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Cost Optimisation of a Formula Student Monoposto

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***Abstract* - The following paper deals with several cost optimisation techniques which a Formula Student Team can use in their daily functioning for building a cost effective and budget friendly vehicle. This paper will throw light on various cost curbing aspects a team can use, especially the teams which are newer in the FSAE competitions and are planning for starting a structured team. Also, guidance will be provided for excelling in Static Events such as the Cost and Manufacturing event or the Business Logic Case event held at all the FSAE Competitions world-wide. A proper Financial planning and execution is must for designing and manufacturing a formula student vehicle. Proper Charts, Tables and Graphs have been used for the easy references of students and their teams.**

Keywords- FSAE, Static Events, Cost Reduction, Cost Report, Bill Of Materials(BOM), Radar Chart, Lean Manufacturing, Analysis.

A. INTRODUCTION

1.Background

Formula Student is an Engineering Design event featuring students who are pursuing their Graduation and Post-Graduation from different disciplines of Engineering and Technology. The students of different National and International colleges form their team which collectively designs and builds an open wheel formula type monoposto or race car based upon prescribed set of internationally approved rules and standards, which is further judged and granted technically fit status by recognised experts from the field of mobility engineering. The main objective of this is to comply students with a practical holistic approach of designing and manufacturing of a four-wheel Automobile along-with the skills of management and leadership. It also develops among the students the basic idea of how an industry is operated and functioned. The events organised for the students are divided in to four major parts; which are (i)Technical Scrutineering and Tests (ii)Dynamic Events (iii)Static Events.

The technical scrutineering involves complete inspection of the car, by engineering experts; in terms of mechanical as well as electrical applications as per an internationally prescribed list of technical elements.

The Dynamic Events are permitted for only those cars who have the passed the technical scrutineering, testing the overall Dynamic Conditions of the, manufactured car. These events are a Run against Time. Parallelly comes the Static Events which involves the Design Report presentation event, the Cost and Manufacturing Event and the Business Logic Case/Business Presentation Plan. All these events determine the amount of knowledge Team has gained while designing and manufacturing the car by themselves; and the parameters on which they have performed the research work behind designing or selecting the specific designs/materials for each and every part of the vehicle. All the Teams are further judged on the same basis by Industrial Experts and Judges.

The Cost and Manufacturing Event/Cost Report is a very vital part of the entire preceding. It teaches the Team to take steps which can lead to the cost optimisations of their Formula Student Vehicle.

2. COST AND MANUFACTURING EVENT/COST REPORT

The main motive behind conducting this event is to determine the Team's knowledge behind the manufacturing processes used and the costs involved in making the car. This consists up of the trade-off decisions, design optimisations made, smart manufacturing techniques, cost reductions involved since last manufacturing, make or buy decisions and the differences between mass and prototype, design and production. Other factors included are Financial and Resource planning, Environmental Influence of Vehicle Production, etc. This event is divided in to two parts (i)Bill of the Materials and Costed Bill of the Materials (ii)Cost Discussion.

2.1 Bill of the Materials(BOM) and Costed Bill of Materials(CBOM)

The BOM is a sorted list of each and every vehicle part along-with the processes used to manufacture them and the fasteners and tooling used to assemble them to the car. The CBOM consists up of the costs involved for each of things mentioned above.

The BOM is broken down in to the manner-

i. BOM to Systems. As per the Internationally followed FSAE Rule Book systems are of Eight types namely, Brakes, Engine and Drivetrain, Electrical, Tubes and Spaceframe, Miscellaneous Fit and Finish, Steering, Suspension, Wheels and Tires.
ii. Systems are further broken into Assemblies.
iii. Assemblies into Parts
iv. Parts into Materials used and Processes used to manufacture it for the machined parts.
v. Processes are further broken into Fasteners used and Tooling involved to assemble the parts with the vehicle.

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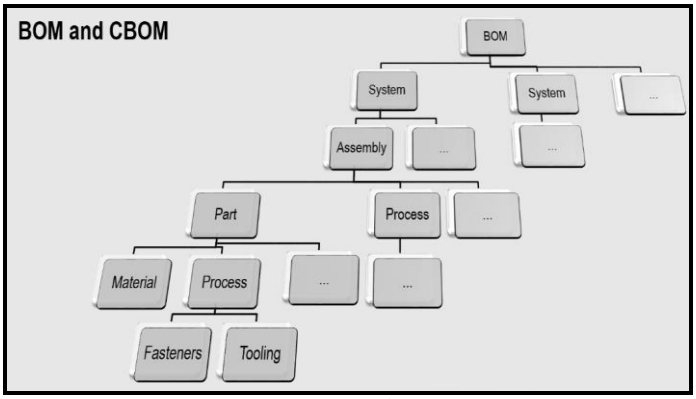

Fig 1: Characterisation of BOM/CBOM

Area of Commodity	Asm Code	Assembly	Rev. Lvl.	Part Code	Component	Description	Unit Cost	Quantity	Material Cost	Process Cost	Fastener Cost	Tooling Cost	Total Cost
Brake System	A1000	Brake Line Assembly	AA			Complete Brake Line Asm	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Engine & Drivetrain	A2000	Engine Assembly	AA			Complete Engine Assembly	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Frame & Body	A3000	Pedal and Control Assembly	AA			Complete Control Assembly	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Electrical	A4000	Battery Assembly	AA			Battery Assembly	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Miscellaneous Kit &	A5000	Seat Assembly	AA			Complete Seat Assembly	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Steering System	A6000	Steering rack Assembly	AA			Complete Steering rack	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Suspension	A7000	Damper Assembly	AA			Complete Damper Assembly	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .
Wheels & Tires	A8000	Wheels and Tires Assembly	AA			Complete Wheels and Tires	₹ .	0	₹ .	₹ .	₹ .	₹ .	₹ .

Fig 2: A Common CBOM Template (as per the allocated systems)

2.2 Cost Discussions

This section deals with the team's understanding of the costs calculated in the CBOM, financial planning and resource managements, their understanding with mass and prototype productions, smarter manufacturing techniques which can be used, environmental influence of manufacturing and much more related varied concepts.

B. MOTIVE

The main motive behind Formula Student is to gain the practical knowledge of building a race-car, along-with the understanding of several industrial methods and goals which are involved in the manufacturing of a car in an optimum price.

i. Financial Investments made must be based on proper research and should just not be simply vague.

ii. The market must be thoroughly checked and all the feasible alternatives of any material/part/process should be compared with each other and finally the most cost effective one should be finalised for application.

iii. Gradual Cost Optimisation with the best things included according to the chalked-out budget; should be one of the primary motive of Formula Student.

Understanding the need to curb extra costs and becoming financial-friendly; is among one of the major traits which today's Industrial or Manufacturing sectors demand. So, one needs to be aware of all the Technical, Mechanical as well as Administrative aspects which can lead to cost effectiveness.

C. *COST CURBING STEPS*

i. Raw Material Selection- For any part which is to be designed by the team, proper material selection is the basic step before proceeding for the designing phase. Alternatives to various materials usually used for manufacturing the product, available at lower costs and providing the same properties, must be selected and procured. This will lower the initial cost of the product. Material selection must not be done randomly. Radar Charts or Spider Charts can be plotted on various properties including material cost and the best one should be selected.

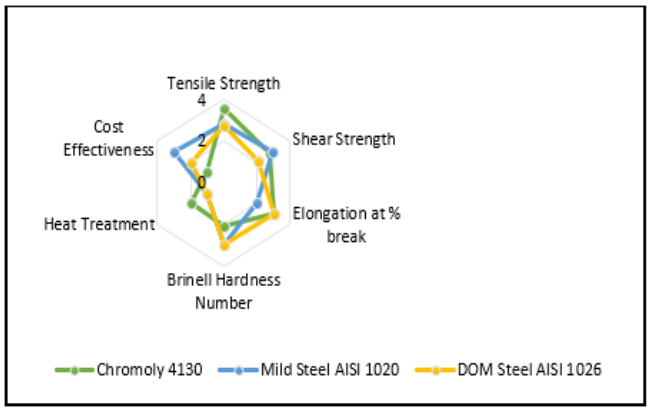

Fig 3: Example of Radar Chart for Material Selection

ii. Process Selection- Choosing the right manufacturing process, also leads in curbing the actual cost of the prototype vehicle. Proper analysis of the process being used must be done before finalising it. Opting for processes of lesser hourly rates will turn out as more cost effective for the team. If the Surface Finish of the part being manufactured can be compromised leading to lesser costs than such processes must be preferred. For example, If the sprocket wheel of the prototype can be machined using Waterjet, then CNC milling should not be chosen for that, as CNC Milling will prove to be costlier than the Waterjet machining. Certain processes even depend upon the raw-materials being chosen.

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TABLE 1: Overall Cost difference from Process Selection of two vehicles of Team Hermes Racing, India

DRIVEN SPROCKET WHEEL					
2016-17			2017-18		
Material Name- Mild Steel	Material Cost(per kg=₹145..36)	₹ 131.14	Material Name- Aluminium T7	Material Cost(per kg=₹747.34)	₹ 485.06
Machining Proccess- Laser cutting, Drilling, Grinding	Machining Cost	₹4,682.00	Machining Proccess- Waterjet Cut	Machining Cost	₹3,900.07
	Proccess Cost-			Proccess Cost-	
	Assemble	₹ 6.32		Assemble	₹ 6.32
	Installation	₹ 6.32		Installation	₹ 6.32
	Drilled Holes	₹ 22.12		Drilled Holes	₹ -
	Fasteners Cost-			Fasteners Cost-	
	Fastners(*12)	₹ 379.20		Fastners(*8)	₹ 252.80
	Tighten	₹ 30.81		Tighten	₹ 30.81
	TOTAL	₹5,257.91		TOTAL	₹4,681.38

iii. Design Optimisations- Optimisations are a key to cost reduction. This may not strike to everyone in general but keeping the designs optimised as much as they could be; will definitely reduce the cost of that specific product. Optimised designs lead to the removal of extra materials from the product and thus lesser raw material in-terms of weight will be required. Also, the manufacturing of such designs will be done at lesser costs because Total Machining Cycle Time will be reduced.

TABLE 2: Cost optimisation by Weight Reduction of an Upright of two vehicles of Team Hermes Racing, India

UPRIGHT					
2016-17			2017-18		
Material Name- Aluminum Premium	Material Cost(per Kg=₹747.34)	₹ 1,617.13	Material Name- Aluminum T7	Material Cost(per kg=747.34)	₹1,121.80
Machining Proccess- CNC Milling	Machining Cost	₹11,376.00	Machining Proccess- CNC Milling	Machining Cost	₹6,658.91
	Proccess Cost-			Proccess Cost-	
	Assemble	₹ 6.32		Assemble	₹ 6.32
	Installation	₹ 6.32		Installation	₹ 6.32
	Drilled Holes(x6)	₹ 165.90			
	Fasteners Cost-			Fasteners Cost-	
	Fastners(*5)	₹ 158.00		Fastners(*9)	₹ 284.40
	Tighten	₹ 154.05		Tighten	₹ 277.29
	TOTAL	₹13,483.72		TOTAL	₹8,355.04
TOTAL WEIGHT OF A PIECE= 2 kg			TOTAL WEIGHT OF A PIECE= 0.584 kg		

iv. Lean Manufacturing- This may seem as an Industrial Term but is a key element required to reduce the extra costs which may involve investments on daily basis. Lean Manufacturing leads to reduction of wastage and a systematic arrangement of various things including the inventory. Money is wasted if extra materials are procured from the market and if some carelessness is shown in maintaining the Stock Inventory. These are some small things which should be kept in mind by the team members while working and taking decisions.

v. Make v/s Buy Analysis- A make or buy research for the spare parts/assemblies should be conducted by the team for opting the most Cost-efficient way. This is mostly used for the Business Logic Case event. The analysis can prove out to be a cost savvy technique for achieving profits for the business set-up and can also create a good impression on the judges.

TABLE 3: An example of Make v/s Buy Analysis

MAKE			
	CNC	Waterjet	Casting
Raw material required for 1 car(kg)	5.17	5.17	0.56
Cost of raw material required for 200 cars	₹ 8,28,580.00	₹ 8,19,940.00	₹ 88,753.13
Cost of machine	₹ 14,50,000.00	₹ 12,45,000.00	₹ 9,45,000.00
Total Labour/Overhead/Equipment	₹ 9,50,000.00	₹ 3,55,265.63	₹ 33,216.56
Total	₹ 32,28,580.00	₹ 24,20,205.63	₹ 10,66,969.69
BUY			
	CNC	Waterjet	Casting
Raw material required for 1 car	5.17	5.17	0.56
Cost of raw material required for 200 cars	₹ 8,28,580.00	₹ 8,19,940.00	₹ 88,753.13
Machining hr for 1 car	11	14	18
Machining cost for 200 cars	₹ 9,75,000.00	₹ 8,300.00	₹ 1,22,011.50
Cost of finishing		₹ 2,80,139.06	₹ 34,316.56
Total	₹ 18,03,580.00	₹ 11,08,379.06	₹ 2,45,081.19

vi. Lesser Fasteners Involved- Fasteners should not be simply used everywhere to attach an assembly or part. Reduction of fasteners must be done to reduce the costs invested in buying them. Lesser Fasteners means simpler designs and are easy access when installed on the vehicle. Also, this will save the assembly and dis-assembly time of the team.

vii. Use Lesser Reaction Tools- As mentioned in the previous point, involving lesser fasteners can curb cost. This is so because doing so will lead to lesser usage of reaction tools and thus reducing the costs required in tightening the Bolts/Nuts and installation of fasteners. This reduces the overhead costs invested and turns out to be an effective point for the Cost Report event.

viii. Proper Analysis and Validation- Parts designed by the team itself, should undergo proper structural/thermal/dynamic Analysis using a CAE software and must be validated completely before getting them ready for machining/manufacturing. Doing so will eliminate the chances of errors and mistakes (if any) before the product is machined/manufactured or else if a part is wrongly made then the entire money invested in that goes in vain and a newer part is required to be made requiring extra money to be invested in it.

ix. Virtual Assembly of Entire Car- Once the designers complete the designing phase, one of the CAD engineer of the team must facilitate with the complete Virtual Assembly of the entire car over any CAD software. This will give the team, a proof that all the parts designed by its members are perfectly made, no Hindrances are occurring in the assemblies, thus all the parts can be proceeded further for manufacturing. Ignorance of this step may direct to Machining/Manufacturing errors which further leads in the processing of wrong dimensional parts wasting, causing impossible situations for assembling them and a sheer wastage of money.

x. Heat Treatment- This may seem as Technical term and a vague point for cost reductions to many, but factually it is not.

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The parts being manufactured must be heat treated after processing to get them endured from failure/fracture. This will help the parts to last for longer durations preventing cost involvements in getting them processed on regular basis. Although Heat Treatments may sometime turn out to be a costlier process for the teams; in such cases pre-Heat Treated Raw Materials can be used as they are commonly available in the market, thus causing cost optimisations for the team.

xi. Welding Techniques- It may not come to the notice of the teams, but they waste a lot of money in the welding processes and in its apparatus. This can be made cost friendly in innovative ways. For example, if a team is doing Metal Insert Gas (MIG) Welding, the Carbon-di oxide gas cylinder used for welding can be mixed with 20% of Argon Gas, which lowers the cost of the Gas cylinder. Thus, expenses are optimised. Also, doing so is an Environmental friendly step which can prevent the release of toxic welding fumes which occur due to the Carbon-di oxide gas.

xii. Simple and Lightweight- Keeping the parts simpler in design and lighter in weight will help in reducing the extra costs which may be required to invest in assembling them or attaching them.

xiii. Machine Setup/Install Costs- Possible reductions in costs must be made during Machine Setup and Installation processes. It proves out cost efficient for the Cost Report of the team.

xiv. Providing Tolerances- Dimensional and Manufacturing tolerances must be provided to the parts to prevent any harm due to certain Human/Machining errors, causing wastage of the part/assembly.

xv. Monitoring Overheads- The day to day overhead costs of the team involved in activities such as Transportation, Procurement, Inventory Control or Promotional/Recreational Activities must be invigilated efficiently for wastage of Money. This will indeed help the team in reducing the overhead costs, which can be used by it for other productive purposes.

D. CONCLUSION

The points mentioned above can be brought in daily practice by the teams and it will surely help them in attaining a very cost-effective Formula Student monoposto; especially for the newer teams in the league. Formula Student design competition is meant to develop a holistic approach of a student towards Engineering and Managerial aspects.

Optimising the costs and making a budget friendly vehicle help the students to deal with Trade-off decisions, which indeed helps in developing their decision-making abilities and enhances their Leadership skills along with their Effective Engineering skills, which are a prime requirement of the Industry. Also, by following the mentioned steps a team can pave their way in making a very Efficient Cost Report and Cost Discussion reports, giving fruitful Statics results at their respective events of participation.

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