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Effects of welding operating factor on shipyard panel line's production quantity

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Panel line;
Simulation.

Abstract. Welding processes play a major role in ship production. If the welding process can be performed in less time, ship fabrication can be completed in a shorter time. Therefore, it is a significant issue for welding time to be ended as soon as possible. For this, the operator factor, which is a component of welding time calculation, could be increased. If this is done, welding time could be decreased. The purpose of this study is to determine the effects of operator factor on the production quantity of a panel line. Here, the panel line of a shipyard situated in Turkey was illustrated as an example. Whole workstations of a panel line were taken into consideration and modeled in a SIMIO simulation environment. By changing the operator factor in a web welding work station on a panel line, different welding time values were achieved. These welding time values were then inserted into a simulation model and the model was run for a specified period. Finally, the production quantities of the panel line were obtained as an output. Thus, the effects of a changing operator factor on panel line throughput were determined.

1. Introduction

In recent years, a really tough competitive environment in global industries such as automobile and ship building industries, etc., can be seen. In order for companies to keep their competitive edge, they need to meet customer demand on time, as customers often expect to receive quality welded products on time [1]. On time delivery in ship production is very significant. Shipbuilding is traditionally a labor-intensive assembly industry that employs the welding process as a basic production technology [2]. In other words, welding is the largest labor component in shipbuilding [3]. To be able to deliver a ship to its owner on time, or prior to delivery time, welding operations in shipbuilding need to be performed as quickly as possible.

Arc welding is used extensively in shipbuilding, and most is performed by humans [4]. This is hard work, due to difficult work conditions because of fumes, high temperatures and welding positions. Furthermore, there are some related welding activities such as supplying parts, loading or unloading parts, removing parts and so on. Therefore, a welder is not able to constantly perform the welding process, and sometimes has to stop welding for these welding related activities or because of welding conditions. The operator factor indicates how much a worker spends his time on actual arc welding.

One of the most critical skills required to fabricate a ship is welding, and welders play a major role in shipbuilding [5]. So, the operator factor is a very significant issue. The operator factor is the ratio of arc hours to clock hours for a welder. In other words, the welding operator factor is the percentage of actual arc time while welding a specific length of weld.

The operator factor is often used in weld time calculation. Therefore, it is a basic component in the weld time equation. Total welding time is calculated

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as:

$$T = (V \times N \times C)/(D \times K).$$

Here:

T : Total welding time (hr);

V : Volume of weld (m^3/m);

N : Length of specified weld (m);

C : Specified gravity of metal (kg/m^3);

D : Deposition rate (kg/hr);

K : Operator factor (%).

Correia and Ferraresi [6] compared two welding processes, namely SAW (Submerged Arc Welding) and GMAW (Gas Metal Arc Welding) in terms of operational cost. In their study, while calculating operational costs, the operation factor was defined as the ratio between the open arc time and the total welding time, which is employed in equation [2]. Miller calculated labor and overhead costs by employing the operator factor, which was considered as 30%, which means only 30% of the welder's day is actually spent welding [7]. In the same way, Blodgett made an equation to determine the labour costs for GMAW, which contained an operator factor deemed as 30% [8].

As can be seen from the weld time equation, while the operator factor increases, total welding time decreases. As a result of this, the welding operation is completed in a shorter time, because a welder with a high operator factor can deposit more filler materials in a welding place in less time.

In this study, a panel line belonging to a shipyard situated in Turkey is used as an illustrative example. The shipyard has a capacity of 30000 tonnes of steel per year and often fabricates containerships. In the shipyard, there is a huge covered steel fabrication plant. The block assembly area is outside and the assembly operations of aft and bow blocks are undertaken in covered buildings. Profile cutting, profile bending, nest cutting, and the pre-fabrication area are placed in the steel fabrication plant, as well as the panel line. The manual welding operation is performed in the web welding station on the panel line. In the work, welding time in the web welding station was calculated according to the weld time equation. In the same way, completion times of the other work stations on the panel line were calculated. Then, the panel line was modeled by SIMIO simulation software and station completion times were inserted in the simulation model. Afterwards, the simulation model was run along a specified time, and the panel line's production quantity was found as the output of the simulation model. In the next step, the operator factor changes and, as a result of this, the web welding station completion time also changes. The panel line simulation model was run again and again, according to the new operator factor values, and, finally, the effect of the operator factor on panel line production quantity was determined.

1.1. SIMIO

Simulation has been with us for over 40 years [9]. In this section, general knowledge about SIMIO is given. SIMIO is a simulation software which can model dynamic or complex systems. In SIMIO, some modules are employed to model some events. For instance, if you want to put a machine in your simulation model, you can use a server module. At the beginning of the modelling, you should select the source module in order to define the entities which will be flowing in the system. At the same time, the user can insert the information of how often and how many entities will enter the sytem. The entities entering the system are processed and for this, the user should drag the server modules. In the server module, the user can insert some data such as processing time, capacity type, failures and so on. After the entities are processed in the server modules, they leave the modules and exit the system. The sink module represents system exit. The system can run as much as the user desires and the outputs, such as throughput, work in process, queues, bottlenecks, waiting time and so on, can be achieved.

2. Methodology

In this study, a methodology which comprises 5 steps was implemented, as shown in Figure 1. In the first

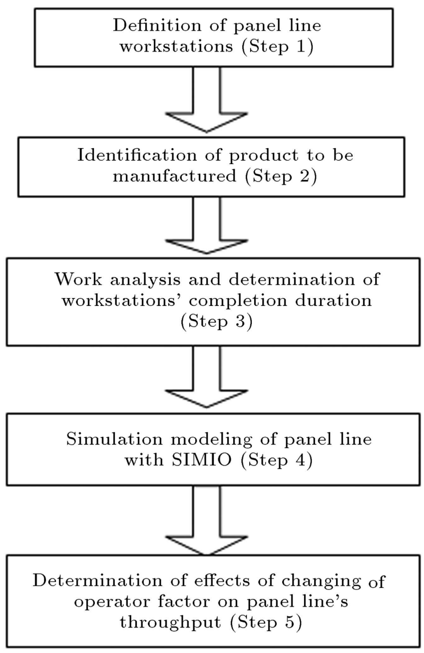

Figure 1. The stages of the study.

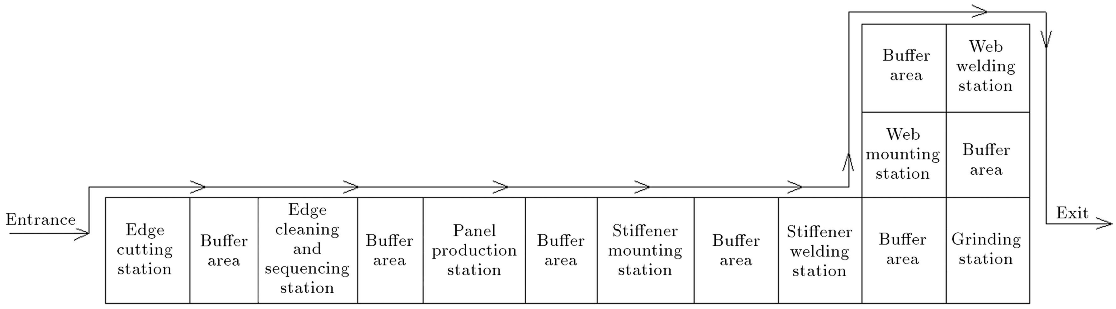

Figure 2. General arrangement of panel line.

step, workstations that constitute a panel line were defined and expounded. After that, in the second step, the product to be manufactured in the panel line was idendified and some knowledge given about its structure. Then, a detailed work analysis of workstations in the panel line was performed and their completion durations were determined. In the fourth step, a simulation modeling of the panel line was built by using SIMIO software. In the last step, the effects of changing the operator factor on panel line throughput were determined.

3. Application

3.1. Definition of panel line workstations (Step 1)

There are 9 workstations on a panel line. Figure 2 depicts the general arrangement of the panel line. The first station on the panel line is the panel production station. But, prior to the panel production station, there are two more workstations; edge cutting and edge cleaning-sequencing. Therefore, it is considered that a panel line consists of nine workstations. In this section, identification of these nine workstations on the panel line was undertaken.

3.1.1. Edge cutting station

In this study, this station was deemed the first workstation on the panel line. In this station, the edge cutting operations of the flat plates are carried out. Edge cutting operations are needed to be performed on flat plates, which constitute the panel structure, in order to get them into specific dimensions. For this, plates are loaded onto a railed transport vehicle by means of a overhead crane capable of lifting 15 tons, then the plates are laid down on the plasma cutting machine by the other overhead crane, also capable of lifting 15 tons. Later, the edge cutting operation starts. After the cutting operation is over, the cut plates are unloaded onto the buffer area.

3.1.2. Edge cleaning and sequencing station

After the edge cutting operation is over, the plates are transferred to the edge cleaning and sequencing station. In this station, slags, which result from the edge cutting operation, are removed by employing a grinding machine on a grinding table. Then, the plates are unloaded to the buffer area by using an overhead crane capable of lifting 15 tons. Finally, the plates are sequenced on sequencing areas, according to the assembly turn.

3.1.3. Panel production station

After the edge cleaning and sequencing station, the plates are transferred to the panel production station. Here, the panel structure is fabricated by submerged arc welding. In the first step, the plates are fixed to the panel line by a conveyor fixing mechanism. Then, they are sent to the tolerance plate welding area, where the tolerance plates are welded with tack welding. The submerged arc welding operation starts from the tolerance plates, because the welding becomes more stabilized. After that, the plates are transfered to a submerged arc welding machine with a conveyor. Here, the plates are welded by submerged arc welding and are then sent to the buffer area.

3.1.4. Panel cutting station

In this station, the cutting, blasting and marking operations of the panel are performed. The panel fabricated in the panel production station gets to Buffer Area 2. Then, the panel is transfered to a panel cutting machine with a conveyor. Firstly, the set-up operation of the machine is carried out and blasting and marking operations are done. Then, the inside and counter cutting operations of the panel are performed. Finally, the panel is transfered to Buffer Area 1.

3.1.5. Stiffener mounting station

In this station, stiffeners are mounted on the panel by tack welding. Stiffeners, which are stacked in a profile stock area, are transferred to the porter system by an overhead crane capable of lifting 10 tons. Then, the porter system carries the stiffeners to the conveyor. A profile mounting machine with a special transporter unit carries the stiffeners to the panel and makes their alignments on the panel. Finally, the stiffeners are mounted on the panel by spot welding.

3.1.6. Stiffener welding station

Here, stiffeners are welded onto the panel by TIG welding method. Welding operation are performed automatically. After the welding operation is completed, the panel with stiffeners are transferred to the buffer area.

3.1.7. Web mounting station

In this station, web structures are mounted on a flat panel assembly and a major sub assembly is fabricated. The porter system transports the web structures to the web mounting area and a crane capable of lifting 2×6 tons takes the web structures from the porter system and aligns them onto a flat panel assembly. Web structures are fixed onto the flat panel assembly by tack welding.

3.1.8. Web welding station

In this station, the major sub assembly, which is fabricated in the web mounting station, is transfered from the buffer area to the web welding area by a conveyor system, and the TIG welding operations of the structure are carried out.

3.1.9. Grinding station

This is the last work station of the panel line. The major sub assembly is transfered from the buffer area to the grinding area by a conveyor system. In the grinding area, the grinding operations of the welding places of the web structures are performed. So, slags are removed from the web structures.

3.2. Identification of product to be manufactured (Step 2)

The panel line is a kind of assembly line and it produces flat structures in a logic of group technology. The panel line manufactures flat panels with stiffeners, as well as major sub assembly. In this study, it is assumed that the major sub assembly structure is fabricated on the panel line. Figure 3 shows the major sub assembly. As can be seen from Figure 3, it consists of some single section parts and sub assemblies. After the flat panel is fabricated, stiffeners are mounted on it and then minor and sub assemblies are assemblied. Finally, a major sub assembly structure is produced at the end of the panel line.

3.3. Work analysis and determination of workstations' completion duration (Step 3)

In this step, a detailed process analysis of workstations on the panel line is carried out. Every workstation was investigated in a comprehensive way and work activities determined. The durations of the work activities were calculated and finally the completion times of the workstations were achieved. The completion durations of the workstations are shown in Table 1.

Here, in the web welding station, completion time was calculated in accordance with the weld time equation. In this calculation, the operator factor is deemed as 0.1. Table 2 shows how to calculate the web welding station completion time.

3.4. Simulation modeling of panel line with SIMIO (Step 4)

Figure 4 depicts the simulation model of the panel line. The panel line was modeled using SIMIO software.

Table 1. Completion durations of workstations on panel line [10].

Station name	Completion duration (min)
Edge cutting	111.5
Edge cleaning and sequencing	119.217
Panel production	368.19
Panel cutting	227.314
Stiffener mounting	175
Stiffener welding	214.8
Web mounting	476
Web welding	4731.12
Grinding	112

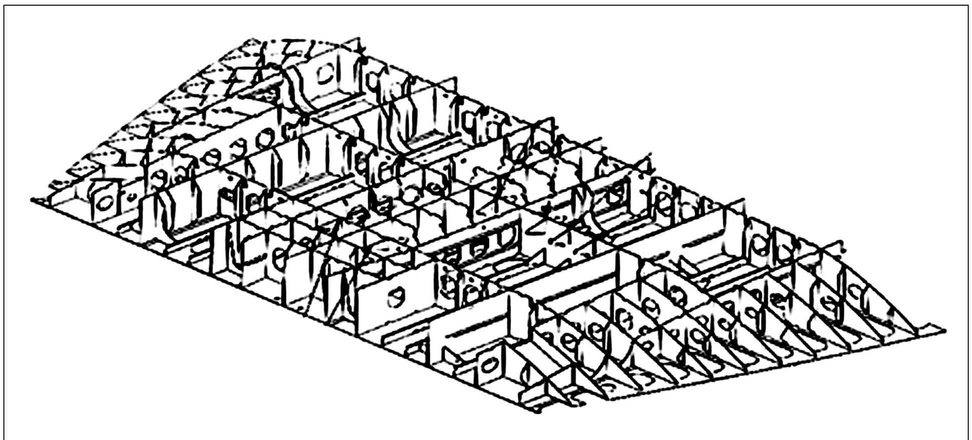

Figure 3. Major sub assembly.

Table 2. Welding time calculation in web welding station.

Welding parts	Welding length (m)	Volume of weld (m^3/m)	Specific gravity of metal (kg/m^3)	Deposition rate (kg/hr)	Operator factor	Welding time (hr)	Worker quantity	Completion time (min.)
Web structure welding	85.4	0.0000315	7870	3.5	0.1	60.488	4	907.32
Plate part welding	492.712	0.000021	7870	3.5	0.1	232.658	4	3489.87
Section part welding	4.42	0.000224	7870	3.5	0.1	22.262	4	333.93
Total web welding station completion time								**4731.12**

Table 3. Server's contents.

Module name	Capacity type	Work schedule	Ranking rule	Processing time (min)
Edge cutting	Work schedule	Standart week	First in first out	112
Edge cleaning and sequencing	Work schedule	Standart week	First in first out	119.217
Panel production	Work schedule	Standart week	First in First out	368.19
Panel cutting	Work schedule	Standart week	First in First out	227.314
Stiffener mounting	Work schedule	Standart week	First in First out	175
Stiffener welding	Work schedule	Standart week	First in First out	214.8
Web mounting	Work schedule	Standart week	First in First out	476
Web welding	Work schedule	Standart week	First in First out	4731.12
Grinding	Work schedule	Standart week	First in First out	112

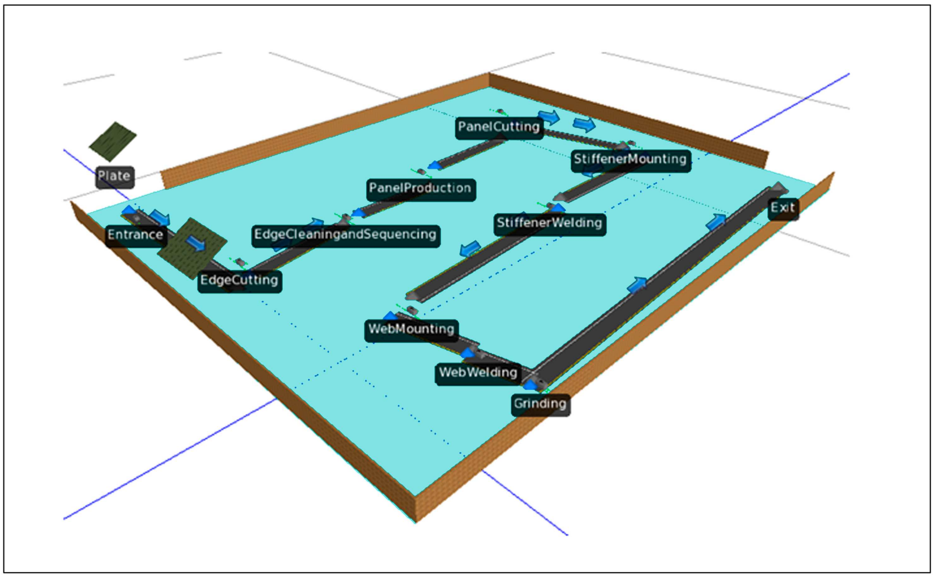

Figure 4. Simulation model of panel line.

There are nine server modules and ten conveyor steps in the simulation model and each of them represents the workstations and connections between workstations.

The server module in the simulation represents the workstations on the panel line and its content is illustrated in Figure 5 and Table 3. Accordingly, capacity type means whether or not the working period is fixed. In other words, it shows labour hours. In this study, labour hours are based on a work schedule. This is deemed as a standard week, which means the company works eight hours per day. The ranking rule was chosen as the first in first out rule, which means that whatever comes first is processed first. It is the processing time in the last column, and it shows the completion durations of the workstations.

The conveyor step represents the conveyors be-

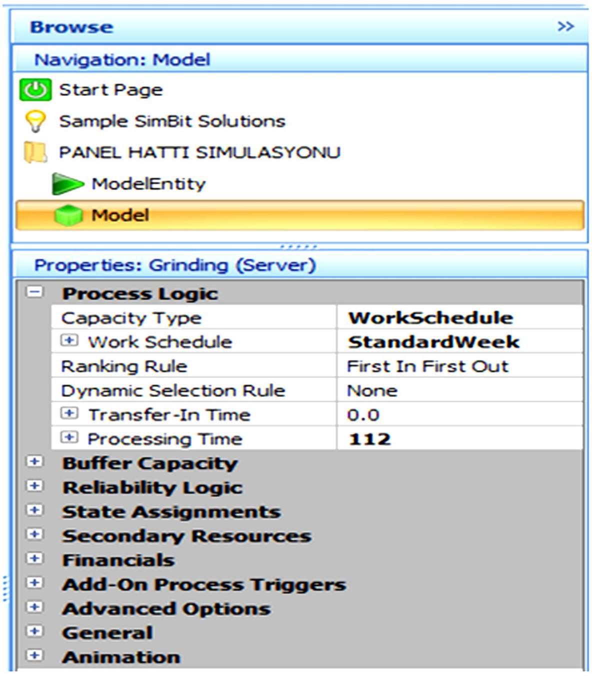

Figure 5. Interface of server module.

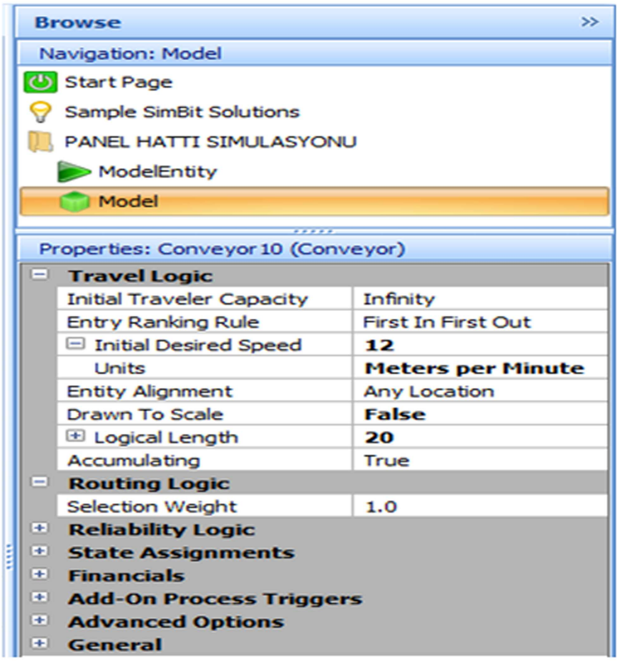

Figure 6. Interface of conveyor step.

tween workstations. In this study, conveyor speed was thought to have a desired speed of 12 meters per minute. Furthermore, each conveyor between workstations has a length of 20 meters. The contents of the conveyor step were shown in Figure 6 and Table 4.

After the simulation model was built, the system was run for four months, and the production quantity was attempted to be found.

3.5. Determination of effects of changing operator factor on panel line throughput (Step 5)

In this section, the effects of changing operator factor on panel line production quantity were investigated. The operator factor was altered from 0.1 to 1.0. When this was done, the welding duration of the web welding station was also changed. This time change was put in the simulation model and the model was run for 4 months. At the end, the production quantity of the panel line was found. Therefore, it was found how much the change of operator factor affected the panel line throughput. In Table 5, this effect can be seen clearly.

As can be seen from Table 5, while the operator factor is increasing, panel line production quantity (throughput) is increasing as well. Figure 7 represents the relation between operator factor and panel line throughput. According to Figure 7, the relation between the operator factor and panel line throughput is proportional.

Figure 8 depicts production quantity enhance-

Table 4. Conveyor's contents.

Module name	Initial desired speed	Units	Drawn to scale	Logical length (m)
Conveyor 1	12	Meters per minute	False	20
Conveyor 2	12	Meters per minute	False	20
Conveyor 3	12	Meters per minute	False	20
Conveyor 4	12	Meters per minute	False	20
Conveyor 5	12	Meters per minute	False	20
Conveyor 6	12	Meters per minute	False	20
Conveyor 7	12	Meters per minute	False	20
Conveyor 8	12	Meters per minute	False	20
Conveyor 9	12	Meters per minute	False	20
Conveyor 10	12	Meters per minute	False	20

Table 5. Changing of system throughput according to operator factor.

Operator factor	Total activity duration (hr)	Total activity duration (min.)	No. of welding team	Web welding completion time (min.)	Panel line throughput (unit)
0.1	315.41	18924.6	4	4731.15	11
0.2	157.705	9462.3	4	2365.575	23
0.3	105.136	6308.16	4	1577.04	35
0.4	78.852	4731.12	4	1182.78	47
0.5	63.082	3784.92	4	946.23	59
0.6	52.568	3154.08	4	788.52	71
0.7	45.058	2703.48	4	675.87	83
0.8	39.426	2365.56	4	591.39	95
0.9	35.045	2102.7	4	525.675	107
1.0	31.541	1892.46	4	473.115	118

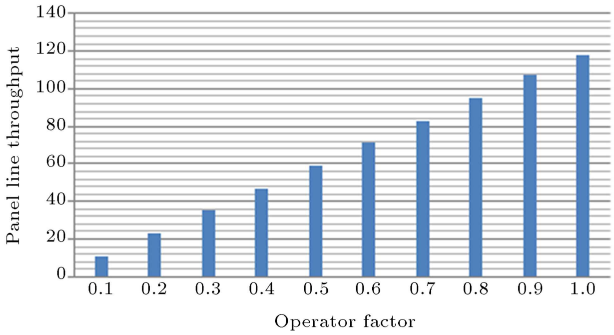

Figure 7. Relation between operator factor and panel line's production quantity.

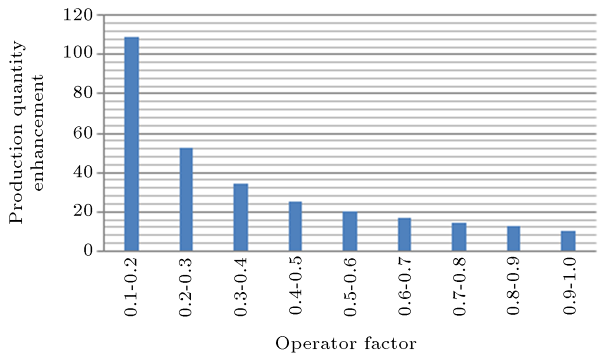

Figure 8. Production quantity enhancement between operator factors.

ment between operator factors. For instance, if the operator factor can be increased from 0.2 to 0.3, panel line production quantity increases 52%. In the same way, when operator factors increase from 0.3 to 0.4, panel line throughput increases 34%. Considering Figure 7, it can be seen that the panel line can fabricate 23 units in the value of 0.2 of the operator factor, and also fabricate 35 units in 0.3 of the operator factor. That means an enhancement of 12 units from 0.2 to 0.3 values of the operator factor. Therefore, the production quantity increases 52%. The others were similarly calculated.

4. Conclusion

In this study, it was aimed to determine the effects of operator factor changes on panel line production quantity. As can be seen above, the increasing of the operator factor directly affects panel line production quantity. In other words, a higher operator factor increases production quantity. By increasing the operator factor, less welding time can be achieved on the panel line and this situation leads to higher production quantity on the panel line. This means that a shipyard can fabricate major sub assembly structures in less time. So, shipyard production engineers have to focus on how to increase the actual arc welding of the welder.

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Biographies

Murat Ozkok received MS and PhD degrees from the Naval Architecture Department at Istanbul Technical University, Turkey, and is currently working for the Karadeniz Technical University in Turkey. His research interests include ship production techniques, ship fabrication processes, process improvement and simulation.