Lead Time Reduction in the Production of a **Composite Thruster Bracket of Satellites** usingPlug and Cure Tooling, Universal Jig and Lean Concepts

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Abstract— These instructions give you guidelines for preparing papers for IJSER JOURNALS. Use this document as a template if you are using Microsoft Word 6.0 or later. Otherwise, use this document as an instruction set. The electronic file of your paper will be formatted further at IJSER. Define all symbols used in the abstract. Do not cite references in the abstract. Do not delete the blank line immediately above the abstract; it sets the footnote at the bottom of this column. Don't use all caps for research paper title.

Index Terms- Minimum 7 keywords are mandatory, Keywords should closely reflect the topic and should optimally characterize the paper. Use about four key words or phrases in alphabetical order, separated by commas.

INTRODUCTION

Satellite is a man-made system that is placed around orbit of the earth or any another planet to collect information and to communicate the same to the terrestrial networks. It has two basic parts the Mission Payload and the Spacecraft Bus. The payload performs the mission of the space craft like earth's imaging, photography, weather forecast and also provides communication. Whereas, the spacecraft bus supports the payload by providing required mechanical support, stability, orbit and attitude control, electric power, thermal control and a two way command and data link to the ground.

The spacecraft orbit is perturbed by gravitational effects of the sun & the moon, and by the Oblateness (Spheroidal shape) of the earth. To keep the orbital elements within allowable limits (attitude control) orbital corrections are performed throughout the life of the spacecrafts. This orbit and attitude control is performed by thrusters in modern day spacecrafts [1].

Thruster is a part of auxiliary propulsion system of the satellite, which performs the task of keeping the satellite in the right orbital location. They are configured at various locations with preferred orientation based on centre of gravity, type and

mass of the spacecrafts (satellite) to provide active control

torque.

The thruster considered in our case study is typically bi-propellant system consisting of mixed oxides of nitrogen (MON-3) and mono methyl hydrazine (MMH). It is activated through on board controller or through ground command which leads to small firing causing the movement of satellite in opposite direction of the thrust applied and bring it to correct attitude or orbit. Generally their capacity is 22N, 10N etc. are decided based on required thrust force [2].

The thrusters are hard mounted to the spacecraft bus of the satellite by thruster brackets. Thruster Bracket is a composite material component, which holds the thruster onto it on one side and is connected to the structure of satellite (spacecraft bus) on the other side. It is provided with cut-outs to accommodate the thruster and also to allow cable/Plumb line of the thruster to pass through it. Thruster bracket bears vibration loads during launching stages and provides a required Thruster mounting platform with necessary angular orientation

For the thrusters to work efficiently the designer poses strict technical requirements in the manufacture of thruster brackets. The main specifications are:

- Light weight
- Angular tolerance
- Dimensional tolerance
- Stiffness Requirements.

In our study, Thruster brackets are made of CFRP material, manufactured by manually laying-up of bidirectional prepreg having a thickness of 0.08 mm over a metallic tool up to 25 plies of prepreg with different orientation [0/90 ±45°] etc. is used. Thruster brackets are L shaped having an overall thickness of 2 mm; interior angle being either 80° or 90°, 96-120 mm wide, 150-180 mm height with 20 mm L shaped stiffeners

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from inside face at the ends. Cut-outs and slots are provided in the bracket. The CFRP Prepreg layup and tool combination is vacuum bagged to remove the air inside the bag thereby applying uniform atmospheric pressure of 1 bar on the component and finally it is cured in an atmosphere of high temperature and pressure. A model of the Thruster Bracket is as shown in the **Fig 1**.

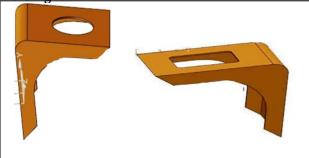


Fig 1: Model of Type-1 Thruster bracket with a Cut-out on the face (left side) and slot on the back (right side).

Manufacturing process of Thruster Bracket involves laying-up and curing of bracket without slots or cut-outs at the Composite Lab. The Basic Processing Steps in the manufacture of the thruster brackets are as follows:

- The tooling is cleaned and then The Tool-tech is applied to the tooling surface.
- The prepreg is removed from the refrigerator and is kept at room temperature for thawing.

• The prepreg is laid on the cutting table and cut to the desired size and orientation using templates.

• Backing paper from the prepreg is removed and the prepreg is laid on the tooling surface in a particular fashion based on its orientation.

• Entrapped air between prepreg sheets is removed using a squeezing roller after applying each prepreg sheet. Intermediate compaction is carried out for every 5 layers.

• After applying all the prepreg sheets, vacuum bagging arrangements are made by applying release film, barrier film, breather, and bagging materials as seen in the **Fig-5**.

• The entire assembly is then placed into the autoclave using a trolley if the structure is large.

• Connections to thermocouples and vacuum hoses are made and the autoclave door is closed.

• The cure cycle data are entered into a computer-controlled machine and monitored.

• After cooling, the vacuum bag is removed and the part is taken out. [3]

And then the thruster bracket is sent to the CNC machine shop which is located around 500 metres away from the Composite Lab in another building.

At the CNC machine Shop the brackets undergo manufacturing processes like drilling for making slots, cut-outs, P.C.D holes (precisely dimensioned) and for the thruster bracket fixation holes to clamp the bracket with the main satellite structure. The total production process involves lot of **lead times** from the beginning to till end.

A new *proposed process* is introduced to reduce lead times involved in the currentproduction process to make the whole process **In-house**, and to also avoid mechanical stresses involved due to drilling in the process in the component.

To realise the above objective it is required to develop a special **Plug and Cure** tooling which is used to lay up the various types of brackets with in-situ cut-outs and slots as shown in **Fig-2**. to provide the PCD holes on the bracket for accommodating the thruster as well as the structural fixation holes, it is necessary to design and develop a special **Universal Jig** as shown in **Fig-3**. The Universal Jig is designed to suit the existing conventional vertical milling machine and with necessary clamping for the bracket during drilling of holes, so, that all the critical dimensions are met with simplicity and ease of operation.

1.1 Plug and Cure Toolings:

Tool-making is a challenging segment of the composites manufacturing area. A tool transforms the raw material to a given shape. Without the tool, the raw material cannot be shaped to the final dimension and size requirements of the part as shown in **Fig 2**. The Plug and Cure Tooling is provided with a recess and a suitable plug to accommodate it. Each layer of wet prepreg is laid up on the tool and the slots are then cut manually to the size of the recess (without the plug inserted).after the required numbers of layers are stacked, curing is done with the plug inserted in the tool.

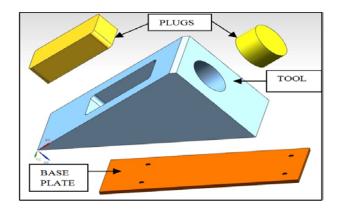


Fig 2: Model of the newly designed and developed Plug and Cure tooling assembly with its Parts for the Type -1 bracket as shown in Fig 1.

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Here the prepreg is cut at every layer of lay-up process after laying, the left out small pieces of prepreg in shape of cut-outs and slots can be utilised for other applications like Doublers for satellites which is a stiffener used in other projects.

The Basic requirements of tooling's:

- 1) Light Weight.
- 2) Stable at cure Temp (Usually 350° F).
- 3) Withstand Loads of 100 psi.
- 4) Smooth Finish in Part Area.
- 5) Acceptable to release Agent.
- 6) Have Expansion Factor Compensation.
- 7) Wear Resistant to Scraping.
- 8) Resistant to Solvent Cleaning.
- 9) Machinable or Capable of Lamination.
- 10) Locate and Support All Components.
- 11) Capable of Producing Production Article within Tolerance and Process Specification.
- 12) Requires Vacuum Integrity.
- 13) Cross Section to have Uniform Heat-Up Rate.
- 14) Compatible to Shop Equipment.
- 15) Good thermal conductivity.[4]

1.2 Universal jig concept:

A jig is a type of fixture with means for positive guiding and supporting tools during drilling, boring and related operations. Hence, drill jig is usually fitted with hardened bushes to locate, guide and support rotating tools. The advantages in the use of jigs and fixtures are so great, and so varied, that these devices have also naturally found their way into the production of parts in limited quantities as well as into manufacturing processes outside the machine shop, and even outside metalworking industry [5].

In this study it minimizes the setting and manufacturing lead times which helps in our main objective lead time reduction.

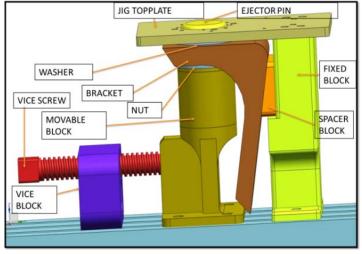


Fig 3: Model of the newly designed and developed Universal Drill Jig assemblyalong with its Partsperforming drilling operation of PCD holes for the Thruster Bracket Type-1 as shown in **Fig1**.

The term universal jig covers two different types of equipment:

First type consists of a drill jig body with a quick acting clamping and locking mechanism which can be provided with an interchangeable drill bushings top plates and sub bases (adapters) to support the work.

The **second type** comprises a set of building elements which can be temporarily assembled to a fixture and dismantled after use. They are built for **In-house** advantage as shown in **Fig-3**. When holes are grouped closely together, it may not be possible to use any of the bushes mentioned and the steel plates which suit the individual jobs is made which can be screwed and dowelled to the jig body [6].

1.3 Lead Time:

Lead time is the total time required to manufacture an item, including order Preparation time, Queue time, Setup time, Run time, Move time, Inspection time, and Put away time. It is the time interval between the initiation and the completion of a production process [7].

1.4 Lean Manufacturing:

Lean manufacturing is a manufacturing Strategy that seeks to produce a high level of throughput with a minimum of input. It is created to represent less human effort in the company, less manufacturing space, less investment in tools, less inventory in progress, and less engineering hours to develop a new product in less time by eliminating waste NVA that inflate costs, lead times and inventory requirements.[8][9]

1.5 Value Stream Mapping (VSM):

The value stream mapping (VSM) method is one of the tools of the Lean Manufacturing Technology. It originated in the Toyota Production System (TPS). In Toyota this method was called "The Material and Information flow mapping". This is an analysing and designing flow chartingtechnique that visualise, process and track (steps) which are value addingfor the customer and (activities) which are Non value adding to the customer[10].Wolfgang Apel et al. [11] state that "The main principle of lean manufacturing is to reduce waste in an operation, such as long lead times, defects and material wastes". VSM is lean manufacturing tool used to distinguish between value-adding and non-value adding processes [12] [13]. Rother and Shook [14] state "VSM is a tool, which identifies ways to get material and information to flow without interruption". Hines and Rich [15] state that" The VSM is a basis for implementation of a plan that helps to see and focus on flow with a vision of the idea". Hines et al. [17] identified three main types of activities that are prevalent in organizations:

- (1) Non-Value Adding (NVA) activities.
- (2) Necessary but Non-Value Adding (NNVA) activities.
- (3) Value Adding (VA) activities.

2 VSM Methodology:

- 1. Study of current state of Thruster Bracket production process.
- 2. Identification of VA, NVA& NNVA activities for current state of production process.
- 3. New Proposed state of Thruster Bracket production process is developed and implemented by Eliminating and Minimizing NVA by designing and developing new Plug and Cure Tooling and Universal Jig.
- 4. Process Flow Chart, VSM, for Current State & Proposed State are represented and analysed.
- 5. Finally conclude stating that new proposed state of production process of bracket shows the improvement in productivity by decreasing the NVA activities. The details of which is discussed in the next section [16] [10].

2.1 Study of current state of production process of Thruster bracket:

Stage-1 (Steps 1-4 includesIndenting, review and release of fabrication drawing of the thrustersbracket).

It starts with the initiation of any satellite launching project where there is the requirement of a minimum 16 Thruster brackets. The projects group indent the required type of bracket and their quantity to the structures group. Later on receipt of the indent by the structures group, it is reviewed by the section head and also the appropriate fabrication drawings are released here the process undergoes NVA time and delay (2+3+1+2) = 8 hours. 2 hours for indenting, 3 hours for the receipt of the indent and various crosschecks making for availability of raw material, labour etc. by the structures team, 1hour for the final review by the section head and 2 hoursto release the fabrication drawings.As shown in **Table 1& 2 and Fig 6** VSM for Current State.

Steps 5&6 (Process-I):

Fig 4: Prepreg cutting and laying up Proceess

Further the structures lab starts its process of manufacturing by initially selecting the appropriate tool (based on type of bracket) and cleaning it, & later applying the tool-tech (Teflon coated fibre glass) over the tool for easy removal of component in later stages. Further the template is prepared to cut the prepreg cloth, and pressure plates are cut to stiffen the vacuum bagging process. Both the process consume 4 hours & 12 Hours respectively i.e. (4+12) **=16 hours** as shown in **Fig 4& 5**.

Steps 7 & 8 (Process II&III):

Now the CFRP prepreg material is cut according to the templates sizes and layup process is started as shown in **Fig 4**. Initially 5 layers are laid then they are vacuum bagged to compact as shown in **Fig 5**. The same process is repeated till 25 layers are complete this process is called the prepreg lay-up technique which takes 12 hours to complete. Once the lay-up process is complete the tool along with the CFRP laid-up material is vacuum bagged where air is pumped out by suction are later they are transferred to the Autoclave for curing This whole process takes 8 hours (12+8) hours respectively = 20 hours The details of which are given in**Table 1&2 and Fig 6** VSM for current state.

Steps 9 & 10 (Process-IV):

Later the cured bracket is trimmed and finished and sent for inspection where it may face a delay due to queuing so the process takes (2 + 2) = 4 hours respectively. The details of which are given in **Table 1&2 and Fig 6** VSM for current state.

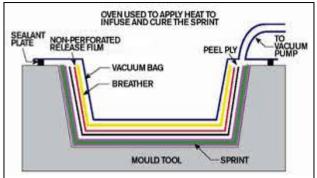


Fig 5: Vacuum bagging process.

When all the process are over the bracket is further indented for machining to CNC machine shop which takes 20-30 minutes of paper work along with 10-15 minutes of transportation time till it reaches the appropriate location. The same amount of time is utilised for indenting the CNC Machine shop for further machining. Meanwhile bracket is kept in buffer stock and NVA time is not accounted separately for this process. The details of which are given in **Table 1&2 and Fig 6** VSM for current state.

Stage-II (Step 11, Acceptance of indent and check for availability of Man Machine& Material):

After acceptance of the indent by the CNC machine shop, it is studied by the section head and further sent to appropriate operator to machine the bracket. The availability of machines are checked and the also the queuing and scheduling of various other works are checked which may take 3 hours (Waiting time).Totally (3+3) hours = 6 hours for the above two process respectively As shown in Table 1&2 and Fig 6.

Step 12-14(Process V & VI):

Now the actual machining work starts with the finalization of Lplates, Grippers, Vacuum suction devices and fixtures for holding the brackets. The machine is cleaned, and vacuum suction device is kept around to collect the dust particles of the composite bracket. The bracket is loaded for slots and cut-outs removal, followed by the P C D holes drilling. The whole process may take approximately (3+3+3) **=9 hours** respectively. As shown in **Table 1&2 and Fig 6**, VSM of Current state Production Process).

Step 15 (Process-VII):

After all the machining the bracket is inspected for its accuracy in CMM machine which may take 6 hours due to the sequencing/queuing. The finished bracket is finally transported to the projects group to complete the cycle. The total lead time is:

Step 1-4	8 hours
Step 5-6	16 hours
Step 7-8	20 hours
Step 9-10	4 hours
Step-11	6 hours
Step12-14	9 hours
Step 15	9 hours
Total Lead time (L/T)	72 hours
Total V A time (V/A)	55 hours
Total NVA time (NVA)	17 hours

 Table 1:
 Process Flow Chart for the current state of Thruster Bracket ProductionProcess.



							_	
	Process Flow Chart for the Current state of Production process			0	Т	I	D	S
	of all the activities involved in stages.			Р	r	n	e	t
				e	а	s	1	0
S	The entire production process involves two stage of manufacturing	No Of	Processing	r	n	Р	а	r
L	process of the thruster bracket stage-1 that takes place in the composite lab	People	Time	a	s	e	у	a
Ν	as well as stage-2 that takes place at CNC machine shop	Involved	(Hours)	t	Р	с		g
0	Stage-1			i	0	t		e
				0	r	i		
	Step 1-10			n	t	0		
	At the composite Lab					n		
1	Project group indent their requirement based on the project		2	0			Δ	V
2	Reciept of the indent by the composite lab		3	-				-
	and further sent for review by section head			-0-	₽		Γ·Υ	▼
3	Review of the indent, Material and labour availabilty by the Section Head		1	0	⇒		b b	V
4	Release of fabrication drawing to the composite lab operators		2	Õ	à		-0	⊽
	Process-I							
5	Tool required for the lay-up is cleaned and Tool-tech applied	2	4	O	⇒		D	V
6	Pressure plates and Template cutting is done to size the preppreg cutting	2	12	Ō	i a⇒		D	▼
	Process-II			T	,			
7	Prepreg cutting is done with the help of templates and 25 ply lay-up	2	12				<u> </u>	
-	is done manually in 5 intermediate stages vaccum bagging	_		Ó	⇒		D	V
	Process-III			Ŧ	,			
8	Final Vaccum Bagging and curing of the bracket with the tool in oven	2	8	Ó	⇒		D	V
	Process-IV			T				
9	Trimming of the bracket and preliminary inpection	2	4	-Ó-	- 13	- 0	D	V
	(waiting time utilized in indenting the machining details to CNC Mc Shop)					1		
10	Indenting for the further drilling works by the composite lab			~	1		-	
	to the CNC machine shop		3	-0-	¢	-	D	
	Stage- 2					·		
	Step 11-16 at the CNC Machine shop							
11	Acceptance of indent and checking for the availability of the operator		3	0	₽		ÌΡ	V
	Process-V						H T	
12	Preperation of the tools and tackles of the CNC and loading of the bracket	2	3	0	⇒		Þ	▽
	Process-VI	_						
13	Slots and cut-outs machining	2	3	0	- 🗃		D	▽
14	Loading of the bracket for drilling and completing the job	2	3	ō	i ⇒		D	- Ž
	Process-VII	-		Ť				v
15	Final CMM inspection of the finished bracket and delivery of the bracket	2	6	0-	- =>	- 57	D	▽
	to the projects group	2	, v	-	-	-	-	V
\rightarrow			3	0	_⇒́		D	V
	with some waiting time		72 Hours	<u> </u>	-			V
	Total time taken in both stages							
	Considering the 8 hours /day working Schedule total no of days =		9 Days				<u> </u>	

 Table 2:
 Details of Process Activities /Steps showing Processing Time, Value Aadded Time & Non Value Added Time.

	The entire production process involves two stage of manufacturing				
	process of the thruster bracket, (stage-1 that takes place in the composite lab)				
	and (stage-2 that takes place at CNC machine shop)				
S		No of	Processing	VA	NVA
L		people	Time	Time	Time
N	Stage-1	Involved	(Hours)	(Hours)	(Hours)
0	Step 1-10 at the Composite lab				
1	Project group indent their requirement based on the project		2	0	2
2	Reciept of the indent by the composite lab		ĭ 3	0	3
	and further sent for review by section head				
3	Review of the indent, Material and labour availability by the Section Head		1	0	1
4	Release of fabrication drawing to the composite lab operators		2	0	2
	Process-I				
5	Tool required for the lay-up is cleaned and Tool-tech applied	2	4	4	0
6	Pressure plates and Template cutting is done to size the preppreg cutting	2	12	12	0
	Process-II				
7	Prepreg cutting is done with the help of templates and 25 ply lay-up	2	12	12	0
	is done manually in 5 intermediate stages vaccum bagging				
	Process-III				
8	Final Vaccum Bagging and curing of the bracket with the tool in oven	2	8	8	0
	Process-IV				
9	Trimming of the bracket and preliminary inpection	2	4	4	0
10	Indenting for the further drilling works by the composite lab				
	to the CNC machine shop		3	0	3
	Stage- 2				
	Step 11-16 at the CNC Machine shop				
11	Acceptance of indent and checking for the availability of the operator		3	0	3
	Process-V				
12	Preperation of the tools and tackles of the CNC and loading of the bracket	2	3	3	0
	Process-VI				
13	Slots and cut-outs machining	2	3	3	0
14	Loading of the bracket for drilling and completing the job		3	3	0
	Proces-VII				
15	Final CMM inspection of the finished bracket and delivery of the bracket	2	6	6	0
	to the projects group				
	with some waiting time		3	0	3
	TOTAL TIME IN HOURS		72	55	17
	TOTAL NUMBER OF DAYS ON BASIS OF 8 HOURS PER DAY		9 Days	≈ 7 Days	≈ 2 Davs
	%OF VA= VALUE ADDED TIME /TOTAL PROCESSING TIME x 100 =	79%	VA = VALUE		
	%OF NVA= VALUE ADDED TIME /TOTAL PROCESSING TIME x 100 =	21%	NVA =NON		DED
	NOT THAT ARE ADDED TIME /TOTAL PROCESSING TIME X 100 -	£1 /0	INVA-INOIN	ALOLAI	

2.2 Study of proposed state of production process of bracket.

Stage-I (Step 1-9 Process - I, II, III & IV): remains common in both the processes.

So the Manufacturing lead time for Step (1-9) is as shown in tabular column:

Step 10: Process - V

The drill jig is assembled over the bed of conventional drilling machine, Thruster bracket is loaded on to the jig through the ejector pin and locked with Allen bolts provided in the die plate from the top as shown in **Fig 3**.

Making the die plate as template its holes are transferred to the bracket by the drill bit very carefully which takes 3 hours for completion if done with utmost care and waiting of 2 hours so totally **5 hours**. Step 11 &12: Process – VI

Final inspection as well as the CMM measurement takes 2 hours each and the delivery takes only an hour. So this process takes Totally **3 hours** for completion. As shown in**Table 3 & 4 and Fig 7** VSM for Proposed state.

Step 1-4	8 hours
Step 5-6	16 hours
Step 7-8	20 hours
Step 9	4 hours
Step-10	5 hours
Step12-14	3 hours
Total Lead time (L/T)	56 hours
Total V A time (V/A)	45 hours
Total NVA time (NVA)	11 hours

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CURRENT STATE VSM OF PRODUCTION PROCESS OF THE COMPOSITE THRUSTER BRACKET

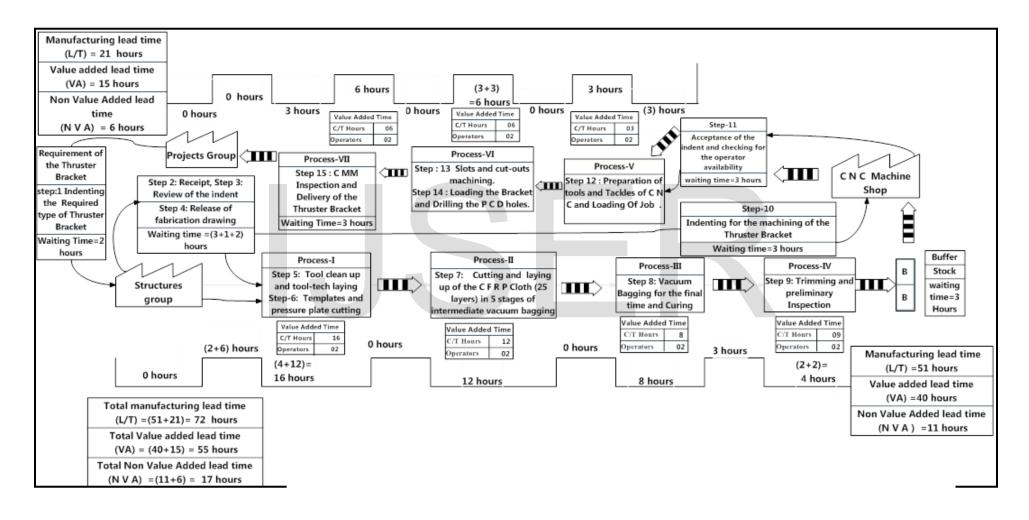


Fig 6: Current State Value Stream Mapping of production process of the Composite Thruster Bracket

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 Table 3: Process Flow Chart for the current state of Thruster Bracket Production Process.

	Process Flow Chart for the proposed state of Production process			0	Т	I	D	S
	of all the activities involved in stages.			Р	r	n	e	t
				e	а	s	1	0
		No Of	Processing	r	n	Р	а	r
		People	Time	а	s	e	у	a
	The entire production process involves only one stage of manufacturing	Involved	(Hours)	t	Р	с		g
s	process of the thruster bracket that takes place in the composite lab			i	0	t		e
L	Stage-1			0	r	i		
\mathbf{N}				n	t	•		
0						n		
1	Project group indent their requirement based on the project		2	0	ſ		D	V
2	Reciept of the indent by the composite lab		3	0	₽		Э	V
	and further sent for review by section head			0	4		Ÿ	v
3	Review of the indent, Material and labour availabilty by the Section Head		1	0	₽		Ģ	V
4	Release of fabrication drawing to the composite lab operators		2	0	₽		0	∇
	Process-I							
5	Tool required for the lay-up is cleaned and Tool-tech applied	2	4	Ō-	⇒		Ο	V
6	Pressure plates and Template cutting is done to size the preppreg cutting	2	12	0	₽		Ο	- V
	Process-II			i				
7	Prepreg cutting is done with the help of templates and 25 ply lay-up	2	12	0	Û		D	V
	is done manually in 5 intermediate stages vaccum bagging			Ŷ	~			v
	Process-III			- 1				
8	Final Vaccum Bagging and curing of the bracket with the tool in oven	2	8	Q	ſ		D	
	process-IV			i				
9	Trimming of the bracket and preliminary inpection	2	4	O	ł	-	D	
	process-V					· ·		
10	Assembling of the drill jig over the conventional milling machine		3	0	÷		Ľ,	V
	and loading the bracket to it for drilling the P C D holes on top face			0.	~~			•
	Process-VI				``	4		
11	Final inspection of the Bracket and CMM Measurement	2	2	0	ſ	L L	D	
	with a few hours of waiting time		2			1		
12	Delivery of the finished barckets to the projects group		1	0	IJ,		D	
	Total time involved in manufacturing the Brackets		56					
	Considering the 8 Hours day Total no of days involved		7 days					

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Table 4: Details of Process Activities /Steps showing Processing Time, Value Added Time & Non Value Added Time.

	The entire production process involves only one stage of Manufacturing	Number	Processing Time	VA	NVA
L	Process of the thruster Bracket that takes place in the composite lab	Of People	(Hours)	Time	Time
Ν	Stage-1	Involved		(Hours)	(Hours)
0	_				
1	Project group indent their requirement based on the project		2	0	2
2	Reciept of the indent by the composite lab				
	and further sent for review by section head		3	0	3
3	Review of the indent, Material and labour availabilty by the Section Head		1	0	1
4	Release of fabrication drawing to the composite lab operators		2	0	2
	Process-I				
5	Tool required for the lay-up is cleaned and Tool-tech applied	2	4	4	0
6	Pressure plates and Template cutting is done to size the preppreg cutting	2	12	12	0
	Process-II				
7	Prepreg cutting is done with the help of templates and 25 ply lay-up	2	12	12	0
	is done manually in 5 intermediate stages vaccum bagging				
	Process-III				
8	Final Vaccum Bagging and curing of the bracket with the tool in oven	2	8	8	0
	Process-IV				
9	Trimming of the bracket and preliminary inpection	2	4	4	0
	Process-V				
10	Assembling of the drill jig over the conventional milling machine				
	and loading the bracket to it for drilling the P C D holes on top face		3	3	0
	Process-VI				
11	Final inspection of the Bracket and CMM Measurement		2	2	0
	with a few hours of waiting time	2	2	0	2
12	Delivery of the finished barckets to the projects group		1	0	1
	TOTAL TIME IN HOURS		56	45	11
	TOTAL NUMBER OF DAYS ON BASIS OF 8 HOURS PER DAY		7 days	≈ 6 days	≈ 1 days
	%OF VA= VALUE ADDED TIME /TOTAL PROCESSING TIME x 100 =	86%	VA = VALUE ADDED		
	%OF NVA= VALUE ADDED TIME /TOTAL PROCESSING TIME x 100 =	14%	NVA =NON VALUE ADDED		

PROPOSED STATE VSM OF THE PRODUCTION PROCESS OF THE COMPOSITE THRUSTER BRACKET

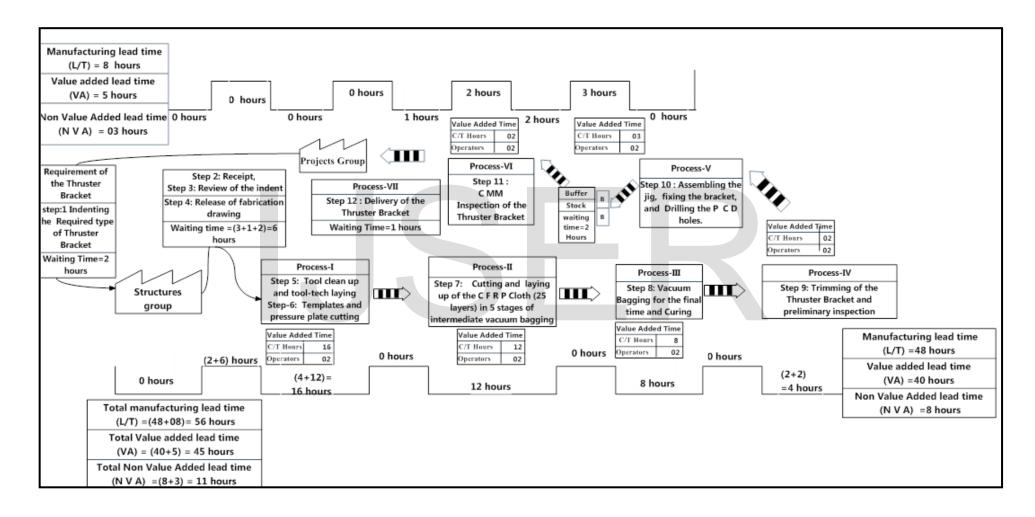


Fig 7: Proposed State Value Stream Mapping of production process of the Composite Thruster Bracket

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3 Results and Discussions:

In the current state VSM the total lead time involved in manufacturing of one thruster bracket is given by:

Total lead time	=	9 days	
Total value added time	~	7 days	
Total non-value added time	*	2 days	
The total (VA) in current state			
Is (7/9 days)	=	78%	
The percentage of (NVA) in			
current state is (2/9 days)	=	22%	

In future/proposed state VSM, The total lead time in involvedin manufacturing of one thruster bracket is given by:

Total lead time	=	7 days	
Total value added time	~	6 days	
Total non-value added time	~	1 day	
The total (VA) in current state			
Is (6/7 days)	=	86%	
The percentage of (NVA) in			
current state is (1/7 days)	=	14%	

Comparing the values from current state to future state reveals that:

- 1) The percentage of total lead time reduction is given by:
- = (Total lead time of current state Total lead time of Proposed state) X 100

(Total lead time of current state)

= (72-56)/(72) X100 = 22.22%

i) The graph shows decrease in lead time from Current state to Proposed state i.e. 9 Days is reduced to 7Days as shown in **Fig 8**:

The percentage increase in value-added time is given by:

= (VA time in current state– VA time in proposed state) X 100

(VA time in Current state)

= (55-45)/(55) x 100 = **18.18%**

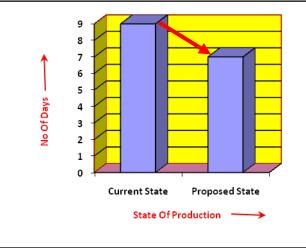


Fig 8: Graph comparing the total lead times in terms of Days between current state and proposed state

Graph shows increases in value added time from current state to proposed state 78% of VA is increased to 86% of VA as shown in Fig 8:

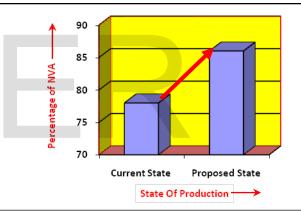


Fig 9: Graph comparing the value added times in terms of percentage reduction between current state and proposed state.

The percentage of decrease in non-value added time is given by:

(NVA time In Current state– NVA time in Proposed state) X 100

(NVA time in current state)

 $(17-11)/(17) \times 100 = 36 \%$

The graph shows decreases in non-value added time from current state to future state 17 Hours is reduced to 11 Hours as shown in **Fig 10**:

=

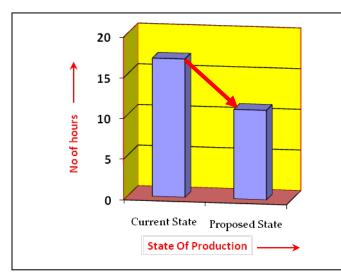


Fig 10: Graph comparing the Non Value Added times in terms of No Of hours between current state and proposed state.

4 Conclusion:

1) The results of the study shows that the total lead time of the composite thrusters bracket for the proposed production process is reduced by using new plug and cure tooling and specially designed universal jig. This is attained by eliminating and minimising the NVA activities from the current state production process, and thus reducing the total lead time.Increase in the VA activities time and decrease in the NVA activities time in the proposed production process, which is evident from the following results obtained.

2) The lead time reductions for the production process of the Thruster Bracket in:

Terms of number of days	=	2 days
The percentage of total lead		
time reduction	=	22.22%
The percentage of increasing		
In Value-added activity time	=	18.18 %
The percentage of decreasing in		
non-value added activity time	=	36 %

- 3) The prepreg cut-out and slot pieces obtained after plug and cure Lay-up can be utilised for another application named Doubler for spacecrafts.
- The future scope of this project is a study on mechanically induced Stresses in a bracket due to the process of drilling.

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