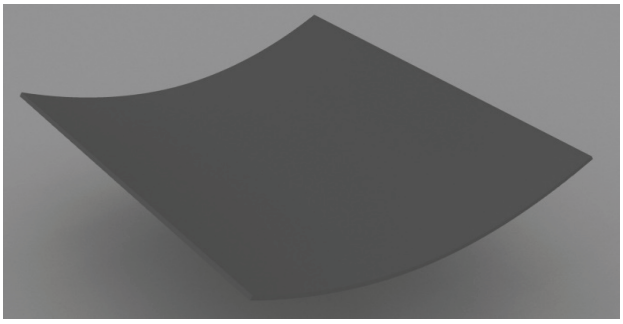

Figure 2: Curved plate after bending operation.

In this study, the plate bending work shop belonging to a shipyard which is located in Turkey (Tuzla Region) was taken into consideration. In this way, it is aimed to find the most suitable manufacturing system in terms of production quantity and work in process at the plate bending work shop. In general, there are two types of specific areas at plate bending work shop. The first one is the plate stock area where the arriving flat plates coming from nesting work shop are stacked and the second one is buffer area where the curved plates are located. Furthermore, there are two cranes which transport flat and curved plates. Figure 3 depicts a general view of plate bending work shop.

This study consists of five phases. In the first phase of the study, the work flow of plate press operation was determined. After determining the work flow, in the second phase, the work activities were modelled in SIMIO simulation environment. According to the results achieved from simulation, the available case was presented and the results were evaluated. This phase comprises the third phase of the study. Then, some alterations were carried out on the simulation model in the fourth phase and the effects of them were determined in the fifth phase. The phases of the work are shown in Figure 4.

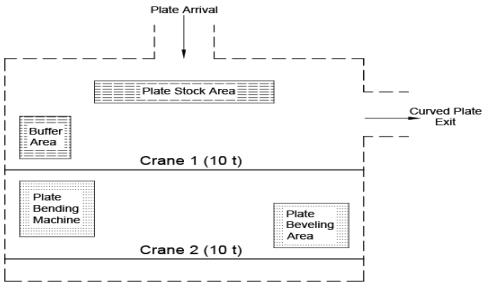

Figure 3: General view of plate bending work unit.

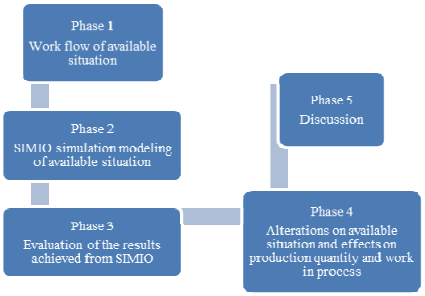

Figure 4: Phases of the work.

2. SIMULATION APPLICATIONS IN SHIPBUILDING INDUSTRY

In most shipyards, especially in Turkey, the production simulation usage is very limited. For this reason, sufficient productivity is not able to be obtained from the machines and equipment purchased. Whereas, the machines or equipment purchased should improve the level of part stock and amount of production. If this is not the case, the investment that the shipyard management made becomes meaningless.

Simulation tools help investors make true decisions since it reflects the real life on computer environment. The simulation can be used to show the expected results of inserting new technologies or equipment into the shipyard [9]. The real system can be modelled by simulation software and run the model along a specific period. After running, some results such as amount of production, number of waiting parts for processing can be achieved. These results are evaluated and the alterations to be done are decided. Then, these alterations are implemented on simulation model and the effects on system production quantity and work in process (WIP) can be determined. Therefore, the purchasing decisions are able to be taken with more accuracy.

In literature, there are many simulation applications concerning shipbuilding. Dain et al [10] determined the effects of different scheduling alternatives on labour costs and probability of missing the deadline by simulating shipyard production system. Medeiros et al [11] created a simulation model of plate fabrication line in order to evaluate the effects of new technologies on fabrication line. Kim et al [12] built a simulation model of shipyard dock including crane movements and unit erection. Lee et al [13] created the simulation model of panel assembly shop and implemented various scenarios including due dates, resource capacity etc. Okumoto and Hiyoku [14] developed an assembly simulation program and simulated pipe unit assembly operations. Cha and Roh [15] simulated block erection process. Song and Kang [16] simulated a big shipyard and attempted to find the most suitable shipyard layout by replacing the production resources in order to increase the production. Charris and Arboleda [17] built a simulation model of supply chain process at a naval shipyard and presented a model which helps operation planning and decisions on capacity by using ARENA simulation software.

3. IMPLEMENTATION

3.1 WORK FLOW OF AVAILABLE SITUATION (PHASE 1)

In available situation, there are number of two cranes, an oxygen cutting machine to do bevel cut operation, a plate bending machine to curve the plates. The work flow of plate bending operations is depicted in Figure 5. The flat plates which are fabricated in nest cutting workshop are transported to plate bending workshop so as to being curved (Step 1). The crane loads the plates from trailer (Step 2) and transports them to plate stock area (Step 3) and then unloads them on plate stock area (Step 4). After that, the other crane loads the plates placed on plate stock area (Step 5) and transports and unloads them to plate bevelling area in order to perform bevel cutting operation (Step 6 and 7). Before bevel cutting operation, the set-up operations of oxygen cutting machine are performed (Step 8) and then the bevel cuttings of the plates are carried out (Step 9). Then, the plates which are subjected to bevel cutting are sent to press bending machine by crane (Step 10, 11, and 12). In the same way, the set-up operations of press bending machine are made (Step 13) and plate bending operation is completed (Step 14). After that, the curved plates are sent to the buffer area (Step 15, 16, and 17).

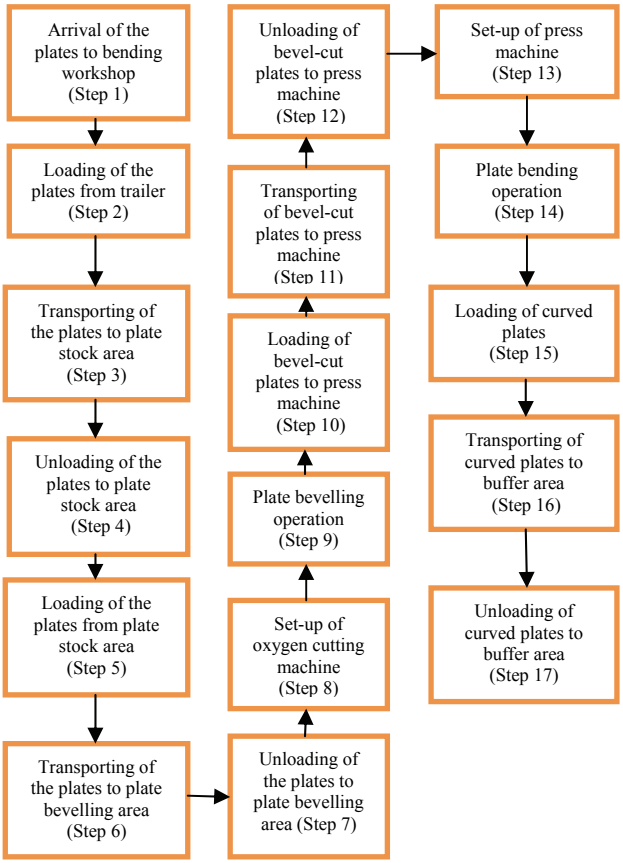

Figure 5: Work flow of plate bending operation.

3.2 SIMIO SIMULATION MODELLING OF AVAILABLE SITUATION (PHASE 2)

In this phase of the study, the simulation model of the available situation of the press bending workshop was created. Figure 6 shows the simulation model of plate bending workshop in SIMIO environment. In simulation model, some data are needed. It was assumed that the workshop is operated according to work schedule between 08:00 and 17:00. Plate arrivals are arranged according to arrival table which mean that the plates come to press bending workshop in a specific time. In this model, the plates coming from nesting area arrive at the bending workshop at 09:00 a.m. and the numbers of plates per arrival are 8 which mean that numbers of 8 plates are sent to bending workshop by crane at a specific time. Furthermore, in reliability logic section of SIMIO, failure times are indicated and all machines and cranes do fault once in 24 weeks and repair operation takes 10 days. In the model, plate bevelling and press operations take 39 and 150 minutes, respectively.

As for crane's data, loading and unloading times of the cranes are assigned 1.3, and 1.2 minutes and the speed of them is 20 meters per minute.

In SIMIO simulation environment, the servers and the modules are connected with paths and the length values of these paths are entered into the model. Here, there are five main paths which connect plate arrival-plate stockyard, plate stockyard-plate bevelling, plate bevelling-plate bending, plate bending-buffer area and plate bending-plate stockyard and their lengths are 10, 15, 7, 8, and 22 meters, respectively. After creating the model, it was run between January 1 and December 31, 2015.

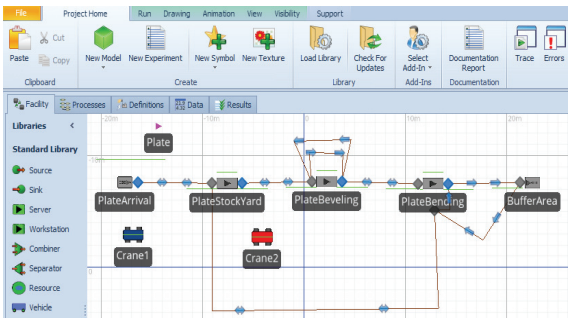

Figure 6: SIMIO modelling of the press bending workshop (Available situation).

3.3 EVALUATION OF THE RESULTS ACHIEVED FROM SIMIO (PHASE 3)

In this phase, the results obtained from Section 3.2 will be evaluated. Here, two parameters will be taken into consideration, which are number of curved plates fabricated and number of plates waiting for press bending operation. Therefore, the performance of plate bending workshop will be rated according to these two parameters.

Figure 7 depicts the simulation result of number of plates waiting for bending operation. Accordingly, the average number of plates waiting for bending operation is 659 which mean that average 659 plates remain in front of bending machine in order to be processed throughout a year. However, according to Figure 8, plate bending workshop can fabricate number of 737 plates in one year.

The obtained results are not satisfactory because there is huge number of plates waiting for bending operation in front of press machine. It seems impossible to stock up such a number of plates so it is necessary to improve work in process and production quantity of the system.

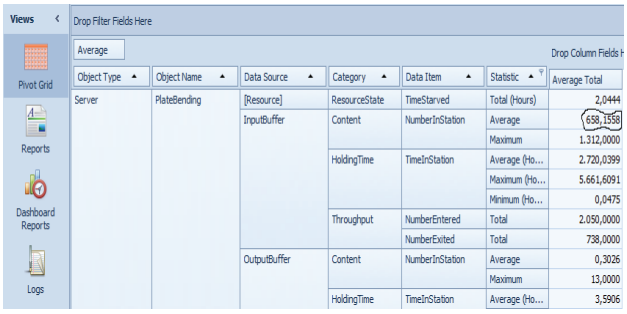

Figure 7: Simulation result of number of plates waiting for bending operation.

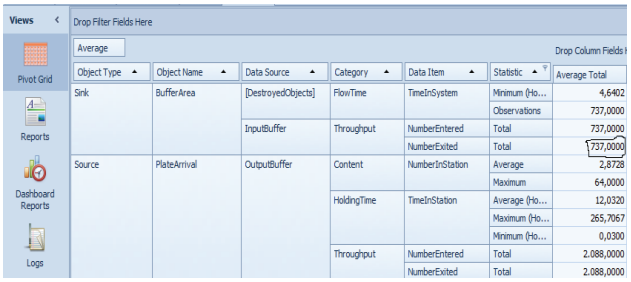

Figure 8: Simulation result of number of curved plates fabricated.

3.4 ALTERATIONS ON AVAILABLE SITUATION AND EFFECTS ON PRODUCTION QUANTITY AND WORK IN PROCESS (PHASE 4)

In this phase, various alterations will be done on available situation of plate bending workshop. There are four alterations in this section. In Alteration 1, available situation of plate bending work shop keeps its structure excepting bending processing time. The bending processing time will be changed. In Alteration 2, one crane will be removed from the bending work shop and also the bending processing time will be changed. In Alteration 3, one crane and bending machine will be added to the bending workshop while two cranes and machines are added in Alteration 4.

3.4 (a) Alteration 1

Here, it is assumed that the bending operation time is getting lower and in this case, it will be calculated whether the production quantity and number of plates waiting for bending will be affected.

At the available situation, the processing time of bending machine is 150 minutes. In Alteration 1, the bending processing time was reduced from 150 minutes to 70 minutes and the simulation results regarding the number of curved plates fabricated and the plates waiting for bending operation were achieved by running the simulation model depicted in Figure 6 for each value of bending processing time.

Table 1 shows the effects of bending operation time on number of plates waiting for bending operation and number of curved plates fabricated in a year. It can be seen from Table 1 that the number of curved plates fabricated is increasing while the bending operation time is getting lower. However, number of plates waiting for bending operation is getting lower. Figure 9 and 10 depict the values of number of plates waiting and production quantity of plate bending workshop for the processing time of 140 minutes. Therefore, the fact that the bending processing time is getting lower improves the work in process and production quantity of plate bending workshop.

Table 1. Effects of Alteration 1 on parameters.

Bending processing time (minutes)	Number of plates waiting for bending operation (Average)	Number of curved plates fabricated
150	659	737
140	633	787
130	604	845
120	569	914
110	528	994
100	479	1090
90	418	1208
80	345	1353
70	250	1538

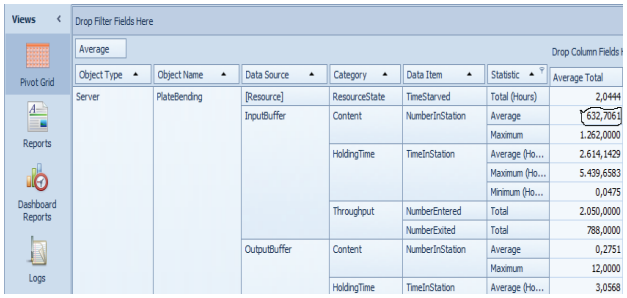

Figure 9: Simulation result of number of plates waiting for bending operation (After Alteration 1).

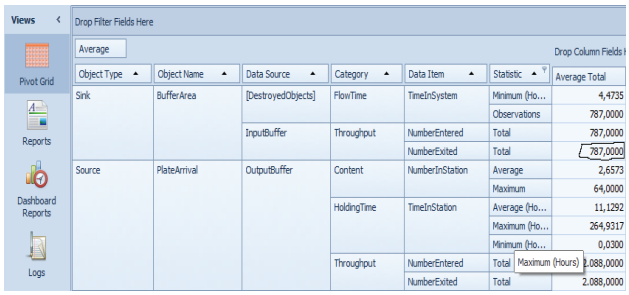

Figure 10: Simulation result of number of curved plates fabricated (After Alteration 1).

3.4 (b) Alteration 2

In this part, a little change was made on available situation. In available situation, there are two cranes but here there is only one crane which performs all handling operations. Figure 11 shows the simulation model of bending workshop after Alteration 2. As can be seen from Figure 11, there is only one crane doing handling operations.

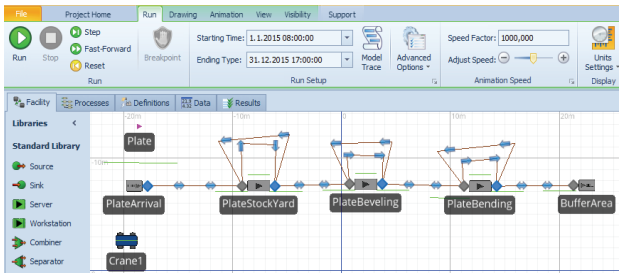

Figure 11: SIMIO modelling of the press bending workshop (After Alteration 2).

When the simulation model was run, the values of number of plates waiting for bending operation and number of curved plates fabricated after Alteration 2 were obtained. Figure 12 and 13 depict these values for the bending processing time of 150 minutes. Accordingly, the values of number of plates waiting for bending operation and number of curved plates fabricated were improved. While number of plates waiting was reduced to 633 plates, number of curved plates was increased. Therefore, using just one crane instead of two cranes is better.

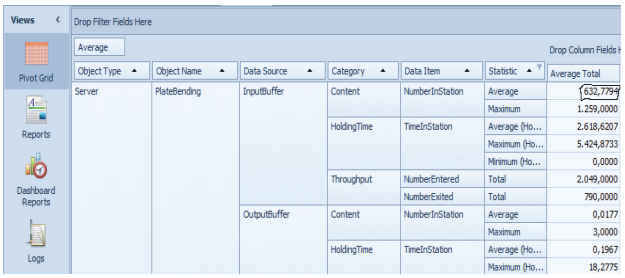

Figure 12: Simulation result of number of plates waiting for bending operation (After Alteration 2).

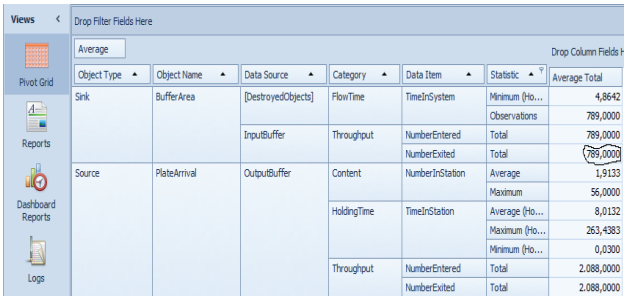

Figure 13: Simulation result of number of curved plates fabricated (After Alteration 2).

Number of plates waiting and number of curved plates fabricated were achieved for various bending processing time and Table 2 shows these values. It can be concluded from Table 2 that the values of parameters are improving as the bending processing time is getting lower.

Table 2. Effects of Alteration 2 on parameters.

Bending processing time (minutes)	Number of plates waiting for bending operation (Average)	Number of curved plates fabricated
150	633	789
140	605	845
130	571	910
120	533	986
110	487	1076
100	432	1184
90	365	1315
80	280	1480
70	173	1691

3.4 (c) Alteration 3

In this section, one more press machine and crane were added to the plate bending work shop. Therefore, in comparison with the available situation, the number of crane becomes 3 instead of 2 while the number of press machine is 2 instead of 1. Figure 14 demonstrates the simulation model of the plate bending work shop.

In the same way, the simulation model was run for each bending processing time and some simulation results such as the number of curved plates fabricated and the plates waiting for bending operation were obtained as presented in Figure 15-17. The number of plates waiting for bending machine 1 and 2 are 133 and 132, respectively. Besides, the number of curved panel fabricates is 1509 for the bending processing time of 150 minutes. Table 3 shows the production quantity and work in process for each bending processing time.

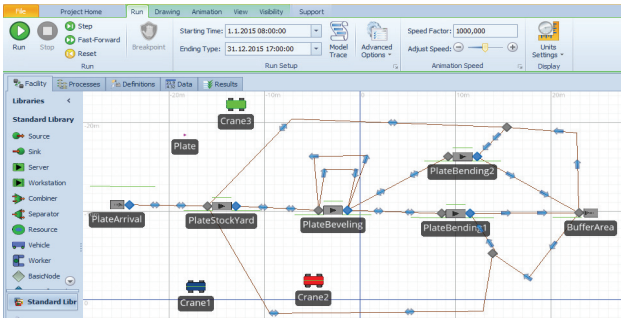

Figure 14: SIMIO simulation model of plate bending workshop (After Alteration 3).

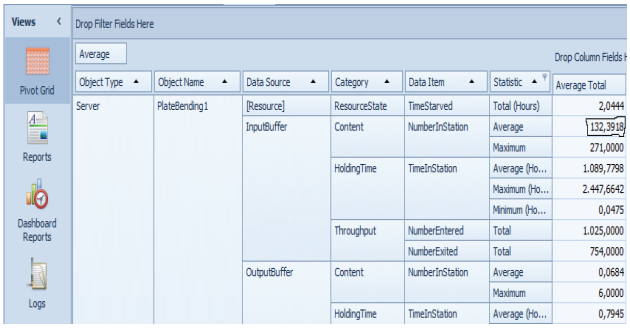

Figure 15: Simulation result of number of plates waiting for bending machine1 (After Alteration 3).

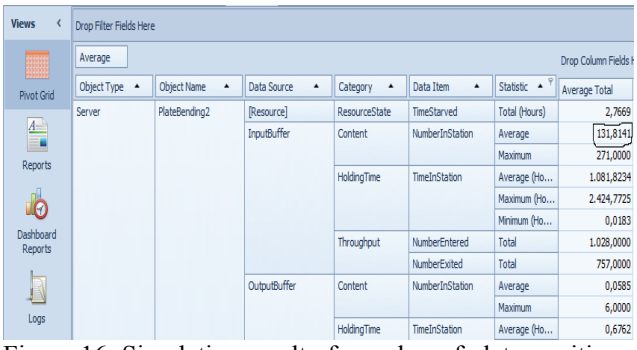

Figure 16: Simulation result of number of plates waiting for bending machine2 (After Alteration 3).

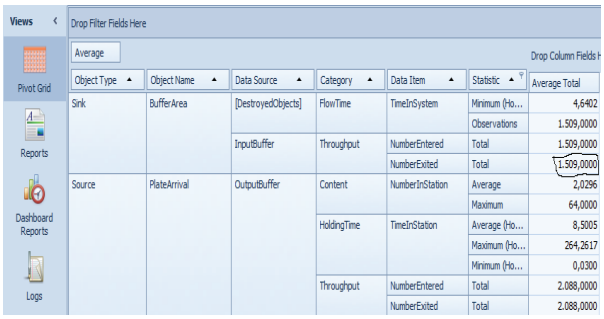

Figure 17: Simulation result of number of curved plates fabricated (After Alteration 3).

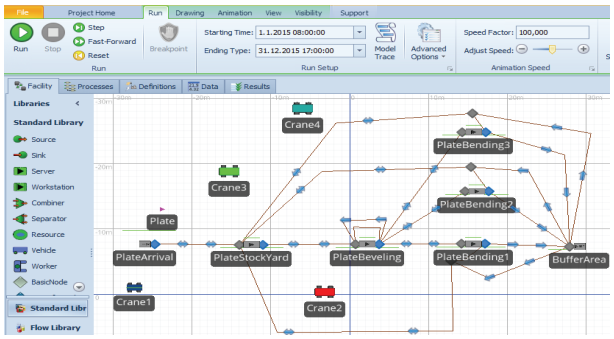

Figure 18: SIMIO simulation model of plate bending workshop (After Alteration 4).

Table 3. Effects of Alteration 3 on parameters.

Bending processing time (minutes)	Number of plates waiting for bending operation (Average) (Press machine 1)	Number of plates waiting for bending operation (Average) (Press machine 2)	Number of curved plates fabricated
150	133	132	1509
140	108	107	1605
130	77	77	1726
120	42	42	1864
110	11	11	2000
100	3	3	2035
90	2	1	2041
80	1	1	2049
70	1	1	2051

3.4 (d) Alteration 4

Here, four cranes and three bending machines were utilized at the plate bending work shop. Figure 18 shows the simulation model of Alteration 4. In the same way, the processing time of bending operation again changed from 150 minutes to 70 minutes and the simulation values of the number of curved plates fabricated and the plates waiting for bending operation were obtained for each bending operation time. Figure 19-21 demonstrates the simulation result of the number of the plates waiting for bending operation for the processing time of 150 minutes. Accordingly, numbers of two plates are available in input buffer area of the bending machines. On the other hand, the bending work shop can produce number of 2035 plates per year for the processing time of 150 minutes as shown in Figure 22. Table 4 depicts all values of number of waiting plates and curved plates fabricated for each bending processing time. It can be easily seen from Table 4 that the decreasing of bending processing time has almost no effect on production quantity and work in process.

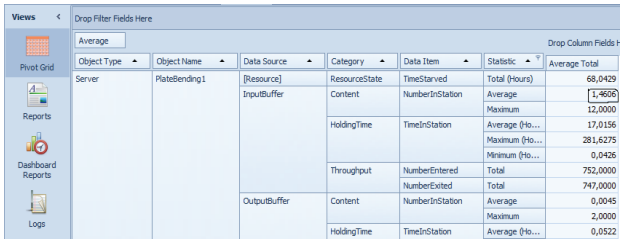

Figure 19: Simulation result of number of plates waiting for bending machine1 (After Alteration 4).

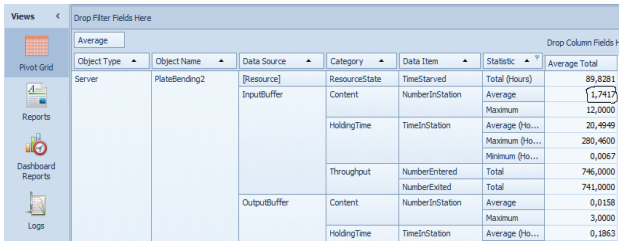

Figure 20: Simulation result of number of plates waiting for bending machine2 (After Alteration 4).

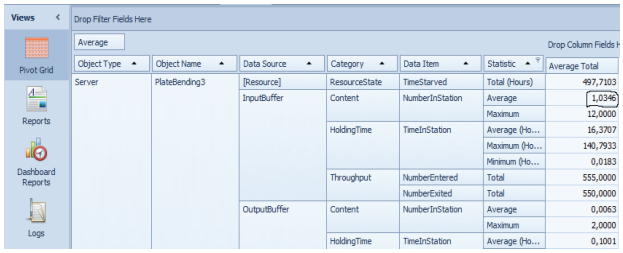

Figure 21: Simulation result of number of plates waiting for bending machine3 (After Alteration 4).

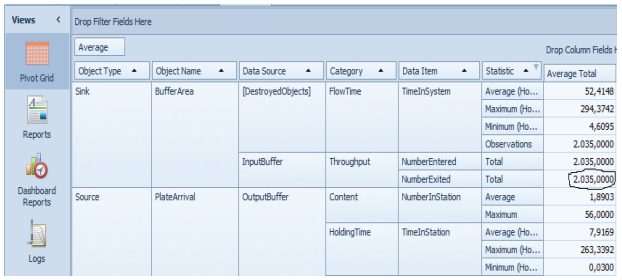

Figure 22: Simulation result of number of curved plates fabricated (After Alteration 4).

Table 4. Effects of Alteration 4 on parameters.

Bending processing time (minutes)	Number of plates waiting for bending operation (Average) (Press machine 1)	Number of plates waiting for bending operation (Average) (Press machine 2)	Number of plates waiting for bending operation (Average) (Press machine 3)	Number of curved plates fabricated
150	2	2	2	2035
140	2	1	1	2040
130	1	1	1	2044
120	1	1	1	2049
110	1	1	1	2050
100	1	1	1	2051
90	1	1	1	2051
80	1	1	1	2051
70	1	1	1	2052

3.5 DISCUSSION (PHASE 5)

In this section, the comparison of the changes performed above was done. Figure 23 and 24 demonstrated the comparisons of Alterations which mentioned in previous sections. It was seen for Alteration 1 and 2 that decreasing the plate bending processing time increased the number of curved plates fabricated while it decreased the number of plates waiting for bending machine. On the other hand, for Alteration 3, increasing in the number of curved plates fabricated and decreasing the number of plates waiting for bending machine were available until the bending processing time of 110 minutes. After that, there is almost no change for the parameters. For Alteration 4, decreasing the processing time of bending machine has no effect on parameters.

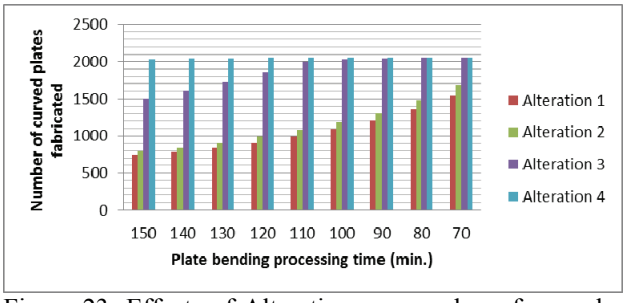

Figure 23: Effects of Alterations on number of curved plates fabricated.

When doing a general assessment, the alterations affected the parameters in positive way. But, as the processing time of bending machine is decreasing, the effects of alterations are decreasing as well. Therefore, if the bending processing time can be decreased sufficiently, there is no need for some alterations. For instance, after the bending processing time of 110 minutes, Alteration 4 is unnecessary. But, if the bending processing times are between 150 and 110 minutes, then Alteration 4 can be carried out. When one crane was removed from the available situation of plate bending workshop (Alteration 2), it was seen that it influenced the parameters in positive way. Therefore, working with only one crane instead of two cranes is better for the shipyard. These effects become clearer while the processing time of bending machine is decreasing.

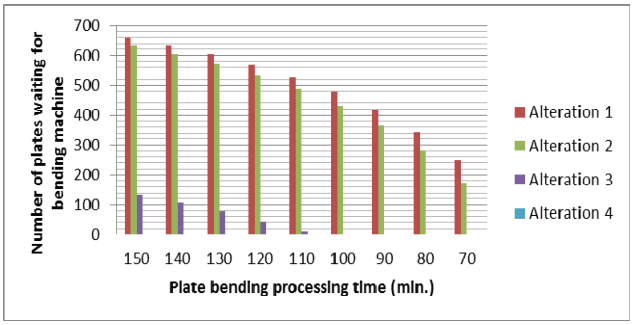

Figure 24: Effects of Alterations on number of plates waiting for bending machine.

4. CONCLUSIONS

In this study, plate bending work shop was taken into consideration for revealing the effects of some changes on available situation and two parameters such as number of plates waiting for bending machine and number of curved plates fabricated were selected as performance indicators. The study showed that working with only one crane instead of two cranes at available situation increased the number of curved plates fabricated and decreased the number of plates waiting for bending machine. But in spite of this, the number of plates waiting for bending machine is too high. Therefore, some changes in addition must be performed. When one more crane and bending machine are added to available situation, the number of curved plates fabricated and plates waiting for bending machine are dramatically improved. More specifically, if three cranes and two bending machine are used and the processing time of bending machines is reduced to 100 minutes, the number of plates waiting for bending operation (3 plates) and the number of curved plates fabricated (2035 plates) become more satisfactory. So, shipyard administration should add one more crane and

bending machine to the available situation and the plate bending time of machines must be around 100 minutes. On the other hand, it can be said that using four cranes and three bending machines are unnecessary for plate bending work shop.

The shipyard administration has to perform work shop works for bending operations. It is believed that the bending operations will be more effective if the recommendation presented in this study is applied by shipyard administration. Therefore, one more crane should be added to the available production system of plate bending work shop. In addition, one plate bending machine should be placed to the system and the processing time of plate bending machined must be also arranged to 100 minutes. In this way, three cranes and two plate bending machined become available in the work shop and this is the most convenient and effective arrangement for the plate bending work shop.

This study contains some limitations. The processing times of the machines, the loading and unloading times of the cranes and the failure times were considered as deterministic value since these times were measured only once. Whereas, these duration values could be changed after each measurement. So, these processing times can be deviated from standard value. Therefore, these measurements can be repeated many times and the deviations can be taken into consideration.

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