ANALIZE PROIZVODNIH KAPACITETA AUTOMATIZIRANIH LINIJA ZA ZAVARIVANJE U BRODOGRADILIŠTIMA

ANALYSIS OF SHIPYARD'S AUTOMATED WELDING LINES PRODUCTION CAPACITY

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Sažetak: U radu su prikazani rezultati analiza proizvodnih kapaciteta automatiziranih linija za zavarivanje u jednom brodogradlištu. Analize su provedene na dva tipa broda (dva reprezentanta), na kojima su analizirani tipovi zavarenih spojeva izvedeni u dijelu montaže pri proizvodnji oplate broda. Kao osnova za procjenu trenutne razine automatizacije zavarivanja postignute u ovoj ranoj fazi proizvodnje broda, uzeta je godišnja proizvodnja brodogradilišta. Temeljem provedenih analiza predloženo je unaprjeđenje proizvodnog procesa u brodogradilištu.

Abstract: The paper presents results of analysis of production capacity of automated welding lines in selected shipyard. Analysis was carried out on two ship representative types, on which are analysed welded joint types produced at section assembly of ship hull production. As a base for assessment of current level of welding automation achieved in this early phase of ship production is taken the shipyard year production. Base on analysis a suggestion for shipbuilding process process improvement are proposed.

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1. INTRODUCTION

To assess capacity of installed automated welding lines for a ship hull assemblies welding, and to analyse possible ways of improvements, an analysis of welded joint types, produced at a section assembly of a ship hull production, is carried out. The analysis is based on a yearly production program of selected shipyard. Obtained results give information of how much capacity is needed for current production volume. Based on that information, possible approaches of capacity improvements of installed automated welding equipment are commented.

2. ANALYSIS OF WELDED JOINT TYPES [1]

To assess a demand for the capacity of automated welding lines, the analysis of yearly ships production for selected shipyard is conducted. Based on production of five ship hulls per year, a number of needed subassemblies, panel assemblies and completed panel assemblies are determined.

Two types of ship representatives are selected and that are 23400 dwt chemical tanker (in further text denominated as Type A), and 47300 dwt oil/chemical tanker (Type B). The main characteristics of selected ships representatives are shown in table 1.

Table 1: A main characteristics of ships' representatives

Main characteristics	Ship type	
	Chemical tanker (Type A)	Oil / Chemical tanker (Type B)
Length overall, LOA (m)	168,00	182,50
Length between perpendiculars, LPP (m)	160,80	174,80
Breadth, B (m)	26,40	32,20
Depth, moulded to upper deck, H (m)	13,80	17,50
Design draught, D (m)	9,02	12,20
Deadweight, (dwt)	23 400	47 300

2.1 Production at Panel Subassemblies

The analysis of panel subassemblies production is conducted for two selected ships types. The analysis has taken into account only simple panel subassemblies, excluding corrugated bulkheads and curved hull subassemblies. An example of automated welding line is shown on figure 1.

As it is shown in table 2, analysis of panel subassemblies production has resulted with following information:

- Lengths of fillet welds (m),
- Lengths of butt welds (m),
- Number of panel subassemblies prepared for later ship hull construction,
- Number of elements (plates and profiles) in subassemblies,
- Mass of subassemblies.

In order to determine the maximum load capacity and the needed capacity of automated welding lines, the analysis of the needed capacity in the most loaded period of the year is conducted. In doing so, two basic scenarios are analyzed, namely:

- Scenario 1 – Same sections of both ships are produced at a same time,

- Scenario 2 - A mid-ship section of one ship and the engine section of the other ship are produced at a same time.

Figure 1: Automated welding line

Table 2: Analysis of Type A and Type B ships at a panel subassemblies production

	Group	Length of fillet welds, m	Length of butt welds, m	No. of subass.	Number of elements		Total			
					Completed panels ass. (no. of plates and profiles)	Other (no. of plates and profiles)	Mass, kg	No. of plates	No. of profiles	No. of elements
Type A	Stern	1114	179	116	18	487	68317	165	340	505
	Engine room	1648	86	251	242	753	123331	416	579	995
	Cargo tanks	27677	1132	2287	2692	7826	1462185	2682	7836	10518
	Bow	1661	33	303	84	675	63612	320	0	759
	Superstructure	3649	276	337	0	1144	123551	368	776	1144
Total for Type A		35749	1706	3294	3036	10885	1840996	3951	9531	13921
Type B	Stern	1070	94	150	66	387	48667	162	291	453
	Engine room	4083	148	666	493	1404	177229	723	1174	1897
	Cargo tanks	15116	257	1772	4672	2446	908539	1817	5301	7118
	Bow	2885	50	417	246	984	117832	439	791	1230
	Superstructure	7697	194	722	0	2397	209442	767	1630	2397
Total for Type B		30851	743	3727	5477	7618	1461709	3908	9187	13095
3 × Type A		107247	5118	9882	9108	32655	5522988	11853	28593	41763
2 × Type B		61702	1486	7454	10954	15236	2923418	7816	18372	26190
Total for five ships		168949	6604	17336	20062	47891	8446406	19669	46965	67953

Results of scenarios analysis are shown in table 3 and table 4. Comparing these two scenarios it can be concluded that the demand for fillet weld is some 7 % higher in Scenario 2. At the same time, the demand for butt welds is 27 % higher in Scenario 2, but total demand for butt welds is negligible in comparison to fillet weld demand.

Table 3: Analysis of weld lengths for scenario 1

	Length of fillet welds, m	Length of butt welds, m	Total length of welds, m
Total for Type A	4269	82	4351
Total for Type B	8749	261	9010
Total for Scenario 1	13018	343	13361

Table 4: Analysis of weld lengths for scenario 2

	Length of fillet welds, m	Length of butt welds, m	Total length of welds, m
Total for Type A	13938	437	14375
Total for Type B	-	-	-
Total for Scenario 2	13938	437	14375

2.2 Production at Panel Assemblies

Panel assemblies' production analysis has had an aim to obtain information about:

- Number of panel assemblies produced yearly,
- Masses of panel assemblies.

The analysis of number of panel assemblies' yearly production is shown in table 5, while results of the analysis of weld lengths for two production scenarios are shown on table 6 and table 7.

Table 5: Analysis of Type A and Type B ships at panel assemblies production lines

Group	Type A					**Total for Type A**	Type B					**Total for Type B**	**3 × Type A**	**2 × Type B**	**Total for five ships**
	Stern	Engine room	Cargo tanks	Bow	Superstructure		Stern	Engine room	Cargo tanks	Bow	Superstructure				
Number of panels	6	34	122	10	0	**172**	2	34	103	10	0	**149**	**516**	**298**	**814**

Table 6: Analysis of weld lengths for scenario 1

	Length of fillet welds, m	Length of butt welds, m	Total length of welds, m
Total for Type A	6009	829,5	6838,5
Total for Type B	4890	858,5	5748,5
Total for Scenario 1	10899	1688	12587

Table 7: Analysis of weld lengths for scenario 2

	Length of fillet welds, m	Length of butt welds, m	Total length of welds, m
Total for Type A	5412	1272	6684
Total for Type B	-	-	-
Total for Scenario 2	5412	1272	6684

In the case of panel assemblies, the demand for fillet welds is much higher for Scenario 1, some 50 % higher. Also, demand for butt welds is 33 % higher for Scenario 1.

2.3 Production of Completed Panel Assemblies

Analysis of the production of completed panel assemblies had provided information about:

- Number of completed panel assemblies produced yearly,
- Masses of completed panel assemblies,
- Lengths of butt and filet welds.

The analysis of number of completed panel assemblies production per year is shown in table 8, while results of the analysis of weld lengths for two production scenarios are shown on table 9 and table 10.

Table 8: Analysis of Type A and Type B ships at completed panels

Group	Type A					**Total for Type A**	Type B					**Total for Type B**	**3 × Type A**	**2 × Type B**	**Total for five ships**
	Stern	Engine room	Cargo tanks	Bow	Superstructure		Stern	Engine room	Cargo tanks	Bow	Superstructure				
Number of panels	6	29	84	10	0	**129**	2	32	65	6	0	**105**	**387**	**210**	**597**

Table 9: Analysis of weld lengths for Scenario 1

	Length of fillet welds, m	Length of butt welds, m	Total length of welds, m
Total for Type A	2627,6	36,7	2664,3
Total for Type B	5173,3	204,8	5378,1
Total for Scenario 1	7800,9	241,5	8042,4

Table 10: Analysis of weld lengths for Scenario 2

	Length of fillet welds, m	Length of butt welds, m	Total length of welds, m
Total for Type A	8597,9	410	9007,9
Total for Type B	-	-	-
Total for Scenario 2	8597,9	410	9007,9

Length of fillet welds, in the case of completed panel assemblies is 10 % greater in Scenario 2. The length of butt welds is again negligible.

2.4 Capacity of Installed Automated Welding Equipment

The analysis of ship hull for ships representatives provides the number of produced panel subassemblies, assemblies and completed assemblies. The data about equipment capacity, in terms of lengths of butt and filler welds, as well as, the number of panel subassemblies, assemblies and completed assemblies, that are welding equipment capable to produce within one month period, are extracted from the technical documentation of the automated welding equipment installed within selected shipyard. Comparing these data with, previously calculated, data for Scenario 1 and Scenario 2, showed that installed automated welding equipment have sufficient capacity and that, at the moment, there are no bottlenecks in the production process.

The comparison of the installed capacity and the demand is shown on table 11.

Table 11: Analysis of capacity for selected shipyard

	Installed capacity for selected shipyard		Required capacity for selected production program			
			Scenario 1		Scenario 2	
	Fillet welds capacity, m	Butt welds capacity, m	Fillet welds requirement, m	Butt welds requirement, m	Fillet welds requirement, m	Butt welds requirement, m
Micro panels (panel subassemblies)	20812	0	13018	343	13938	437
Panel line (panel assemblies)	38016	4752	10899	1688	5412	1275
Completed panel assemblies	8600	0	7800,9	241,5	8597,9	410

3. PROCESS IMPROVEMENT

Although installed welding capacity satisfies current demand, it can be seen that an increase in the production volume will in short time create a lack of capacity, firstly at completed panel assemblies' production. Therefore, it is necessary to research a possible ways of capacity increase. Off course, it can be achieved by investing in technology [2]. For example, at subassembly panel production line a high efficiency arc welding process, such is TIME TWIN process, can be installed. Further technological improvement can be in a form of additional robot at the robot micro panel line. At the completed panel assemblies the capacity can be increased by installing robot welding. All mentioned solutions for improvement demands usually considerable investments, and should be considered for implementation when all other, less resource demanding, solutions are exploited.

Bellow will be considered ways of improvement and getting maximum of existing welding equipment through two well know improvement methodologies. The one is Theory of Constraints (TOC) and the other is Lean Manufacturing.

3.1 The Theory of Constraints

Theory of Constraints is based on the premise that the rate of goal achievement is limited by at least one constraining process. Only by increasing flow through the constraint can overall throughput be increased [3, 4].

A constraint is anything that prevents the system from achieving more of its goal. By definition, there are three main types of internal constraints: Equipment, People and Policy.

Assuming that automated welding lines are constraining process in a ship hull preassemblies and assemblies production, and deciding that people and policy, as possible constraints within process, will not be taken into account at the time, the task is to find ways how to make most of installed welding equipment.

The steps that should be followed in TOC methodology application to selected production process are [5]:

Identify the constraint. If the improvement of automated welding lines is in focus, based on the TOC principles, the resource that prevents the shipyard to gain more of its goal are automated welding lines/station it selves.

Decide how to exploit the constraint. In order to get the most capacity out of the constrained processes or equipment, the processes have to be available most of the time. Thus, the process availability has to be assessed and identified tasks that have priority in achieving as higher availability as possible. That certainly involves efficient maintenance. Next thing that has to be put in practice is to process only products that are of acceptable quality. Any product that is of unacceptable quality must be filtered out before they reach the constrained equipment. So, the process quality control has to be stressed out and, if needed, reorganized, embedded in process and made more efficient. The constrained equipment must not wait for other processes. It should be the process/station that is waited for.

Subordinate all other processes to above decision. To put the constrained equipment to work at its maximum, all other connected processes have to subordinate to needs of constrained equipment. That usually means that reorganization of processes, priorities, buffers and other connected resources must take place.

Elevate the constraint (make other major changes needed to break the constraint). In case the constrained welding equipment still prevents achieving desirable throughput, some significant technological changes (investment) in process or equipment should be considered. This can, for example, involves outsourcing part of production, or investing into hardware to raise equipment capacity.

3.2 Lean Manufacturing

As well as TOC, Lean Manufacturing is also based on several main principles which have to be followed, more or less strictly, to gain benefits from efforts puts into process improvement.

The Lean Manufacturing involves five main steps in implementation. Although these five steps are quite strait forward, they encompass main Lean principles and it is not always easy to achieve it [6,7]. At the beginning of most Lean journeys is housekeeping, introduced and accomplished by application of 5S method. By thorough sorting, setting in order and cleaning, which are first three "S" from 5S method, the problems that used to be hidden by sloppy messes are revealed [8].

The five-step process:

Specify value from the standpoint of the end customer. The customer is willing only to pay for the product he/she order. In contest of construction of ship hull, and simplified, the customer is willing to pay for welded joint of acceptable quality. Of course, only those welded joints that are necessary to keep ship construction elements together. No more and no less.

Identify all the steps in the value stream, eliminating whenever possible those steps that do not create value. Value Stream Mapping is a flow of inventory or "the thing” being processed, and flow of the information needed to process it. Each value stream map is primarily focused on the flow of the thing being processed. The welding process is consisting of several activities that are carried out to produce welded assembly. Only few of them are value added activities. All other activities, non value added activities, should be considered as waste, and an effort should be put in to remove or minimize those activities.

Make the value-creating steps occur in tight sequence so the product will flow smoothly toward the customer. At this point also Six Sigma methodology becomes interesting because it is necessary to have high quality to make small batches or, even, single piece flow, and to produce just in time only what the customer demands.

As flow is introduced, let customers pull value from the next upstream activity. It should be kept on mind that the goal is not to maximize output but to maximize throughput or goods purchased by a customer.

As value is specified, value streams are identified, wasted steps are removed, and flow and pull are introduced, begin the process again and continue it until a state of perfection is reached in which perfect value is created with no waste. By definition, continuous improvement is continuous [9]. A lean journey always has a next step and never has an end.

4. CONCLUSION

Efficiency of a contemporary commercial ships production greatly depends of efficiency of welding. Although welding as a process is present in almost all phases of ship production, probably the most of it, take its place in welding of ship hull assemblies. To produce welds of acceptable quality, in quantity and time defined by succeeding processes, automation of welding is, probably, today only solutions. Although automated welding systems are technologically sophisticated system, investments in which are usually considerable, they also have its shortcomings, mainly in flexibility. They are designed, selected and installed in process with clearly defined production goals. To change their application area, both in product range or quantity usually means more investment and technological change on equipment. Before go for that option all other "organizational option" have to be explored. To be able to do that, the needed welding capacity has to be known in all stages of ship hull production. The current, and even future, production range has to be known. The types and quantities of welding joint have to be analysed. Based on such analysis, suitability of installed equipment can be assessed and exploited up to its maximum before an investment in new technology take place. To do so, there are several modern improvement methods, two of them are Theory of Constraints and Lean Manufacturing. By applying main principles of these methods many advantages can be expected, such as decrease of production costs of subassemblies and assemblies, increase in automated welding lines throughput, quality improvement, improvement of process manageability and better working environment.

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