Implementation of new production processes in panel's line

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Implementation of new production processes in panel's line

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ABSTRACT: European shipyards suffer some pressure to implement automatization in their production processes, in order to become more competitive in the global market. The trend of the shipbuilding process towards automatization is costly and needs to be carefully studied by the shipyard, and ensures that a given proposal of new technologies implementation produces positive outcomes for the shipyard. In order to study the possibilities of new production techniques and processes one must first study and understand the current production situation of the shipyard and only then propose alternatives. The production process is made by several phases of construction and the panel line is a key phase of the construction of a block. In this work it is studied the panel line process, with particular focus on industrial case study. A program is being developed for implementing the most advantage approaches into production of a block, minimizing production time, contributing for competitiveness.

1 INTRODUCTION

Today the mainstream ship production scheme is, undoubtedly, the construction by blocks. This type of construction allows a faster production flow, with better quality, mainly due to the possibility of the inside covered areas construction, and also due to the application of production lines of the different production stages. One of this production lines is the panel's line. There are two types of panel line: the straight panel line and the curved panel line. This study will only approach the first one. The curved panel line presents the same working flow, although the significantly difference of its curved characteristic adds more constraints and requirements during its production process. The panel's line is a key phase of the construction of the block and an important production area in the shipyard.

The monitored panel line of this case study is restricted to stiffener welding, i.e., the web fitting and welding is done posteriorly in the block construction shop.

The panel's lines were implemented in the European and Japanese shipyards in the 1960's, in order to respond to the increased demand of very large crude carriers (Cahill et al., 2000). Since then, the panel's line was developing into a more flexible equipment, lower acquisition cost and higher productivity (Andritsos & Prat, 2000).

The characteristics of this construction stage make it very straightforward to apply the lean techniques, hence improving the production and its efficiency (Kolich, Storch, & Fafandjel, 2016).

The data collected in this study may be incorpored in a manufacturing cost analysis (Leal & Gordo, 2017) by supplying detailed data that can improved very much the quality of the estimation of the global cost of the hull from the point of view of the shipyard.

2 COLLECTED DATA

The data collected in this case study is relative to the construction of two naval ships in the WestSea Shipyards S.A., in Viana do Castelo, Portugal. The panel's line is located in the steel processing shop of the shipyard.

2.1 *The current panel line*

The current panel line here analyzed comprehends four main stages: Plate butt welding; oxy-fuel cutting of the plate's blanket; stiffeners fitting and tacking; stiffeners welding.

In Figure 1 is presented a scheme of sequence of workstations. In the first workstation the steel plates are received by the shipyard transporters. If required, the steel plate is previously mechanically beveled. The joining process is a one-side submerged arc welding type, with continues monitoring of the welding quality, during and in the end of the welding process.

The second workstation is responsible for the marking and oxy-fuel cutting of the panel. However, the cutting gantry system do not perform text marking, so supplementary manual work is

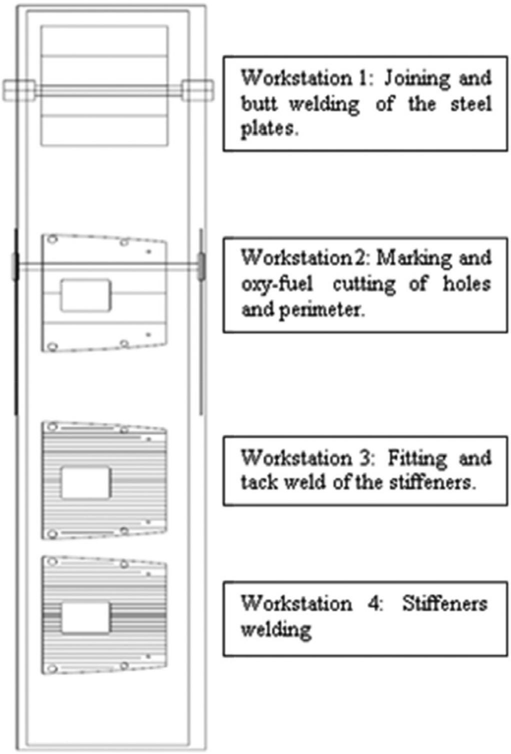

Figure 1. Scheme of workstation's sequence.

needed. In the end of this stage, the dimensional control is crucial, in order to verify the expected panel dimensions.

Although the third and fourth workstations are associated to the stiffener insertion, they are independent workstations. In the first one the stiffeners are fitting and tack welded, and in the fourth workstation the stiffeners are welded through semi-automatic MAG welding.

2.2 *Panels monitored*

In order to study the production flow in the panel line, five different stiffened panels were monitored. All these five panels are different from each other, as we can see in the following figures, although all their steel plate have small thickness, usually five millimeters.

Figure 2 shows the panel P1, which has a 31 m^2 area, composed by three steel plates, and 15 stiffeners, 3 of which larger than the other 12.

Figure 3 illustrates the panel P2, with 87 m^2 of area, five plates, and 23 similar bulb stiffeners.

The third, P3, is shown in Figure 4 and it has 145 m^2 of area, five plates, and 41 stiffeners.

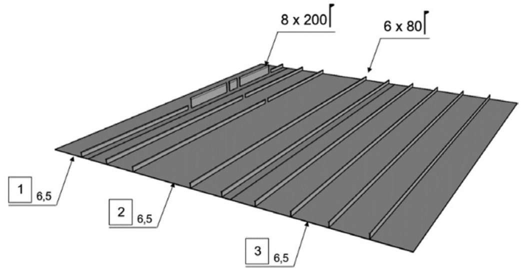

Figure 2. Stiffened panel P1.

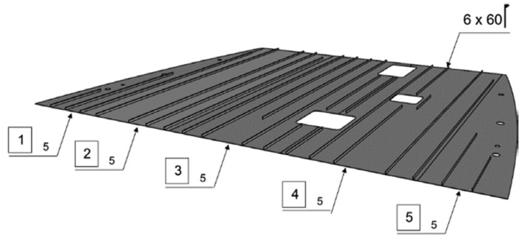

Figure 3. Stiffened panel P2.

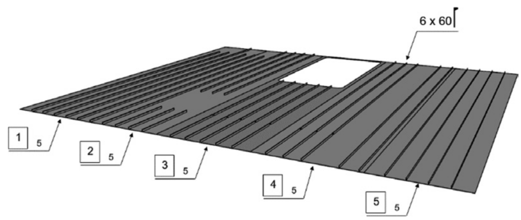

Figure 4. Stiffened panel P3.

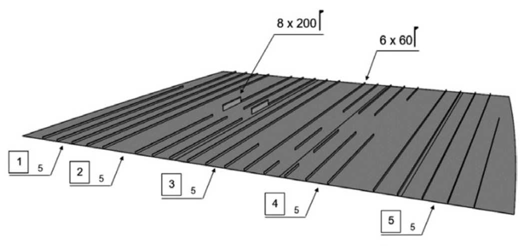

Figure 5. Stiffened panel P4.

P4 has two stiffeners of 200 mm high and thirty with 60 mm high. Its area covers 116.5 m^2, and is composed of five steel plates, as shown in Figure 5.

The panel P5, presented in Figure 6, has 26 m^2, thirteen stiffeners and four plates.

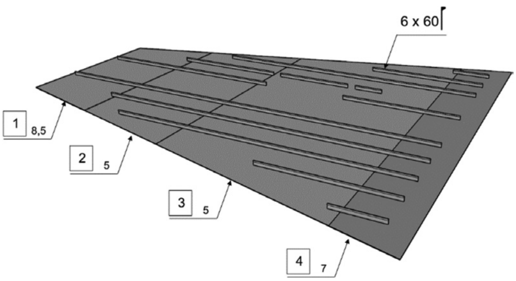

Figure 6. Stiffened panel P5.

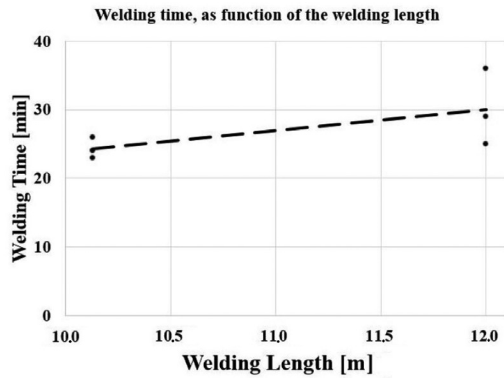

Figure 7. Welding time linear regression.

3 DATA PROCESSEMENT

3.1 *Butt welding of the steel plates*

The joining of the steel plates, as said before, is done through a one-side submerged arc welding, thus avoiding the additional work of turn around the plate blanket and weld in the opposite side, hence obtaining significant less man hours required to perform the butt weld.

Previously to the welding process itself, it is important to take into account the phase of align and tack weld the plates. In this phase, although its time is correlated with the plate's length, *Lp*, in *m*, its correlation has a small significance. According with the data collected, the time required for align and tack welding two plates is given by

$$T_{a,t}\,[\text{min}] = 0.7 \times Lp - 10.78 \tag{1}$$

The data collected from the welding processes observed also allowed to build a linear regression, Figure 7, in order to obtain an expression of the time required for a given welding length, for thin steel plates.

The linear regression presented in the Figure 7 can be expressed by the formula:

$$T_w\,[\text{min}] = 3.1\text{x}\; Lp - 6.9 \tag{2}$$

So, e.g., for weld length values of 10 m, the weld would be done in speed of approximately 41.5 cm/min. The formula above shown gives different speed for different length, what actually is acceptable, because the greater the distance to weld, the greater the possibility of events requiring to stop the process. It is important to stress that all the butt welding processes observed were for 5 mm thickness steel plates.

Although few times the previous mechanical cutting or beveling of a steel plate is needed, this must be account in the panel assembly process. From all the five panels, only one steel plate was required to be previously cut, taking approximately 52 minutes to wear out a length of twelve meters.

Other two phases of this workstation are important to take into account, namely the time required for the preparation of the weld and the post weld phase of checking the weld quality. The first operation is considered independent of the weld length, taking on average 20 minutes per welding. Although some of this work of preparation can be done at the same time of the alignment and tack welding, this simultaneous period can be considered as being only 5–7 minutes. The quality control of the butt weld does not vary much with the weld length, taking the average value of 9 minutes.

For a weld length of 12 meters, and considering that a previous mechanical cut is not required, the expected time distribution of each phase of the butt weld process is show in Figure 8:

3.2 *Marking and oxy-fuel cutting*

After the butt welding of the total plates of the panel, the plates blanket is processed in the second workstation where it is marked and cut, by oxy-fuel technology.

By doing a similar analysis on this workstation, it is possible to get the linear regressions for the marking and cutting of panels with five millimeters thickness.

The linear regression shown in Figure 9 can be mathematically expressed as

$$Tm = 0.08 \times Lm + 23.0 \tag{3}$$

where *Tm* stands for the marking time, in minutes, and *Lm* stands for the marking length, in meters.

The oxy-fuel cutting process data is shown in Figure 10:

The linear regression of the oxy-fuel cutting time can be expressed as

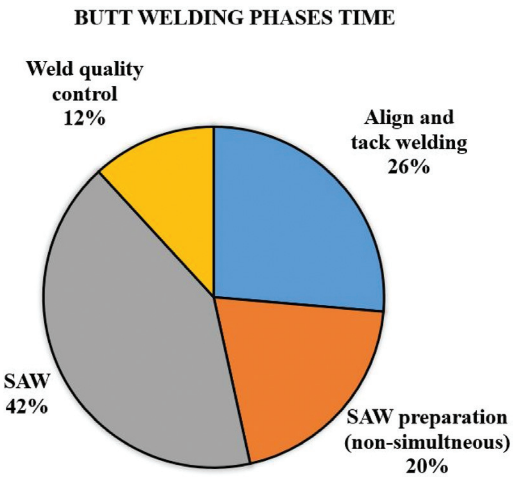

Figure 8. Butt welding phases times.

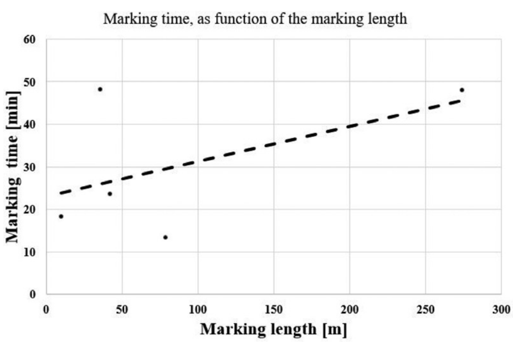

Figure 9. Marking time vs Marking length.

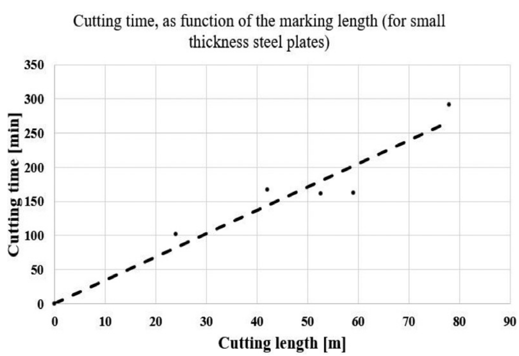

Figure 10. Cutting time versus length linear regression.

$$T_{oxy\text{-}fuel} = 3.42 \times Lc \quad (4)$$

where $T_{oxy\text{-}fuel}$ stands for the oxy-fuel cutting time, in *min*, and Lc stands for the cutting length, in *m*.

So, for the marking activity, the linear regression gives us a speed of approximately 6.0 m/min. For the oxy-fuel cutting the speed is 0.31 m/min. However, during the monitoring of the cutting activity, is was observed that the cutting itself has a speed of 0.41 m/min, hence, we can conclude that 25% of the time is due to procedures other than cutting, e.g., the movement of the cutting head and the pre-heat of the steel plate.

Other phases of this workstation are also important to take into account: the work preparation, that is independent of the cutting length and is about half an hour; the manual marking, because the equipment do not mark text, is performed manually by a worker, taking usually no longer than five minutes; and the dimensional control of the final piece, that is made in 8–10 minutes.

Figure 11 shows an example of the time distribution of the various phases of this second workstation of the panel P2, which has 274 m of cutting length and 78 m of marking length.

Although the manual marking, the dimensional control and the work preparation have somewhat constant times, the cutting time and marking times depends obviously of the required cutting and marking lengths and the technology used (Carvalho, Gordo, Lima, & Guedes Soares, 2006; Gordo, Carvalho, & Guedes Soares, 2006).

3.3 *Fitting and tack welding the stiffeners*

The third workstation is responsible for the manual distribution of the stiffeners, and is usually done by two workers. There are three main work phases in this station: distribution of the stiffeners according with the marking done in the previous workstation; attach the reinforcements with a first tack weld in each stiffener; tack weld the stiffeners

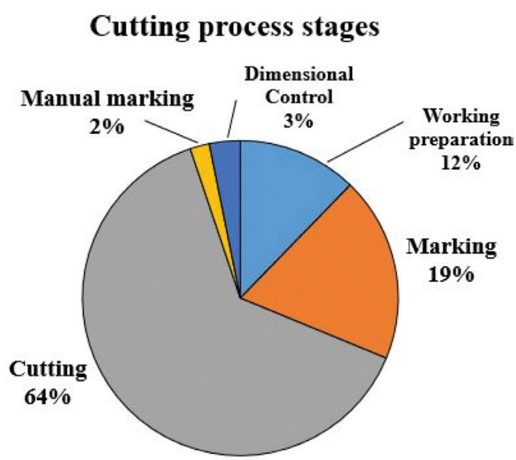

Figure 11. Cutting phases times for oxy-fuel cutting.

along their length; dimensional angular control of the stiffeners, checking their perpendicularity.

According with the monitored work, the time spend on the reinforcements distribution do not vary much with its length, and consumes on average half a minute per stiffener of the panel.

The collected data of the second work phase, i.e., the first tack weld of the stiffeners, allow to create a function of the expected time of the first tack weld, in *min*, to the stiffener's length, L_{st}, in *m*, as presented in Figure 12:

The expected first tack weld time, T_{ftw}, can be estimated by:

$$T_{ftw}\,[\text{min}] = 0.2 \times L_{st} + 2.4 \qquad (5)$$

By similar analysis, the third operation's expected time in *min*, i.e., the complete tack weld time, $T_{ctw,}$ along the stiffener, is given by:

$$T_{ctw}\,[\text{min}] = 2.0 \times L_{st} + 2.0 \qquad (6)$$

The last operation, checking the perpendicularity of the stiffeners, is a relatively fast work, taking in average 40 seconds per stiffener.

Figure 13 shows an example of the time distribution of each phase of this workstation for the panel P2:

3.4 *Stiffeners welding*

The last workstation of the panel line consists on the semi-automatic MAG welding of the stiffeners. The first phase is the welding preparation of the stiffener side without the tack welds, i.e., blow the dust in order to decrease the possibilities of dust contamination during the weld process. After the cleaning, the second phase is the MAG welding of the stiffener side without the tack welds. The cleaning of the surface and deburring the tack welds is the third operation. The fourth operation is the semi-automatic MIG weld of the side of the stiffeners

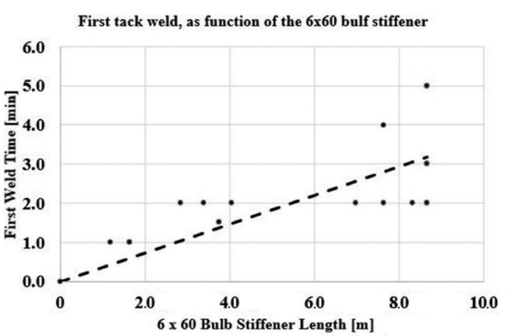

Figure 12. First tack weld time linear regression.

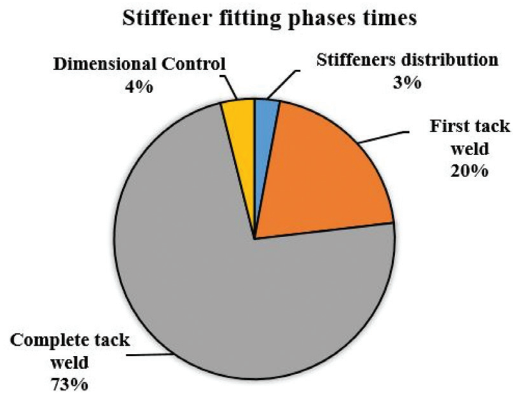

Figure 13. Stiffener fitting phases times.

where originally were the tack welds. Finally, the last phase of this workstation is the quality control of the welds and its correction, if required.

The first operation does not change significantly with the stiffener's length, being on average performed in 5–7 minutes.

The second and fourth operations, i.e., the welding of both sides of the reinforcements, can be analyzed as the same action. So, performing a similar analysis like the ones before, it can be created a simple linear regression presented in Figure 14 and allowing to estimate the time required to MAG-weld, as function of the weld length.

$$T_{MAG} = 1.4\ .\ L_w + 2.2 \qquad (7)$$

where T_{MAG} stands for the MAG welding time, in *min*, and L_w stands for the welding length, in *m*.

The time required for the third operation, where the previous tack welds are deburred, can be estimated by the following formula:

$$T_{\text{tack deburring}} = 0.9\ .\ L_{\text{stiffeners}} + 1.9 \qquad (8)$$

where $T_{\text{tack deburring}}$ is represented in *min*, and the length of the stiffeners, $L_{\text{stiffeners}}$, is in *m*.

The last operation is the weld quality control and correction. Although its required time depends on the welder experience and many other parameters, it can be estimated by the following expression:

$$T_{\text{quality check and correction}} = 0.9 \times L_{\text{stiffeners}} + 1.9 \qquad (9)$$

where the time for quality check and possible corrections is given in *min*.

Figure 15 exemplifies with a seven-meter stiffener, its time distribution of each operation at this workstation is shown below.

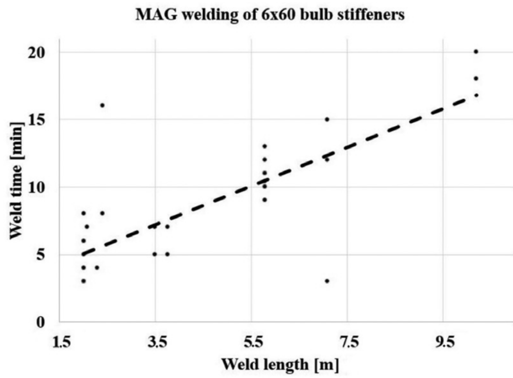

Figure 14. Stiffener welding speed.

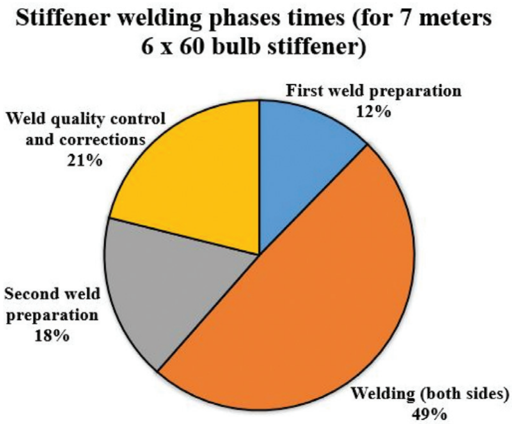

Figure 15. Stiffener welding phases times.

3.5 *Non-productive times*

The previous analyses of the expected times for each one of the four workstations comprehend only the productivity times, i.e., do not take into account the periods that do not generate direct increased value on the product, in this case, the panel. These time periods can be exemplified with situations where the workers are waiting for the equipment availability, waiting for instructions, resting, equipment transportation, problems with the equipment, and other similar situations.

The following Table 1 presents the amount of non-productive time in each workstation although not all the global times of each workstation for each panel were available to collect, we can still build a table showing the amount of non-productive time in each workstation.

The values not shown indicate situations where it was not possible to collect the total times, or these were not feasible.

Table 1. Non-productive times.

Panels	P1	P2	P3	P4	P5
W.S. 1	–	–	62%	71%	–
W.S. 2	–	17%	45%	6%	23%
W.S. 3	59%	32%	33%	34%	–
W.S. 4	22%	55%	38%	–	–

Table 2. Waiting times (in minutes) between workstations.

	WS1→WS2	WS2→WS3	WS3→WS4
Panel P1	–	–	60
Panel P2	–	200	75
Panel P3	90	60	–60
Panel P4	730	120	–

The values presented allow to conclude that, clearly, the first workstation, where the steel plates blanket is assembly, is where the non-productive time is larger. The workstation where less time is spent with non-productive activities is the marking and oxy-fuel cutting workstation. The stiffener related workstations have both a similar average of 40% time of non-productive time.

3.6 *Waiting time between workstations*

The time analysis made in the previous section 3.5 only accounts for the period comprehended between the beginning of the workstation activity and its conclusion, i.e., do not take into account the times of the product waiting to be initialized in the next workstation.

Table 2 presents the waiting times, in minutes, of the panels between the workstations. As for the previous section it was not possible to get all the values for all the panels, however the presented values allow to take some acceptable interpretations.

From the data of Table 2 it is possible to testify the significant smaller waiting times in the transition from the third to the fourth workstation, where even two different works (works of workstations 3 and 4) were performed simultaneously in the same panel (Panel P3). This evidence can be justified mainly due to the important flexibility of the work characteristics of the last two workstations, allowing the execution of the same work on two different panels at the same time, and also the possibility of two different works on the same panel.

So, the greater values shown in the previous table are mainly due to production flow bottlenecks. The monitoring of the panel's work flow allowed also to list some possible justifications for those bottlenecks, like the inflexible relations of the type of work of the first three workstations, and also the production processes speeds.

4 NEW PRODUCTION PROCESSES

In order to study the consequences of possible processes changes in the workstations of the panel's line, namely cutting and welding technologies, a rather simple program was created.

4.1 *Panel's line processes study program*

As said before, the developed program is rather simple, aiming only to give simple results of the stiffened panels production values, as function of the processes implemented in the panel's line, Figure 16.

The program was developed in a way to become user friendly, setting a series of menus and submenus. The user is responsible to input two main set of values: those characterizing the collection of panels to produce, and those characterizing the panel's line.

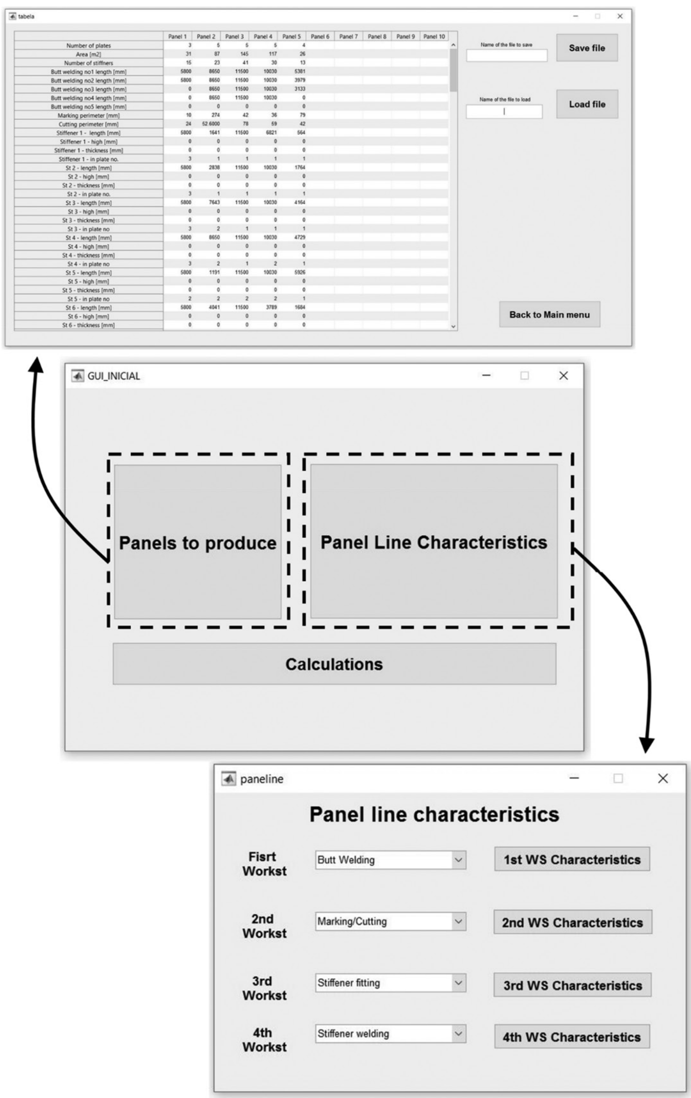

Figure 16. Program interfaces.

Figure 17 presents an example of the user definition of the parameters of the cutting workstation. The main outputs of the program are the time values and the number of man-hours of each construction station of each panel, and it also presents the workstation time distribution scheme of the production of the set of panels studied, as presented in Figure 18.

It is important to stress that the program considers that the panels are produced as fast as possible,

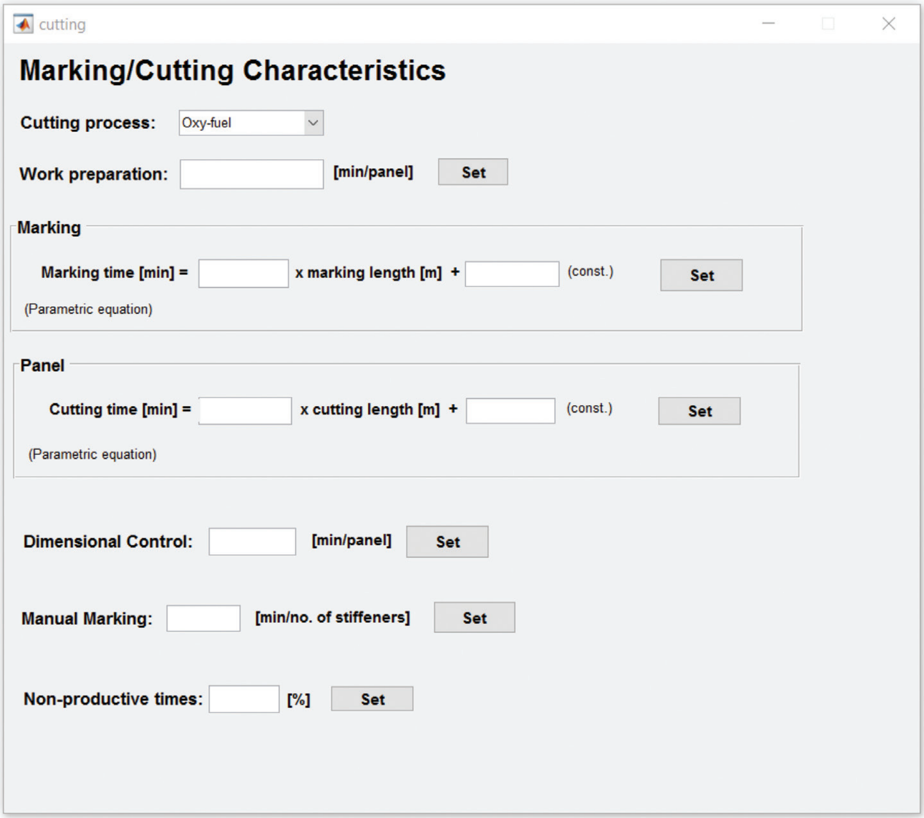

Figure 17. Interface to set cutting characteristics.

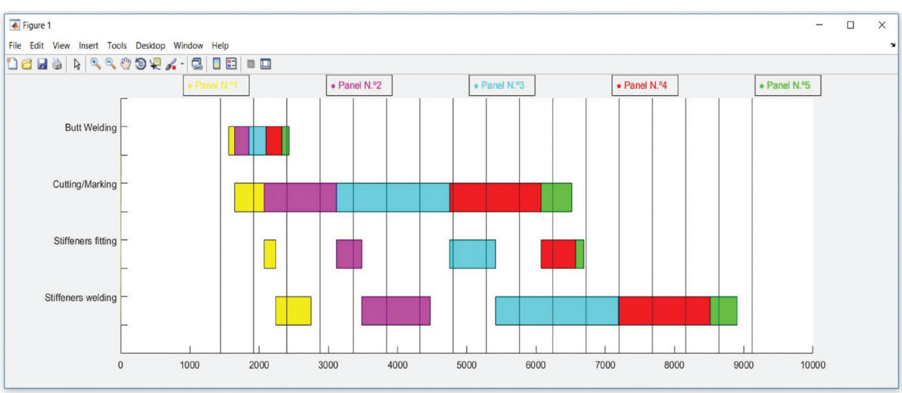

Figure 18. Program output: Panel's line workstation time distribution.

i.e., as soon as the first workstation is concluded for a given panel, the next panel starts immediately his production. Also, as soon as the next workstation is available, the panel continues immediately his production flow.

4.2 *Study of new technologies implementation in the panel's line*

The present chapter pretends to perform a study on the results of the implementation of different techniques and technologies in the panel's line on the production flow time values.

Many combinations of different technologies implementations can be analyzed. However, this paper will only consider individual changes on the process, such as, for example, the case of the production flow where the cutting is performed through plasma, instead of oxy-fuel. Or the consequence on the production flow if fully automatic stiffener welding is implemented.

4.2.1 *Implementation of plasma technology in the cutting workstation*

Today the plasma cutting is being strongly implemented in the building shipyards, with proven benefits on both cut quality and production time. Although not presented on the current panel's line studied in the previous chapters, the *WestSea* Shipyard owns also a plasma cutting system in a different shop, for the cutting of smaller steel pieces from large standard steel plates. A field study (Oliveira & Gordo, 2017) was also realized in this cutting shop, where parametric formulas of the plasma cutting process were obtained.

$$S = -118.8\, t_p + 3037 \tag{10}$$

Where S stands for the plasma cutting speed [mm/min] and t_p stands for the plate thickness [mm]. Thus, considering a 5 [mm] plate thickness, the speed will be of 2.443 [mm/min].

Table 3 presents some differences on the production flow, before and after the implementation of the plasma technology in the second workstation.

Table 3. Implementation of plasma cutting.

	With oxy-fuel cutting	With plasma cutting
Total production time of the panels [days]	15.3	14.1
Total cutting time [hours]	81.3	66.0
Total cumulative waiting times between workstations [hours]	163.4	144.3

The above values show a positive earning on the production flow, namely the shortened period needed to perform the construction of the five panels, a difference of more than one day. The smaller waiting times due to bottlenecks is also important, decreasing periods of non-productive of the panel's line workers due to the congestion of the production flow.

Although important earnings have been show due to the implementation of the plasma cutting, its advantages are better exploited if this plasma technology implementation is integrated on the optimization process of the entire panel's line.

4.2.2 *New solutions for the 3rd and 4th workstations*

Although the current activity of the stiffeners fitting is very obsolete when compared with process implemented in the today's state of the art building shipyards, we will firstly maintain it and analyze the consequences of the implementation of new solution on the stiffener welding workstation.

Although the stiffener mounting and welding gantry systems can be a very complex transformation on the panel's line, carrying considerable sum of investment, other solutions are cheaper and more flexible, like the implementation of parallel stiffener automatic welder, instead of the single side welder currently used.

Despite some not very significant procedures differences, we can consider that the welding rate will be the two times faster with the parallel automatic stiffener welding. Assuming the new welding speed, the next table displays the time values differences between the original stiffener welding situation and the parallel welding solution. Important to stress that the others workstations remain without alterations (current SAW welding, oxy-fuel cutting, manual stiffener tack welding, etc.…).

Although some important time reducing on every item was accomplish, the time reduction of the stiffener welding station in only 17%, justified on the percentage of the other phases of this workstation, shown in Figure 15.

The trend of increased automation of the shipbuilding processes also apply on the panel line stage. The current state of the art European building shipyards leaders had successfully implemented automatic panel's line. Although in most cases all the line is fully automated, we will limit the study on the installation of fully automated production in workstations 3 and 4. The installation of fully automated process would merge the 3rd and 4th workstation in one single stage.

For this study, we will consider a twice as fast track welding process (Mun et al., 2015), through an automated system to place and tack weld the stiffeners, and a four times faster stiffener welding, considering a parallel system torch, able to weld on both sides two stiffeners simultaneously (Santiago, 2012).

Table 4. Implementation of parallel weld carriage.

	Current stiffener welding process	Parallel stiffener welding
Total production time of the panels [days]	15.3	14.0
Total stiffener welding time [hours]	83.1	68.5
Total cumulative waiting times between workstations [hours]	163.4	148.2

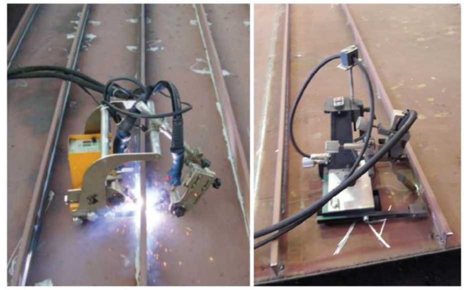

Figure 19. Parallel weld carriage (3), and single weld carriage.

Table 5. Implementation of fully automatic stiffener fitting and welding.

	Current stiffener fitting and welding	Automation of the 3rd and 4th workstations
Total production time of the panels [days]	15.3	11.4
Sum of 3rd and 4th workstation activity time [hours]	113.3	53.7
Total cumulative waiting times between workstations [hours]	163.4	149.5

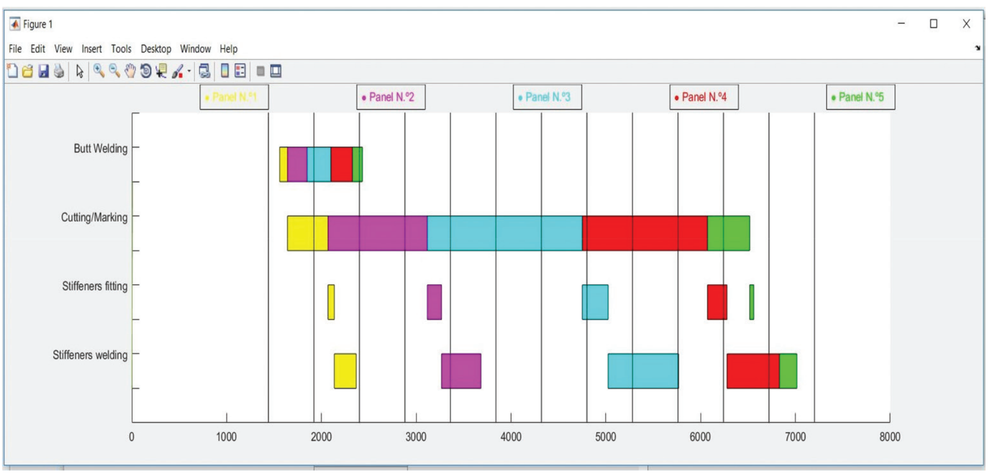

Figure 20. Panel's line workstation distribution times, due to the implementation of a fully automatic stiffener fitting and welding.

Table 5 presented values show significant gains on the period needed to conclude the construction of the five panels. However, the most important concerns the huge decrease on man hours needed to build the panels.

Figure 20 presents the workstation distribution scheme of the situation where the 3rd and 4th workstations were automated.

Through a fast analysis of the scheme of Figure 20, one can easily realize that the new system of fitting and welding of the stiffeners is not being fully used due to the long period of the oxy-fuel cutting process. Hence concluding the importance of the considerations of the integrated factor of all the workstations while doing an improvement project of the panel's line, avoiding to undergo on a great improvement on only one of the workstation without considering the production flow weight of the other ones.

5 CONCLUSIONS

The panel's line is a crucial stage of the block construction in the shipbuilding process, assuming a decisive factor in the entire flow production. The case study carried out and presented on the first part of this paper aimed to serve as a reference and tool on the optimization process of the panel line.

As it is show in the second part of the study, small changes on the workstations may have significant improvements in the flow production, e.g., the implementation of a welding carriage able to do a parallel welding on both sides of the stiffener, instead of the current single side welding carriage.

The quite simple analysis of implementation of different solutions on the panel's line presented also showed that the proposed changes in the production line must be analyzed as a whole, instead of the assumption of individual workstations, independent from the other ones.

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REFERENCES

Andritsos, F., & Prat, J. (2000). *The Automation and Integration of Production Processes in Shipbuilding, State-of-the-Art.*: European Commission Joint Research Centre.

Cahill, P., Shank, R., Crilly, P., Kelly, G., Jutla, T., & Weeks, T. (2000). Implementation of a State of the Art First Operations Shop in a Second Tier Shipyard. *Journal of Ship Production*, 133–150.

Carvalho, I., Gordo, J.M., Lima, J.L., & Guedes Soares, C., (2006). Modelação de custos de corte e soldadura de aço em reparação naval. In Guedes Soares & Gonçalves Brito (Eds.), *Inovação e Desenvolvimento nas Actividades Maritimas* (pp. 905–917). Lisbon, doi: 10.13140/ RG.2.2.22823.75683.

Gordo, J.M., Carvalho, I., & Guedes Soares, C. (2006). Potencialidades de processos tecnológicos avançados de corte e união de aço em reparação naval. I n Guedes Soares & Gonçalves Brito (Eds.), *Inovação e Desenvolvimento nas Actividades Maritimas* (pp. 877–890). Lisboa, doi: 10.13140/RG.2.2.27856.92160.

Kolich, D., Storch, R., & Fafandjel, N. (2016). *Optimizing Shipyard Interim Product Assembly Using a Value Stream Mapping Methodology*. Paper presented at the World Maritime Technology Conference.

Leal, M., & Gordo, J.M. (2017). Hull's manufacturing cost structure. *Brodogradnja, 68*(3), 1–24. 10.21278/brod68301.

Mun, S., Nam, M., Lee, J., Doh, K., Park, G., Lee, H., et al. (2015). *Sub-Assembly Welding Robot System at Shipyards*. Paper presented at the IEEE International Conference on Advanced Intelligent Mechatronics.

Oliveira, A., & Gordo, J.M. (2017). *Cutting processes in shipbuilding—a case study*. *Maritime Transportation and Harvesting of Sea Resources*, Guedes Soares & Teixeira (Eds.), Taylor & Francis, London (in press).

Santiago, P. (2012). *Automation of placement stiffeners in a welding production line*. Instituto Superior Técnico, U. Lisboa.