2nd International Conference Eco-Innovation in Science, Engineering, and Technology
Volume 2021
http://dx.doi.org/10.11594/nstp.2021.1436

NST PROCEEDINGS

OPEN ACCESS

Conference Paper

Optimal Pressure Vessel Project Schedule Planning with Critical Path Method (CPM) at PT. XYZ

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ABSTRACT

Project scheduling is one element of planning that provides various information for time efficiency to complete a project. The success of a project starts from the planning and preparation of the correct and systematic stages. Every company must try to complete the work on time as scheduled to avoid various losses that arise. This research aims to determine the activities that are classified as critical in the production of pressure vessels belonging to one of the leading companies in Indonesia engaged in natural gas processing, which PT is carrying out. XYZ. This study also compares the costs incurred to complete the pressure vessel project with a normal and accelerated duration of work. The method used is the Critical Path Method (CPM) and Microsoft Project software. CPM is a network analysis that aims to optimize the total project cost by reducing completion time. The use of the CPM method can save time in completing various stages of a project. The initial project duration is 952 working hours or 119 working days. It can be accelerated to 884 working hours or 111.25 working days, 7.75 days faster than the initial schedule. There are 24 critical activities, and the labor cost that must be spent is IDR 72,034,400.00 under normal conditions, while the labor cost that must be spent for the acceleration condition is IDR 76,626,400.00.

Keywords: Scheduling, CPM, Microsoft project

Introduction

According to Baits et al. (2020), scheduling is allocating existing resources or machines to carry out a set of tasks within a certain period. Meanwhile, according to Parekh et al. (2020), scheduling is a plan for setting the work sequence and allocating resources, time, and facilities for each operation that must be completed. So that it can be concluded, project scheduling is an activity to determine the period of project activities that must be completed, labor, and the time required by each activity. The purpose of project scheduling is to avoid the risk of delays in completing work (Alavipour & Arditi, 2018). Many cases of delays in completing work are caused by the concept of a project schedule that is less structured so that work activities are less effective and efficient. Planning activities in the fabrication process is a very important problem because it is the basis for fabrication activities to be completed in an optimal time.

PT XYZ is a state-owned company having its address at Jl. Imam Bonjol, Panggungrejo, Pasuruan City, East Java. Engaged in the production of industrial machinery and equipment with a production capacity of 300 tons/month. One of the superior products produced by PT XYZ is a pressure vessel. Pressure vessels are closed containers designed to accommodate liquids or gases

How to cite:
Ngatilah, Y., Pujiastuti, C., Nugraha, I., & Arifin, D. Q. (2021). Optimal pressure vessel project schedule planning with Critical Path Method (CPM) at PT. XYZ. *2nd International Conference Eco-Innovation in Science, Engineering, and Technology*. NST Proceedings. pages 226-235. doi: 10.11594/ nstp.2021.1436

at different temperatures from the ambient temperature. Pressure vessels are used for various applications in various industrial sectors such as the chemical industry (petrochemical plant), energy (power plant), oil and gas, nuclear, food, even household appliances such as water heating boilers or pressure cookers. This research focuses on the manufacture of a pressure vessel currently running at PT XYZ, which was ordered by a well-known company in Indonesia engaged in natural gas processing. The problem currently being faced is that the project end date that the company has scheduled is very close to the deadline agreed upon by the customer. So there is a big risk of delays, which lead to the payment of fines by the company to the customer. Through this research, researchers will try to improve the project schedule by reducing the duration of the pressure vessel project using the Critical Path Method (CPM) (Bintang et al., 2019), with the help of Microsoft Project software as support. According to Kasimoğlu and Akgün (2021), the Critical Path Method (CPM), a method for planning and monitoring projects, is the most widely used system among all other systems that use the principle of network formation. With CPM, the amount of time required to complete the various stages of a project is considered to be known with certainty (Kusumadarma et al., 2020), as is the relationship between the resources used and the time required to complete the project. From the data processing results using the Critical Path Method (CPM), it will be known which activities should be accelerated so that the project can be completed earlier while still paying attention to cost optimization (Sharma & Gupta, 2018).

Material and Methods

The research method starts from field study activities that aim to discover the company's problems. After knowing the problems that occurred, a direct visit to the work site was carried out to collect the data needed in the study. After that, a literature study was carried out in solving the problems to be discussed. Next is the formulation of the problem. This is done so that the research is more focused so that problem solving can be carried out properly. The formulation of the problem that has been made is then used as a reference to determine the objectives of the research and the benefits of the research carried out both for the author, the company, and the interests of further research. Data collection (both primary and secondary data) is carried out directly. The data needed is activity data and the duration of making pressure vessel products, a total of 84 activities that will be simplified to 39 activities without changing the total duration of the project. This simplification is only needed for ease of calculation during data processing using CPM. The initial data that has been collected is then made a network diagram to determine the duration of the project and also critical activities in the pressure vessel project (Francik et al., 2018). After making the network diagram, the next step is making a schedule using Microsoft Project, the use of this software aims to make the schedule can be done quickly, easily, and accurately. The calculation of the critical path is carried out using forward and backward calculations, activities classified as critical activities are activities with a total float of zero. It is this critical activity that must be shortened by the duration of the activity so that the project duration can be accelerated (Kholil et al., 2018).

Result and Discussion

The stage carried out in this research is data collection. The data used is the pressure vessel manufacturing process activity, a total of 84 activities which will later be simplified to 39 activities without changing the total duration of the project. This simplification is only needed for ease of calculation during data processing. These data are summarized in table 1.

Table 1. Description of activities and duration of normal activities

No	Task Name	Activity	Predecessors	Duration (Hours)	No	Task Name	Activity	Predecessors	Duration (Hours)
1	Placing Order	A	-	0	21	Manhole Forming	U	T	80
2	General Arrangemant Drawing	B	A	80	22	Marking Leg	V	T	8
3	Bill of Quantity	C	B	80	23	Cutting Leg	W	V	8
4	Re-check Material	D	C	80	24	Leg Fulfillment	X	W	48
5	Purchase Requisition	E	D	16	25	Internal & Eksternal Fabrication	Y	W	96
6	Purchase Order	F	E	80	26	Assy Top Head to Shell, DT	Z	K, M	32
7	Main Material	G	F	160	27	Cutting Nozzle Orentation	AA	Z	16
8	Supporting Material	H	F	256	28	Nozzle Instalation 2	AB	R, U, AA	80
9	Marking	I	G	8	29	Assy Bottom to Shell, DT	AC	P, AB	40
10	Cutting	J	I	8	30	Assy Welding External, Internal	AD	Y, AC	16
11	Shell Forming	K	J	88	31	Assy Leg to Shell	AE	X, AD	32
12	Head Fabrication	L	J	48	32	Final Inspection	AF	AE	8
13	Cutting & Beveling	M	L	8	33	Hydro Test	AG	AF	24
14	Remove Temporary head, NDE	N	M	16	34	Sandblasting Painting Primer	AH	AG	8
15	Making Hole	O	N	16	35	Assy Internal Dimester	AI	AH	16
16	Nozzle Installation 1	P	H, O, R	56	36	Pickling	AJ	AI	16
17	Marking Nozzle	Q	J	8	37	Painting Finishing	AK	AJ	16
18	Nozzle Fabrication	R	Q	80	38	Packing & Handling	AL	AK	8
19	Marking Manhole	S	Q	8	39	Transport at Site	AM	AL	40
20	Cutting Manhole	T	S	8					

The description of these activities is obtained from the company, where the times for each activity have been determined. The description of the activities above is a description of the activities in the initial conditions or normal conditions

Network diagram

A network diagram is a project visualization based on network planning (Permana & Kholil, 2016). After the relationship of each activity and duration is known, the next step can be continued to draw a CPM diagram.

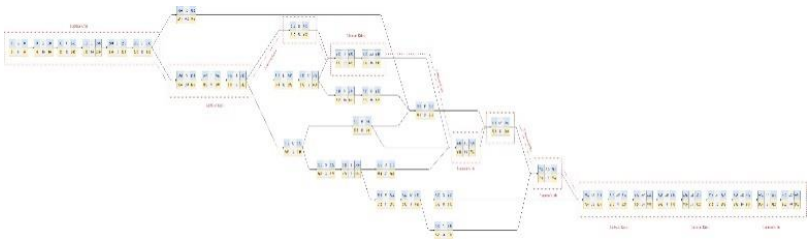

Figure 1. Network diagram

Float and critical path

Total Float (TF) and Free Float (FF) are calculated based on EET and LET obtained from network calculations, while Interferent Float (IF) is calculated based on the difference between TF and FF so that the critical path of the network can be known (Siregar & Iffiginia, 2019):

Table 2. Float and critical path

Activity	ES	EF	LS	LF	F	FF	IF	Critical Path	Activity	ES	EF	LS	LF	F	FF	IF	Critical Path
A	0	0	0	0	0	0	0	Yes	U	536	616	584	664	48	0	48	No
B	0	80	0	80	0	0	0	Yes	V	536	544	672	680	136	0	136	No
C	80	160	80	160	0	0	0	Yes	W	544	552	680	688	136	0	136	No
D	160	240	160	240	0	0	0	Yes	X	552	600	752	800	200	0	200	No
E	240	256	240	256	0	0	0	Yes	Y	552	648	688	784	136	0	136	No
F	256	336	256	336	0	0	0	Yes	Z	600	632	600	632	0	0	0	Yes
G	336	496	336	496	0	0	0	Yes	AA	632	648	632	648	0	0	0	Yes
H	336	592	432	688	96	0	96	No	AB	648	728	648	728	0	0	0	Yes
I	496	504	496	504	0	0	0	Yes	AC	728	768	728	768	0	0	0	Yes
J	504	512	504	512	0	0	0	Yes	AD	768	784	768	784	0	0	0	Yes
K	512	600	512	600	0	0	0	Yes	AE	784	816	784	816	0	0	0	Yes
L	512	560	544	592	32	0	32	No	AF	816	824	816	824	0	0	0	Yes
M	560	568	592	600	32	0	32	No	AG	824	848	824	848	0	0	0	Yes
N	568	584	656	672	88	0	88	No	AH	848	856	848	856	0	0	0	Yes
O	584	600	672	688	88	0	88	No	AI	856	872	856	872	0	0	0	Yes
P	600	656	688	744	88	0	88	No	AJ	872	888	872	888	0	0	0	Yes
Q	512	520	560	568	48	0	48	No	AK	888	904	888	904	0	0	0	Yes
R	520	600	584	664	64	0	64	No	AL	904	912	904	912	0	0	0	Yes
S	520	528	568	576	48	0	48	No	AM	912	952	912	952	0	0	0	Yes
T	528	536	576	584	48	0	48	No									

Calculating Total Float, Free Float, Independent Float, and Critical Path for each activity (Sutanto, 2017):

Total Float = Late Finish – Early Start – Duration

Free Float = Early Finish – Early Start – Duration

Independent Float = ES (next activity) – LF (previous activity) – Duration

The Critical Path is a path that passes through activities where Total Float = Free Float = Independent Float = 0, meaning the path where each activity has no free time, either total float, free float, or independent float. The critical path obtained from the calculations in Table 2 is the path of the A-B-C-D-E-F-G-I-J-K-Z-AA-AB-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM activity with a total time required of 952 working hours or 119 working days.

Project schedule under normal conditions

The project schedule is created using Microsoft Project as a reference for project process control.

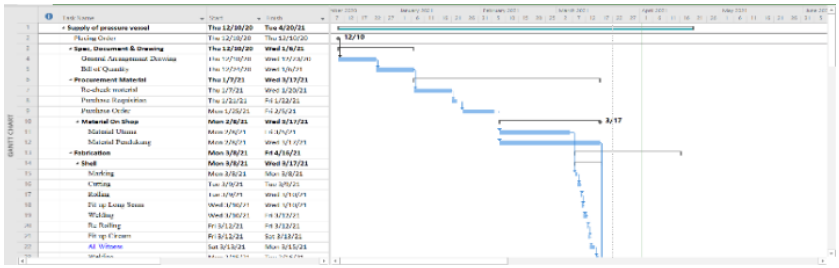

Figure 2. Pressure vessel project schedule (Part 1)

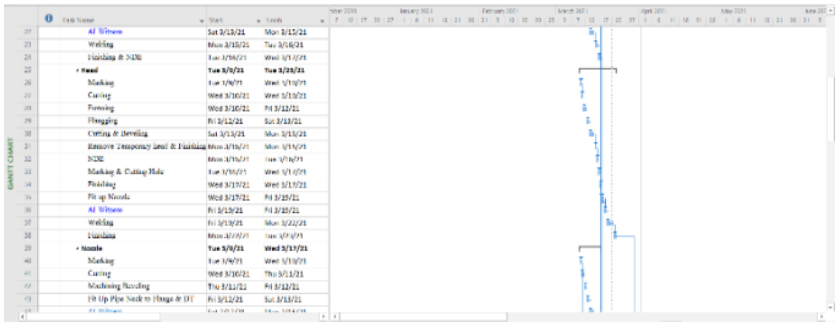

Figure 3. Pressure vessel project schedule (Part 2)

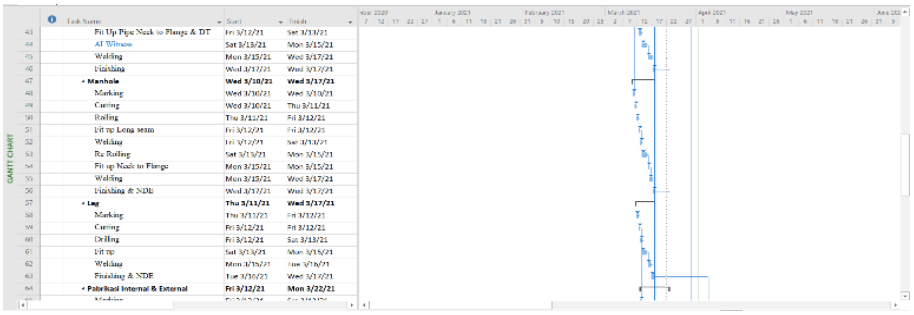

Figure 4. Pressure vessel project schedule (Part 3)

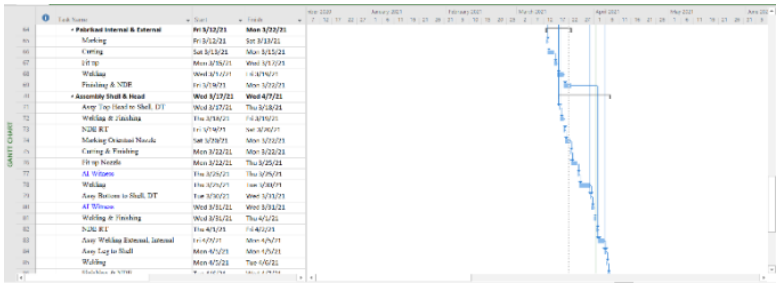

Figure 5. Pressure vessel project schedule (Part 4)

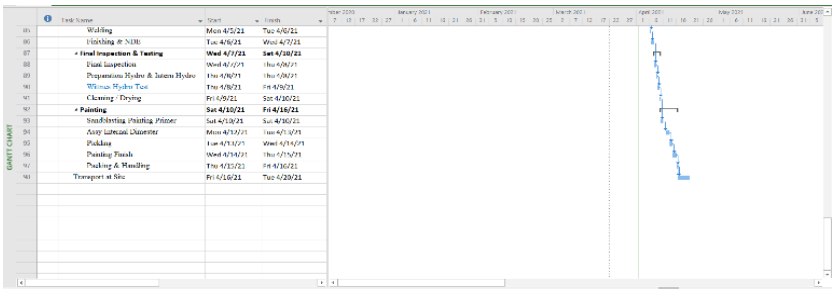

Figure 6. Pressure vessel project schedule (Part 5)

Table 3. Description of acceleration activities

No	Task Name		Normal Duration (Hours)	Acceleration Duration (Hours)	No	Task Name		Normal Duration (Hours)	Acceleration Duration (Hours)
1	Placing Order		0		41		Rolling	8	
	Spec, Document & Drawing				42		Fit Up Long seam	8	
2		General Arrangemant Drawing	80		43	Manhole Forming	Welding	8	
3		Bill of Quantity	80		44		Re Rolling	8	
	Procurement Material				45		Fit Up Neck to Flange	8	
4		Re-check Material	80	56	46		Welding	16	
5		Purchase Requisition	16	12	47		Finishing & NDE	8	
6		Purchase Order	80	56		Leg			
	Material on Shop				48		Marking	8	
7		Main Material	160		49		Cutting	8	
8		Supporting Material	256		50		Drilling	8	
	Fabrication Shell				51	Leg Fulfillment	Fit up	8	
9		Marking	8		52		Welding	16	
10		Cutting	8		53		Finishing & NDE	16	
11		Rolling	8			Pabrikasi Internal & Eksternal			
12		Fit Up long Seam	8		54		Marking	8	
13		Welding	16		55	Internal & Eksternal Fabrication	Cutting	16	
14		Re Rolling	8		56		Fit Up	16	
15	Shell Forming	Fit up Circum	8		57		Welding	32	
16		Witness	8		58		Finishing & NDE	24	
17		Welding	16	8		Assembly Shell & Head			
18		Finishing & NDE	16	8	59	Assy Top Head to Shell, DT	Assy Top Head to Shell, DT	8	
	Head				60		Welding & Finishing	16	
19		Marking	8		61		NDE RT	8	
20	Head Fabrication	Cutting	8		62	Cutting Nozzle Orientation	Marking Orientasi Nozzle	8	
21		Forming	16		63		Cutting & Finishing	8	
22		Flangging	16		64	Nozzle Installation	Fit Up Nozzle	32	
23		Cutting & Beveling	8		65		Witness	8	
24	Remove Temporary Head, NDE	Remove Temporary head & Finishing	8		66		Welding	40	
25		NDE	8		67	Assy Bottom to Shell, DT	Assy Bottom to Shell, DT	8	
26	Marking Hole	Marking & Cutting Hole	8		68		Witness	8	
27		Finishing	8		69		Welding & Finishing	16	
28		Fit up Nozzle	16		70		NDE RT	8	
29	Nozzle Intallation	Witness	8		71		Assy Welding External, Internal	16	
30		Welding	16		72	Assy Leg to Shell	Assy Leg to Shell	8	
31		Finishing	16		73		Welding	8	
	Nozzle				74		Finishing & NDE	16	
32		Marking	8			Finishing Inspection & Testing			
33		Cutting	16		75		Final Inspection	8	
34		Machining Beveling	8		76		Preparation Hydro & Intern Hydro	8	
35	Nozzle Fabrication	Fit Up Pipe Neck to Flange & DT	16		77	Hydro Test	Wittness Hydro Test	8	
36		Witness	8		78		Cleaning / Drying	8	
37		Welding	24			Painting			
38		Finishing	8		79		Sandblasting Painting Primer	8	
	Manhole				80		Assy Internal Dimester	16	
39		Marking	8		81		Pickling	16	
40		Cutting	8		82		Painting Finish	16	
					83		Packing & Handling	8	
					84		Transport at Site	40	

The description of these activities is obtained by applying overtime in preparation activities, where overtime is a maximum of 4 hours in 1 working day and a maximum of 18 hours in 1 workweek. In addition to applying overtime for the preparation section, additional workers are also carried out. By employing 3 daily workers consisting of 2 helpers and 1 welder. The description of the activities above is a description of the activities in acceleration conditions.

Project schedule under accelerated conditions

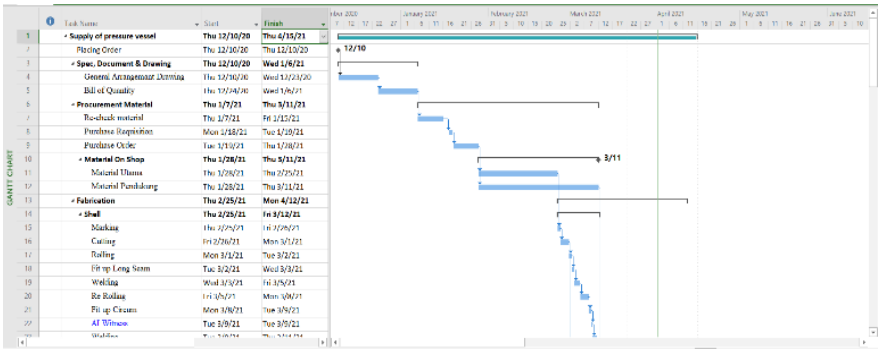

Figure 7. Accelerated Pressure Vessel Project Schedule (Part 1)

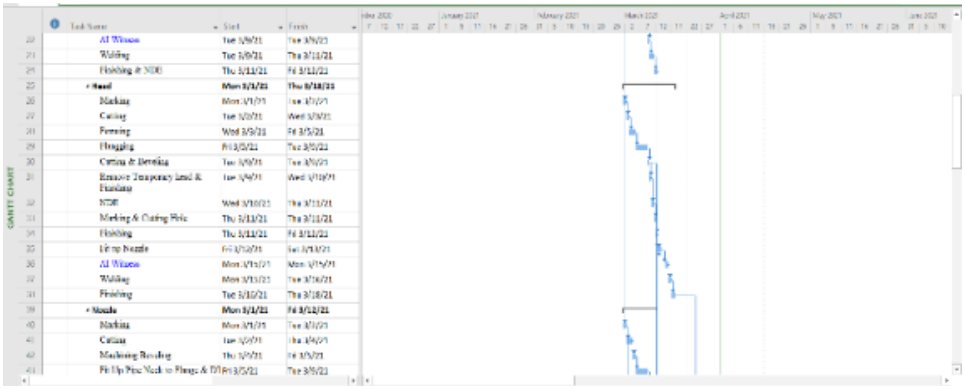

Figure 8. Accelerated Pressure Vessel Project Schedule (Part 3)

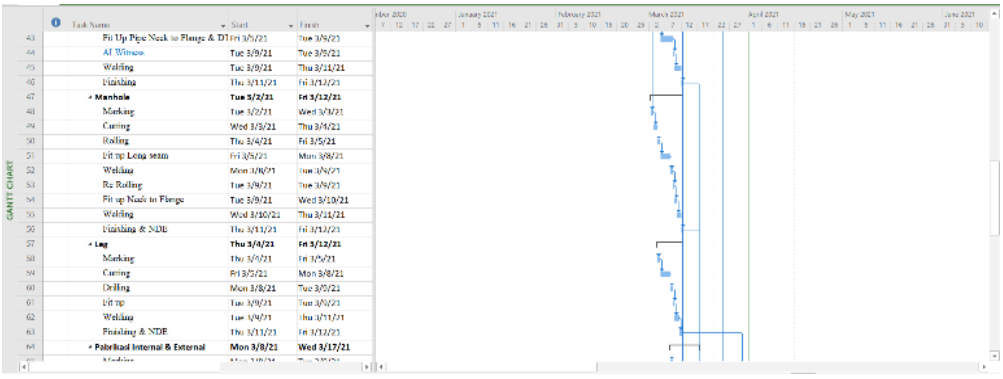

Figure 9. Accelerated Pressure Vessel Project Schedule (Part 3)

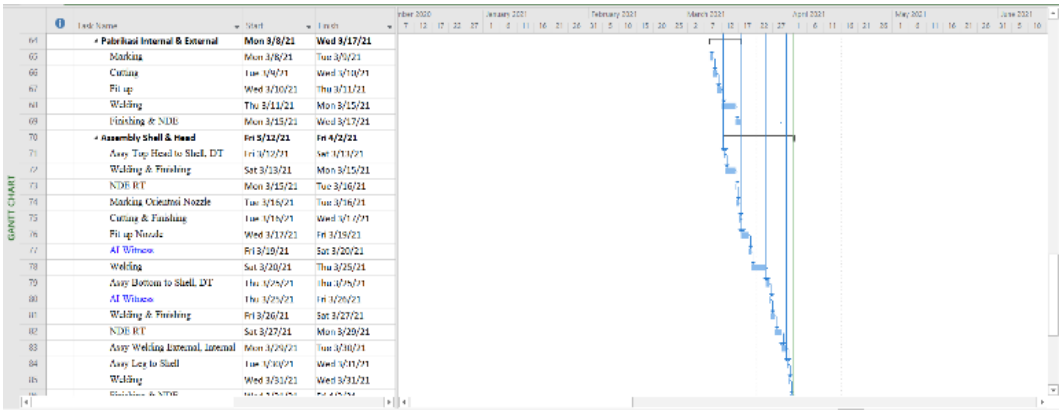

Figure 10. Accelerated Pressure Vessel Project Schedule (Part 4)

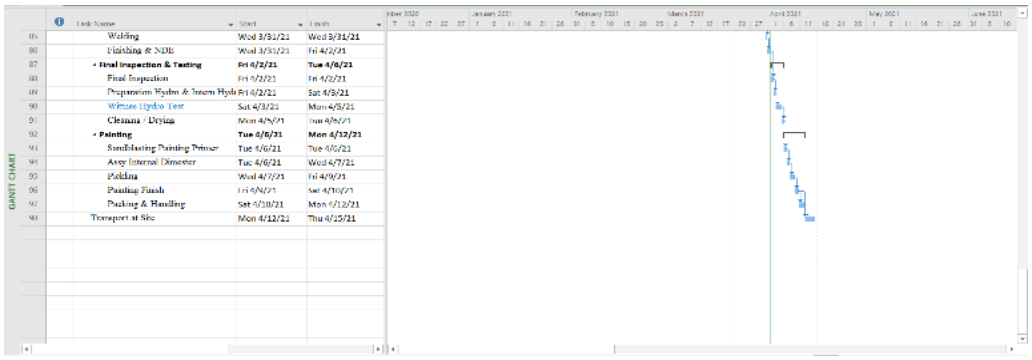

Figure 11. Accelerated Pressure Vessel Project Schedule (Part 5)

Determine labor cost

Calculation of labor costs incurred in the Pressure Vessel project is obtained from the project schedule created using Microsoft Project. Calculation of working hours is obtained by entering personnel data into the resource sheet, then from the resource sheet data, 233 tis determined the assignment of each resource to each task that has been previously determined in the Gantt Table 4.

Table 4. Labor cost (Normal condition)

Resource Name	Quantity	Total Working Hours	Price/ Working Hours	Total Price	Resource Name	Quantity	Total Working Hours	Price/ Working Hours	Total Price
Project Officer	1	192	IDR 29,200	IDR 5,606,400	Welder 4	1	88	IDR 22,500	IDR 1,980,000
Engineering	2	168	IDR 26,000	IDR 8,736,000	Fitter 1	1	64	IDR 23,500	IDR 1,504,000
PPC	3	176	IDR 26,000	IDR13,728,000	Fitter 2	1	56	IDR 23,500	IDR 1,316,000
Quality Control	3	144	IDR 27,000	IDR11,664,000	Fitter 3	1	56	IDR 23,500	IDR 1,316,000
Marker	1	64	IDR 23,500	IDR 1,504,000	Helper 1	1	136	IDR 20,000	IDR 2,720,000

To be continued...

Cutting Machine Operator	1	80	IDR 23,500	IDR 1,880,000	Helper 2	1	136	IDR 20,000	IDR 2,720,000
Rolling Machine Operator	1	80	IDR 23,500	IDR 1,880,000	Helper 3	1	136	IDR 20,000	IDR 2,720,000
Flangging Machine Operator	1	32	IDR 23,500	IDR 752,000	Helper 4	1	136	IDR 20,000	IDR 2,720,000
Forming Machine Operator	1	16	IDR 23,500	IDR 376,000	Blaster	3	8	IDR 20,000	IDR 480,000
Beveling Machine Operator	1	16	IDR 23,500	IDR 376,000	Pickler	2	16	IDR 20,000	IDR 640,000
Drilling Machine Operator	1	16	IDR 23,500	IDR 376,000	Painter	2	16	IDR 20,000	IDR 640,000
Welder 1	1	88	IDR 22,500	IDR 1,980,000	Packer	4	8	IDR 20,000	IDR 640,000
Welder 2	1	80	IDR 22,500	IDR 1,800,000	Total	38		Total	IDR72,034,400
Welder 3	1	88	IDR 22,500	IDR 1,980,000					

From the table, it can be seen the resources and the quantity involved in the project, the total hours worked, overtime hours, and the price/hours worked for each resource. The labor cost if it is carried out with normal duration (without acceleration) is IDR 72,034,400.

Table 5. Labor costs (Acceleration conditions)

Resource Name	Quantity	Total Normal Working Hours	Price/ Working Hours	Total Overtime Hours	Total price	Resource Name	Quantity	Total Normal Working Hours	Price/ Working Hours	Total Overtime Hours	Total price
Project Officer	1	192	IDR 29,200		IDR 5,606,400	Welder 4	1	88	IDR 22,500		IDR 1,980,000
Engineering	2	168	IDR 26,000		IDR 8,736,000	Fitter 1	1	64	IDR 23,500		IDR 1,504,000
PPC	3	176	IDR 26,000	52	IDR 17,784,000	Fitter 2	1	56	IDR 23,500		IDR 1,316,000
Quality Control	3	144	IDR 27,000		IDR 11,664,000	Fitter 3	1	56	IDR 23,500		IDR 1,316,000
Marker	1	64	IDR 23,500		IDR 1,504,000	Helper 1	1	136	IDR 20,000		IDR 2,720,000
Cutting Machine Operator	1	80	IDR 23,500		IDR 1,880,000	Helper 2	1	136	IDR 20,000		IDR 2,720,000
Rolling Machine Operator	1	80	IDR 23,500		IDR 1,880,000	Helper 3	1	136	IDR 20,000		IDR 2,720,000
Flangging Machine Operator	1	32	IDR 23,500		IDR 752,000	Helper 4	1	136	IDR 20,000		IDR 2,720,000
Forming Machine Operator	1	16	IDR 23,500		IDR 376,000	Blaster	3	8	IDR 20,000		IDR 480,000
Beveling Machine Operator	1	16	IDR 23,500		IDR 376,000	Pickler	2	16	IDR 20,000		IDR 640,000
Drilling Machine Operator	1	16	IDR 23,500		IDR 376,000	Painter	2	16	IDR 20,000		IDR 640,000
Welder 1	1	88	IDR 22,500		IDR 1,980,000	Packer	4	8	IDR 20,000		IDR 640,000
Welder 2	1	80	IDR 22,500		IDR 1,800,000	Daily Welder	1	8	IDR, 24,000		IDR 192,000
Welder 3	1	88	IDR 22,500		IDR 1,980,000	Daily Helper	2	8	IDR 21,500		IDR 344,000
						Total	41		Total		IDR76,626,400

From the table, it can be seen the resources and the quantity involved in the project, the total hours worked, overtime hours, and the price/hours worked for each resource. The labor cost if accelerated is IDR 76,626,400. By providing overtime wages for workers from the PPC division and employing 3 daily workers, namely: 1 welder, and 2 helpers.

Conclusion

From the results of data processing using the Critical Path Method (CPM), it can be concluded that the critical path is determined by calculating TF, FF, and IF, based on EET and LET in network planning are activities A-B-C-D-E-F-G-I-J-K-Z-AA-AB-AC-AD-AE-AF-AG-AH-AI-AJ-AK-AL-AM. Thus, a more optimal Pressure Vessel project schedule was made by reducing the time for several activities to accelerate the project. So that the initial project duration is 952 working hours or 119 working days, it can be accelerated to 884 working hours or 111.25 working days, 7.75 days faster than the initial schedule. Accelerating the duration of the project will require more costs compared to working on projects of normal duration. The labor cost (a total of 38 workers) from the pressure vessel project for normal conditions is IDR 72,034,400, while the labor costs incurred for acceleration conditions are IDR 76,626,400. If the company is late in completing the project, the fine that must be paid is 1% of the project value, where the project value is obtained from the total result of the contract value of IDR 952,094,000 with VAT of IDR 95,209,400. If the project value is known to be IDR 1,047,303,000, the amount of the late fine is IDR 10,473,034. Thus, the additional cost of IDR 4,592,000 to reduce the duration of the completion of this project is considered more optimal when compared to the number of fines written in the contract and agreed upon by both parties.

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