Computer Aided Process Planning For Sheet Metal Bending And Its Simulation Using Arena 10.0

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Abstract

Numerous manufacturing industries are under significant pressure to produce high quality, low cost products that can compete in the world marketplace. Sheet metal products are widely used in various industries nowadays. Process planning for bent parts consists of closely related tasks, such as unfolding generation, operation parameters and tool selection, bend sequencing and tolerance verification. The interrelation between tool selection and bend sequencing makes automated tool selection a combinatorial problem. Our current research has resulted in a proactive strategy to downscale the problem complexity.

The research mainly observes the relationship between instantaneous use of machines in the job shop condition, numbers of product being manufactured, production time, number of items waiting, waiting time, and transition time. Aiming at an automated process planning system (CAPP) for bent parts, the aspects of tool selection and process sequencing have been tackled in this study. Process plans if modified dynamically to consider the current state in the manufacturing shop floor, useful results can be obtained.

Keywords: - Computer Aided Process Planning, Bend Sequencing, Processing time.

1. Introduction

Process planning specifies what raw materials or components are needed to produce a product, and what processes and operations are necessary to transform those raw materials into the final product. Process planning typically finds the best way to manufacture the part by finding the optimal processing sequence of the features and the ideal machines to process the part. Its outputs include manufacturing processes, process parameters and identification of the required machines, tools and fixtures needed to perform those processes. The ability of manufacturing to respond to changes in product design, introduction of new products and changes in resource capabilities depends largely on process planning. Process planning is therefore vitally important in providing a competitive edge to manufacturing.

Traditionally process planning was done by experienced planners manuallywhose decision will become the production routing that will be used by production engineer for capacity planning, facility planning, costing and etc. Nonetheless, the main drawbacks of the manual process planning are that it is very time-consuming and there is no consistency in the decision making by humans.

1.1 Computer-Aided Process Planning

CAPP systems are capable of creating more accurate and consistent plans in shorter time with reduction in skilled process planner requirements. As a result, it can simplify and improve process planning to achieve more effective use of manufacturing resources. CAPP system focuses on

1) The creation of part specification data from a coding scheme,

2) Accessing a standard routing file for machine assignments, and

3) The translation of part specifications to NC instruction code for machine operations.

By implementing Computer Aided Process Planning using "Arena 10.0 software", the models have been developed to replicate the actual manufacturing system. They are presented either in static or dynamic manner. Computer-aided process planning in sheet metal industry can help in the planning, decision and it:

- It reduces the demand on the skilled planner.
- It reduces the process planning time.
- It reduces both process planning and manufacturing cost
- It creates consistent plans.
- It produces accurate plans and increases productivity.

Various steps involved in CAPP are Design input, Material selection, Process selection, Process sequencing ,Machine and tool selection ,Intermediate surface determination , Cost/time estimation ,Plan preparation .

After the designs are complete, our automatic process planning system uses the features and generates new ones to aid the production of plans with near-minimum manufacturing costs. Finally, these plans are used to produce parts on an automatic bending system.

2.0 Current situation in process planning

A major reason for the shortcomings of the current process planning practice is the unrealistic assumptions. Those assumptions are identified by as:

- Process plans are assumed to be static and fixed because they are produced in absence of dynamic information. Since no alternatives are built into the static process plan, the process plan information is very constrained.
- Unlimited shop floor resources (materials, machines, tools, fixtures, operators, etc.) availability is assumed during process planning. But usually they are engaged with other tasks, such as processing, breakdown, maintenance, absence, etc
- The desirable resources are repeatedly selected during planning, although the only reason is the process planner's personal preference.

3.0 Methodology

The research starts with collection of real shop-floor data from a sheet metal truck tipper manufacturing company in India. Then steps required to build a simulation model and subsequent functions using Rockwell Arena Software is mentioned. The data collected consisted of manufacturing procedure, type of machines with their maximum capacity, manufacturing rate per hour, part machining and assembly timings , along with practical problems in layout and time and material wasted in transportation within assembly lines where production method as non-automatic at the time of this research.

In this operation care shall be taken for tool selection, and operations like CNC operation on bended parts, hydraulic and air bending machines, milling machine, milling face machine, CNC lathe machine, CNC milling machine and tapping machine

, lathe machine, gas cutting & welding of sub-assemblies of Tipper i.e. *Mudguard assembly, Wheel ChokMtgBkt*, Sub *frame assembly, Floor assembly, Side board assembly, Head board assembly, Tail door assembly, and Sub assembly of load body, assembly of tail gate lock mechanism and load body & Sub frame assembly*.

Fig 1: - Sheet metal Truck Tipper

3.1Priority rules for Operational Sequence

- Shape determining bends should be performed after other bends.
- Faces connected to the part with a single bend can be bent in an early stage.
- Work piece rotations along two axes must be avoided between consecutive bends.
- Combinable bends are preferably bent in a single operation.
- After a bend operation has been completed, proceed with the nearest parallel bend to the same side of the central face.
- The major part of a component should be situated to the operator's side of the press brake.

Based on above data, obtained for different machining operations found as follows for one tipper assembly:-

M/C	Static (sequence)		
	Waiting time (hr)	No. waiting (hr)	Utilization
Cutting	3.5545	0.359	0.2479
Lathe	185.92	18.7131	0.9983
Milling	0.8333	0.01	0.24
Milling face	0	0	0.4375
CNC lathe	3.5367	0.4533	0.8308
CNC Milling	120.11	16.615	0.9758
Tapping	0.2604	0.008	0.1733
Total	314.2149		

Table 1:- Total time taken by all machines operations including waiting, non waiting time and utilization.

3.2 Scheduling Function

Scheduling a decision-making process , is treated as a time dependent function aimed at the utilization of resources to satisfy the process plans for a number of products. *It is static if it is applicable when all jobs are available in the beginning and dynamic if it is applicable when jobs arrive continuously*.

3.2.1 Job Shop Scheduling

Job shop scheduling is a manufacturing facility which makes use of universal resources and can be used for variety of manufacturing operations. Job shop scheduling problem based on five important characteristics including job arrival pattern, number and variety of machines in the shop, number of workers in the shop, particular flow patterns and evaluation of alternative rules.Implementation using Arena Software is shown as follows with inputs as Name and type of entity, time between arrivals and batch size per arrival

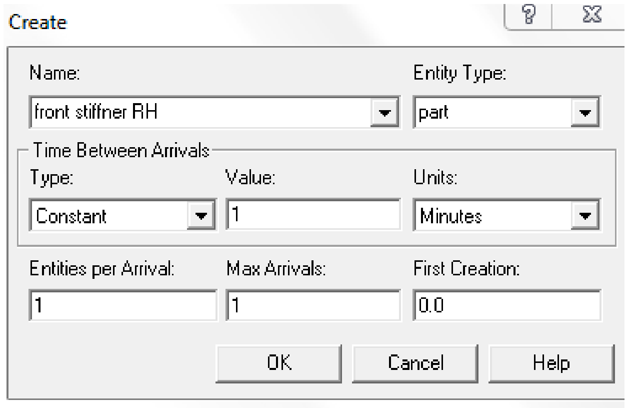


Fig-2:- Input window for Job Shop Scheduling

3.2.2 Dispatching Rules For Dynamic Scheduling

Dispatching rule prioritizes all the jobs that are waiting for processing on a machine. Common dispatching rules used in practice and found in the texts are First-come, first-served (FCFS), Shortest processing time (SPT), Earliest due date (EDD), Critical ratio scheduling (CR). The implementation of this aspect of CAPP in ARENA 10.0 is shown in following image indicating type of action and delay type time. It also takes into note the activity required along with resources available to accomplish the task and variable time required in each operation. Finally it also considers the fact that weather the processed part has to then stored or moved forward for further processing in line.

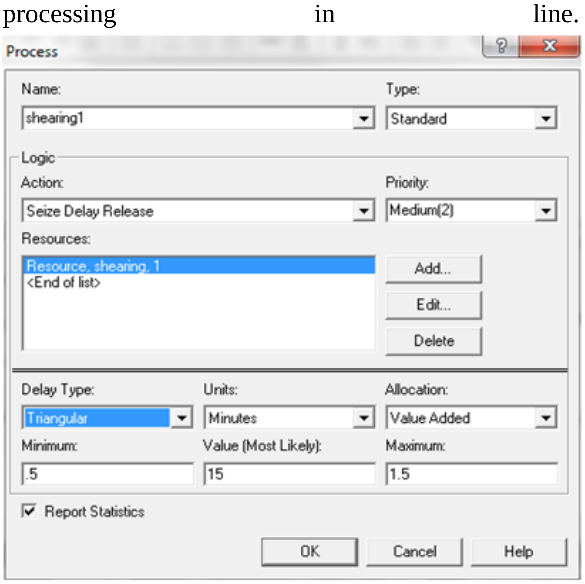


Fig-3:- *Input window for Process parameters, dispatching Rules and values for Dynamic Scheduling.*

3.3 Integration of Capp and Scheduling Function

Various approaches towards integration of process planning and scheduling functions can be devised as follows:-

1. Manufacturing decision making (MADEMA) - This approach identifies the assignment of various factory resources to the production tasks as the common aspects of process planning and scheduling functions.
2. Integrating methodology: - Stresses the assignment of operations to alternative machines. This methodology seeks not only to minimize the make span but also to balance the load of machines.
3. CAPP- Provides alternative machines to carry out the processes. Simulation models can be evaluated numerically and give the necessary realism simulation models can represent real-world systems at almost any level of detail in order to approximate the actual system. This can be depicted as follows:-

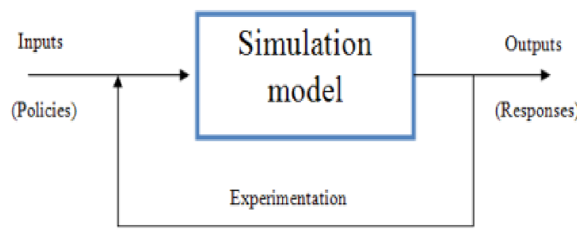


Fig 4:- Simulation Model of CAPP

3.4Simulation Model Building

The models are proposed to investigate the integration of process planning and scheduling function using actual shop floor data. Further assumptions to be made in the models building processes:

1) The areas of the factory, position of human and mechanism of machines are neglected.

2) Transfer times and distances between each machine are neglected.

3) Set-up times and delay times in each machine are neglected. These assumptions are applied to simplify the complication of the simulation model structure.

3.5 Static Model Using Sequence Method

According to the data provided different part types that follow different routes through the system. In the static condition, an item is processing through the system by following just one specific route. Arena sends the entities through a systemautomatically according to a predefined sequence of station visitations. The Sequence data module let us define an ordered list of Stations that can include assignments of attributes or variables at each station. First all parts need of a subassembly need to be defined as follows:-

Create - Basic Process

	Name	Entity Type	Type	Value	Units	Entities per Arrival	Max Arrivals	First Creation
1	rear mounting plate LHRH	part	Constant	30	Seconds	1	1	0.0
2	Rear Mudgaurd SS MTG Panel LHRH	part	Constant	25	Seconds	1	1	0.0
3	outer valancelhrh	part	Constant	25	Seconds	1	1	0.0
4	front mounting panel	part	Constant	25	Seconds	1	1	0.0
5	rear mudguard front MTG plate	part	Constant	25	Seconds	1	1	0.0
6	body guide lock plate	part	Constant	25	Seconds	1	1	0.0

Fig 5:- List of parts to be processed in there sequence

After Assigning parts process are assigned to each part with each process name depicting part number and also sequence of their occurrence in CAPP Arena system.

Process - Basic Process

	Name	Type	Action	Priority	Resources	Delay Type	Units	Allocation	Value	Report Statistics
1	shearing1	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	30	☑
2	drilling1	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	10	☑
3	shearing2	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	25	☑
4	drilling2	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	5	☑
5	bending2	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	30	☑
6	shearing3	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	25	☑
7	drilling3	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	5	☑
8	bending3	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	30	☑
9	shearing4	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	25	☑
10	drilling4	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	5	☑
11	bending4	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	30	☑
12	shearing5	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	25	☑
13	bending5	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	30	☑
14	shearing6	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	25	☑
15	bending6	Standard	Seize Delay Release	Medium(2)	1 rows	Constant	Seconds	Value Added	30	☑

Fig 6:- List of operations to be performed on each part in order of their priority with processing time as input.

An attribute is basically a common characteristic of all entities, but with a specific value that can differ from one entity to another. Next, the main portion of the model's operation consists of logic modules to represent item arrivals, item processing and item departures. The item arrivals have been modeled using the modules shown in figure as follows:-

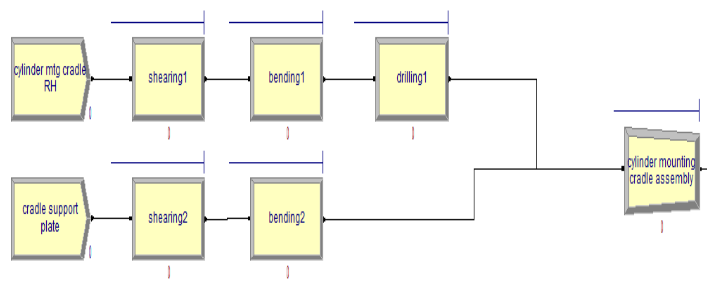


Fig 7:- Logic Modules for Part Arrivals at different stations.

Now that the arriving items were routed according to their assigned part sequence, it now needed to develop the logic for item processing. The logic is that an item arrives to the station, queues for a machine, be processed by the machine and be sent to its next step in the item sequence. The example of the item processing of Cutting operation is shown in figure:-

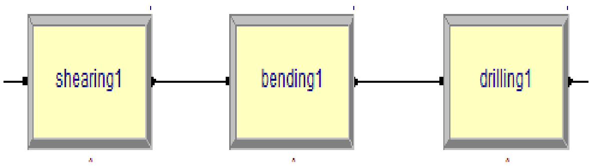


Fig 8- Sequence of operations as defined in Arena Software(Where Number denotes part number in order)

Logic of item processing includes Enter, Process& Leave module which is further defined as follows mentioning delay type, time(units) , priority, estimated times and action as seize delay release due dynamic state of processing material. Finally, having completely defined all the data, the item's exit was the only thing left to define through 'dispose' command.

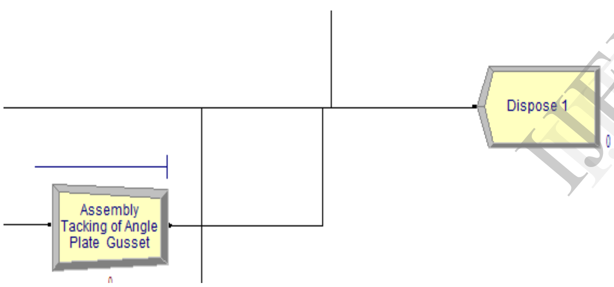


Fig 9:- End of assembly planning with dispose command.

3.6 Tabulate Manual Manufacturing Time

First of all in the below table for this assembly we have noted down manual manufacturing time at the industry level WITHOUT the use of CAPP. Timings noted down represent actual times (timed with a stopwatch) without use of operation sequencing, tool selection and priority orders in machining patterns.

Table-02 Manual Manufacturing Time Of Mudguard Sub-Assembly

SUB ASSEMBLY OF MUDGUARD.			
Description.	**Quantity.**	**Material.**	**Machining time.**
RAER MUD GUARD FRONT MTG PLATE LH/RH	01	ISI 1709 Gr. D	6 Min.
MUDGUARD MTG ANGLE REAR. 1. RECTANGULAR TUBE.	01	ISI 4923 RHS 50X25 X 2.9 mm.	10 Min.
MUDGUARD MTG ANGLE REAR. 2. GUSSET	02	ISI 2062 Gr. A	30 Sec.
REAR MUDGUARD SS MTG PLATE LH/RH	01	ISI 1709 Gr. D	6 Min.
MUDGUARD MTG ANGLE REAR.	01	IS RHS 50X25X 2.9 mm	10 Min.
GUSSET	02	ISI 2062 Gr.A	30 Sec.
CLOUSER PLATE	01	ISI2062 Gr. A	30 Sec.
PLATE	01	ISI2062 Gr. A	30 Sec.
REAR MUDGUARD MIDDLE SS MTG PLATE.	01	ISI2062 Gr. D	5 Min.
FRT MTG PNL	01		5 Min.
FRONT MOUNTING PANEL	02	IS 1709 Gr. D	5 Min.
OUTER VALANCE LH/RH	04	IS 1079 Gr. D	10 Min.

3.7 Make Operation Sequence Of Each Process & On Each Part:-

Make Operation sequence of each part of the sub assembly which we have used in ARENA 10.0 Software after proper priority order and preference rules. It has been denoted as SQ (propriety order) for each process type.

Table-03 Operation Sequence of Mudguard Assembly

Item	Description	Quantity	Shearing	Bending	Drilling
1	Rear Mounting Plate LH/RH	1	SQ1-0.5		SQ2-0.17
2	Rear Mtg SS MTG Panel LH/RH	1	SQ1-0.45	SQ3-0.17	SQ2-0.08
3	Outer Valance LH/RH	1	SQ1-0.45	SQ3-0.17	SQ2-0.08
4	Front Mtg Panel	1	SQ1-0.45	SQ3-0.17	SQ2-0.08
5	Rear Mudguard Front MTG Panel	1	SQ1-0.45	SQ2-0.5	
6	Body Guide Lock Plate	1	SQ1-0.45	SQ2-0.5	

3.7.1 Make Process Flow Chart of Each part of Each Sub assembly which clearly defines the process flow and characteristics:-

Process Flow Chart of Mudguard Assembly

Part Name :-	Mudguard Assembly			
Customer Name :-	Tata Motors			
OPP.NO	OPERATION DESCRIPTION	INCOMING SOURCE OF VARIATION		PROCESS CHARACTERTICS
Sub Part Name- Rear Mounting Plate LH/RH				
10	Shearing	Thickness, Rust,		Operator skill
		Waviness	10	Stopper Position
		Operator Skill		Sharpness of blade
20	Drilling	Thickness of Plate,		Operator skill
		Drill bit size,		Drill Bit Size
		Operator Skill	20	
		Drill bit size for Step Drilling if required		
Sub Part Name- Rear Mudgaurd SS MTG Panel LH/RH				
10	Shearing	Thickness, Rust,	10	Operator skill
		Waviness		Stopper Position
		Operator Skill		Sharpness of blade
20	Drilling	Thickness of Plate,	20	Operator skill
		Drill bit size,		Drill Bit Size
		Operator Skill		
		Drill bit size for Step Drilling if required		
30	Bending	Perpendicularity of Blank	30	Stopper position
		Die & Punch Dimension		Operator skill
		Machine Capacity		Die & Punch Dimension

Fig 10- Process Flow chart of Mudguard subassembly

4.0 Details of Time Taken

Now after running the simulation in software ARENA 10.0, it generates a report of time utilization in the process layout of desired assembly. The software calculates and shows Value added (VA) Time, Non Value added (NVA) Time, Wait Time, Transfer Time, assembly time and then totals time of the entire process. This helps in scheduling as we can study wait time in the manufacturing setup and hence is the main reason for using ARENA in CAPP.

Time

	Average	Minimum Value	Maximum Value
VA Time			
assembly	0.0917	0.0917	0.0917
NVA Time			
assembly	0.00	0.00	0.00
Wait Time			
assembly	0.2583	0.2583	0.2583
Transfer Time			
assembly	0.00	0.00	0.00
Other Time			
assembly	0.00	0.00	0.00
Total Time			
assembly	0.05833333	0.05833333	0.05833333

Fig 11:- Time utilization report

4.1Scheduled Utilization

Scheduled Utilization	Value
bending machine	0.7143
drilling machine	0.1190
shearing machine	0.7381

Fig 12:- Time utilization in the process layout of desired assembly

After noting down all these technical data we will generate a precedence chart of all activities and create a proper process layout with help of knowledge of PERT/CPM we studied in operation's research we will create a proper process sequencing After this work we will create a simulation of process layout using layout software's like ARENA and after giving proper sequencing we can actually implement pre manufacturing troubleshooting. The above methodology was repeated again for all the various sub-assemblies so as to make and simulate the entire assembly of the product and in the end were connected together based on following pert calculations.

4.2 Net Comparison Of Capp &Manual work (Manual Work Time Vs Capp Work Time)

Similarly after repeating the entire process for all the sub-assemblies and following results were obtained:-

Table-04 Results

S.N	Subassembly Name	Manual Time(Hrs)	Simulation Time(Hrs)	Reduction in Time(%)
A	Side Board	1.340	1.033	22.91
B	Mudguard	1.400	1.000	28.57
C	Sub Frame	3.200	2.720	15.00
D	Tail Door Assembly	2.500	2.180	12.80
E	Wheel Chok Mtg Bkt	0.170	0.116	31.76
F	Head Board	1.180	0.716	39.32
G	Total	9.790	7.765	20.68

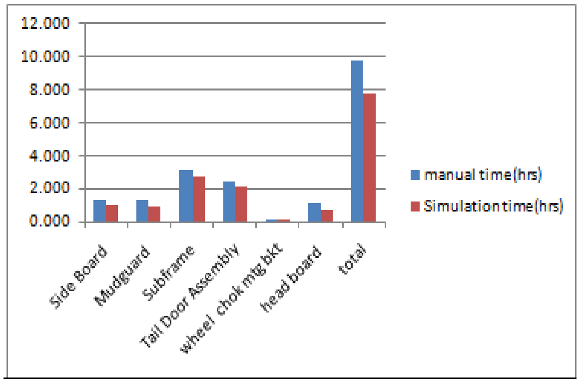


Fig-13 Graph of Capp Time Vs Manual Time Of ALL Assemblies

Since all machines have their own utilization, it means that the machines are running correctly in the simulation. Therefore, it can possibly be said that this dynamic model has been constructed acceptably. Overall, it can be concluded that the performance of manufacturing system is substantially improved when the dynamic process planning has been achieved.

5.0 Implementation of CPM PERT in CAPP.

Critical Path Method has been applied here to find shortest possible time to manufacture the assembly and then implement it with CAPP.

ACTIVITY	SUBASSEMBLY NAME	PRECEDENCE ACTIVITY
A	Side Board	---
B	Mudguard	A
C	Sub Frame	---
D	Tail Door Assembly	A
E	Wheel Chok Mtg Bkt	C
F	Head Board	B,D

Fig 14:- Precedence activity chart for CPM

5.1 PERT CPM Chart calculation

Standard procedure for calculation of critical path method has been applied and processes with difference in end times between forward and backward process end time as numerically zero are taken for critical path method.

PROCESS	DURATION (Hours)	Forward Starttime1	Forward Endtime1	Backward Starttime2	Backward end time	Difference in end times
1-2	3.20	0.00	3.20	0.47	3.67	0.47
1-3	1.34	0.00	1.34	0.00	1.34	0
2-4	0.17	3.20	3.37	3.67	3.84	0.47
3-4	2.50	1.34	3.84	1.34	3.84	0
3-5	1.40	1.34	2.74	4.94	6.34	3.6
4-5	2.50	3.84	6.34	3.84	6.34	0
5-6	1.18	6.34	7.52	6.34	7.52	0

Table 5:- Critical path calculation

So critical path for our assembly is 1-3-4-5-6 with total time as 1.34hr+2.50hr +2.50hr+1.18hr = 7.52hrs

5.2 Critical Path Diagram

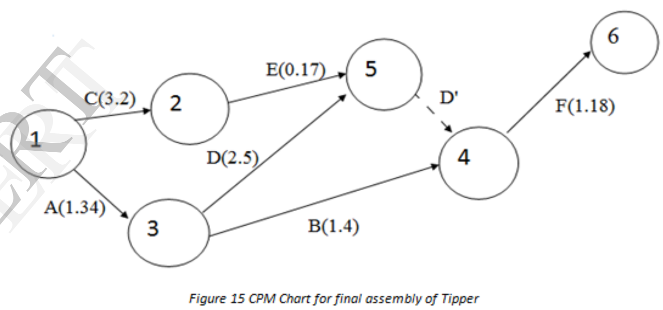
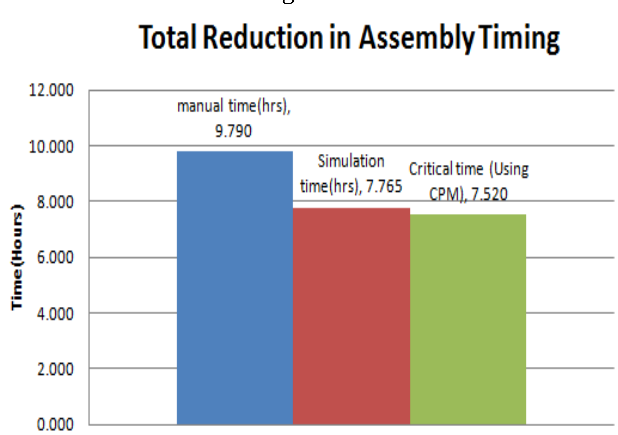


Fig 15- Critical Path Diagram for Tipper Assembly

So our critical path for our assembly is 1-3-4-5-6. Time = 1.34+2.50+2.50+1.18= 7.52. Hence total reduction in manufacturing time can be stated as



From implementation of Computer Aided Process Planning in Sheet metal products manufacturing a significant reduction in manufacturing time has been obtained**. With reference to TOTAL ASSEMBLY TIME has been reduced by 20.68% from 9.79hrs to 7.765 hrs. and with Critical Path Method it has been reduced to 7.52 hours.** This has been possible due to selection of best optimized methods for manufacturing, tool selection, operation sequencing and implementation of project on actual plant site.

6.0 Conclusion

At the present time, global competition and rapidly changing customer requirements are forcing major changes in the production styles and configuration that have great adaptability and flexibility.

Due to the combinatorial nature of the problem and the computational Complexity of detailed sequence evaluations is solved using this software. The uses of computers in process plan have following advantages over manual experience-based process planning:

- It can systematically produce accurate and consistent process plans.
- It leads to the reduction of cost and lead times of process plan.
- Interfacing of software for cost, manufacturing lead time estimation, and work standards can easily be done.
- Skill requirement of process planer are reduced to develop feasible process plan.

Since all machines have their own utilization, it means that the machines are running correctly in the simulation. Therefore, it can possibly be said that this dynamic model has been constructed acceptably. Overall, it can be concluded that the performance of manufacturing system is substantially improved when the dynamic process planning has been achieved.

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