Student Formula-1 Car Manufacturing using DFM/DFA Technology

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***Abstract* - This paper presents the research work done in the field of automotive manufacturing. As the design is the major important in manufacturing process. This paper gives an overview of research that is expanding the domain of design for manufacturing (DFM) into new and important areas. DFM for detailed design, design for production, platform design for reducing time-to-market, design for system quality, design for life cycle costs, and design for environment. The paper concludes with some general guidelines. That suggest how manufacturing firms can develop useful, effective DFM&DFA.**

Keywords: Design for manufacture, Application in Automotive product design, F-1.

INTRODUCTION

Design for manufacturability (also sometimes known as *design for manufacturing* or DFM) is the general engineering practice of designing products in such a way that they are easy to manufacture.

Design for Manufacture (DFM) and Design for Assembly (DFA) techniques are often linked together, but generally apply to two different categories. DFM techniques are oriented primarily towards individual parts and components, and aim to eliminate any expensive and unnecessary features that make them difficult to manufacture. DFA techniques relate to sub-assemblies, assemblies and products, and aim to reduce the cost and time of assembly. These types of techniques (DFM/DFA) are helpful to make strategic materials selections and develop unique product designs and processes.

i. Reduce the total number of parts
ii. Reduce or eliminate adjustments
iii. Simplify assembly operations
iv. Design for parts handling and presentation
v. Select fasteners for ease-of-assembly
vi. Minimize parts tangling

A. DFM/DFA can support both manual and automated processes resulting in significant cost savings through simpler designs of F-1 car with fewer components.
B. Actual examples from the automotive industry are used to support the lecture and participants complete actual design efficiency using the DFM/DFA.
C. Design for Assembly (DFA) concerned only with reducing product assembly cost and minimizes number of assembly operations of individual parts tend to be more complex. Reducing overall part production cost of vehicle and minimizes complexity of manufacturing operations.
D. Similarities in Both DFM and DFA seek to reduce material, overhead, and labor cost. They both shorten the product development cycle time.
E. Reduce Part Count and Part Types. Reduced jigs/fixtures cost improved quality and less documentation for Small inventories. Fewer suppliers Simplified production control Fewer Inspections Less rework.
F. Eliminate separate fasteners when possible. Design multi-functional parts by maximum use of the capabilities of individual manufacturing processes. For example, use near-net shape of moulding and casting.

Substitute electronic correction for mechanical adjustment. Use kinematic analysis to guide design rather than gut feeling. Design Parts to be Self Locating and Aligning. Ease of assembly Better performance of product close to breakdown (since parts tend to stay in position rather than come out/off). Higher cost of manufacturing means more operations, in general. Some guidelines of design for ease of assembly. Consider Access and Visibility for Each Operation Ensure adequate clearance for hands, tools, testing probes etc. Ensure that the assembly worker has clear visibility of the mating features.

Motivation

Vehicle design and manufacturing has prime importance in automobile industry. The final cost of a product is directly proportional to the number of parts used in vehicle.So reducing cost and saving of material using advance manufacturing tool. By keeping this point on focus it is needed to develop an F-1 (SUPRA car).

The objectives of the work as follows-

A. Perform the essential stages of a Design for Manufacture process including the analysis required to overcome typical manufacturing difficulties encountered in product design.
B. Reduction of cost of a product through simplification of its design.
C. To develop a model of an F-1 racing car using DFM/DFA methodology.

Literature Review

Reputed journals and publications are review to get rid of advancement in automotive product and contribution in automotive product manufacturing with respect to design. New technologies are understood and their contribution in manufacturing w.r.t. application.

[1]G BalaMurali[1], B B V L Deepak [2], M V A Raju Bahubalendruni[3], Bibhuti Bhusan Biswal[4] he has given an important information Recent advancement in Design For Assembly (DFA) has driven product designers towards minimizing the number of parts in a product so as to reduce the assembly efforts and cost. Many industries are using the DFA concept on their own and there is no particular method or automation to apply the DFA concept for the products. However, there is also no particular method to develop assembly sequence along with applying the DFA concept for the industrial products.

[2] Whiteside1, E. Shehab2, C. Beadle1, M. Percival1

1Rolls-Royce plc. Moor Lane, Derby: in that paper, During progressive product design and development in the aerospace industry, a lack of effective communication between the sequential functions of design, manufacturing and assembly often causes delays and setbacks whereby production capabilities are unable to realize design intent in high-complexity product models.

[3] Jeffrey V. Herrmann, Joyce Cooper, Satyandra K. Gupta, Caroline C. Hayes, Kosuke Ishii: This paper covers DFM and concurrent engineering, DFM for conceptual design, DFM for embodiment design, DFM for detailed design, design forproduction, platform design for reducing time-to-market, design for system quality, design for life cycle costs, and design for environment. The paper concludes with some general guidelines that suggest how manufacturing firms can develop useful, effective DFM tools.

[4]Triya Nanalal Vadgama, Mr. Arpit Patel, Dr. Dipali Thakkar: A modern Formula One (F1) Racing Car has almost as much in common with an aircraft as it does with an ordinary road car. Aerodynamics has become a key to success. the creation of down force, to help push the car's tyres onto the track and improve cornering forces and design related information.

Methodology And Experimental Investigation

Chassis design

In terms of the chassis itself, there are a multitude of construction types allowed in the student formula competition. each providing their own advantages and disadvantages. A carbon fiber monocoque can be used by teams which having extensive amounts of research and resources into the development of carbon fiber structures. Carbon fiber is a composite that possesses twice the strength of steel, yet is five times lighter, making it the perfect choice for a chassis .any team can prepare this chassis design, taking advantage of its light weight and relative strength. A monocoque is essentially a structural skin, where the body of the vehicle supports the external loading that is being applied from the suspension, brakes, engine, etc. Since the monocoque is also the external body of the vehicle, it is also made to be aerodynamic. The monocoque chassis also must be crash tested and proven to satisfy minimum safety standards set by the design judges. Despite the advantages of this chassis design, there is one glaring drawback; it is very expensive in both cost and time to design and manufacture. At this current stage, a carbon fiber monocoque is not a feasible design choice for this project. Aluminum has been successfully used by various universities in the student formula competition. As a space frame, aluminum is not a likely candidate; as per the rules any aluminum tube member must be made thicker than a comparable steel member. This, combined with the fact that aluminum is not as rigid as steel and is much tougher to weld reliably, makes it a poor choice for a space frame. teams may be decide to use aluminum do so in a monocoque form. Similar to a carbon fiber monocoque, the aluminum frame is also considered the external body of the vehicle. But, an aluminum monocoque does not offer as much weight savings as a carbon fiber one. Thus, for the purpose of these types of project, the extra expense needed for an aluminum space frame is not justified by the benefits expected. The steel space frame is the standard among student formula team. Although heavier than other chassis design, it offers ease of use in material machinability, welding, and cost. For teams who are new to the student formula competition and who may not have a myriad of manufacturing resources, this chassis is the perfect starting point for the first few prototypes. When selecting materials for motorsport applications the most common factors considered are strength, cost and weight . In order to design a competitive vehicle it must be light and yet strong. Some of the common material other than carbon fiber and aluminum are cold-rolled steel, and 4130 chrome-moly steel**.**

FIG-1 Chassis Frame Design

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FIG-2 Chassis Frame & Engine Mounting

FIG-3 Final product of DFM/DFA Student formula car

Suspension design

The suspension design is not heavily regulated like that of the chassis. The vehicle ride height and suspension style are the two main criteria for suspension design; thus providing ample room for design creativity and material selection. Currently the two main material considerations are 4130 chrome-moly steel and aluminum, both with their own sets of benefits and deficits. When using 4130 steel, the A-arms and push rods can be thinner and in turn render an overall smaller suspension package. In comparison, when using aluminum, the A-arms will require a larger radius and greater thickness in order to maintain the same strength and safety

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factor. Although it is possible to optimize an aluminum design with a greater safety factor and less weight the next problem arises during manufacturing of the suspension arms. Aluminum is much more difficult to weld; an inexperienced welder may create less than favorable welds thus impeding the performance of the suspension, creating a concentration of stress as well as a potential fracture point [3]. Further design and development will yield a strong comparison between the two systems, ideally representing one design clearly more effective than the other.
In formula one as well as student formula one vehicle which is working at very high speed so while at cornering there will be maximum amount of weight transfer in lateral and longitudinal directions; so to avoid any type of misbalance of vehicle there should be perfect suspension system equipped in vehicle to avoid any type of unexpected situation while cornering at high speed. To make this sure while designing by considering all parameters double wishbone installation in both front and rear side to get more easy control of wheel alignment and wheel travel to get expected result. But especially for rear suspension the amount of stiffness required in suspension is more than front suspension to avoid losses in power transmission while being smooth working of power transmission.

Front Suspension
For front suspension there are many choices to select but from select double wishbone type of suspension because of its high load handling capacity and rigid support to the wheel geometry. It is ease to control Camber angle, Castor angle and Kingpin inclination angle with double wishbone system.

Rear Suspension
For rear suspension it should be rigid enough to provide more stiffness to wheel travel otherwise it may create problems for transmitting power to the wheel from gearbox. Also it should have very low camber angle and castor angle to transmit power effectively. To meet all these requirements the type of system select double wishbone suspension which is adjusted to very low camber change phenomenon in damping.

Roll Centre
At the time of hard cornering at high speed total weight of vehicle get laterally and normally transfer to one side of the vehicle from deviating with C.G. It is having many adverse results of it as it disturbs the handling of driver and also stability of vehicle which may lead to serious accidents or damage to vehicle and driver.So to avoid this there should be minimum deviation of roll center vertically and horizontally**.**

Engine& Transmission
Intake System According to the student formula rules the intake system must have a limited intake diameter. The restrictor must be 19mm across when using E85 as the fuel. It is important to try to avoid turbulent flow as much as possible. This can most effectively be done by making the restrictor in the shape of a venturi nozzle. The pressure drop is smallest when keeping the difference in diameter relatively small, so that the difference in velocity is small and in turn the pressure drop is small as well. This can be seen when looking at the Bernoulli equation and flow rate. Flow rate is calculated with the diameter of the pipe and the velocity of the fluid.

FIG-4 Transmission Using Sprocket

Steering System
Steering system is the system used for controlling the direction of vehicle while in motion in desired direction. There are many types of steering systems available in automobile sector but as there is racing vehicle there should be minimum lag in steering wheel and should also get steer easily in less time with fewer efforts to avoid jerk to the driver. So from various systems you should use rack and pinion type of steering system due to its maximum durability and easy to adjust the controlling parameters**.**

FIG-5 Steering Mechanism

Brake system
The braking system should be designed lightweight and compact while still providing adequate stopping power. The braking system should provide enough braking force to completely lock the wheels at the end of a specified acceleration run, but remain small enough to fit inside of the front wheels and also prove to be cost effective. For designing of braking system determining parameters necessary to produce a given deceleration, and comparing to the deceleration that a known braking system will produce. Consider some assumptions about the car before the necessary before calculation. Assume the weight of car with

driver, and the location of the car's CG approximately based on the positions of the engine and driver. The first step in the design is to choose appropriate values for these variables based on several factors, including what components are currently available from racing supply companies, component size, and driver input. Choose. The size of the brake rotor based on what is available from vendors.

Brake Pedal

The brake pedal is designed using an motion ratio, and use first-class lever. This allows the brake master cylinders to be located further rearward in the car, reducing the chassis length and mass moment of inertia. To determine the loads for the pedal, try to push as hard as possible on a scale while in a seated position.

Standard Components used for vehicle

The systems of student formula car are bounded by the rules and guidelines. The rules bounding the chassis and suspension should add to the appendix. For the chassis development specify material and dimensions of the tubing for the frame. Correct ergonomic and driver placement also needs to be taken according to the rule book. Driver's helmet needs to be under the front and rear roll line by 2 inches. For the suspension, the wheel bases of the vehicle need to be more than 60 inches. Proper component and center of gravity awareness is also advised and will be tested for during competition. Safety is the number one concern (consideration) when regarding a race car design, manufacturing and testing.

Observations and Conclusion

The scope of DFM methodology has expanded in many ways: to applications for different phases of design, to manufacturing system performance, to platform design and system quality, andto decrease life cycle cost and environmental considerations. This research amalgamated DFM/DFA principles and ProcessCapability knowledge into the creation of a tangible Process to facilitate the release of an engineering model forproduction. This framework was founded on an analysis of the current practice of product definition and development across the automotive and aerospace sectors and promotes the identification of the major stages and activities within the progressive release of a model in order to support manufacturing production like vehicle manufacturing.

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Biography

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