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A Monograph on Cost Optimization in Automotive Manufacturing

A Value Engineering and Functional Analysis Approach

M. Manikandan
K. Karthika

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M. Manikandan
Indian Institution of Industrial Engineering, Navi Mumbai, India.

K. Karthika
Department of Mathematics, SAS, Vellore Institute of Technology, Vellore, India

DeepScience

Published, marketed, and distributed by:

Deep Science Publishing
USA | UK | India | Turkey
Reg. No. MH-33-0523625
www.deepscienceresearch.com
editor@deepscienceresearch.com
WhatsApp: +91 7977171947

ISBN: 978-93-7185-590-7

E-ISBN: 978-93-7185-712-3

https://doi.org/10.70593/978-93-7185-712-3

Citation: Manikandan, M., Karthika, K. (2025). *A Monograph on Cost Optimization in Automotive Manufacturing: A Value Engineering and Functional Analysis Approach*. Deep Science Publishing. https://doi.org/10.70593/978-93-7185-712-3

Preface

In Chapter 1, we describe our problem and deliver the aim and objective of the project. Also give a justification why we must choose this problem. The main aim of this project is to reduce the chain case cost by 21% in two - wheeler products using value analysis, value engineering and functional analysis. We will provide our month wise plan of work to achieve the target in this chapter.

In Chapter 2, we will elaborate the details of the organization TVS Group. The products of the TVS group, process, facilities which are available in the organization will be discussed in this chapter. We will provide the organization structure, its business profile, achievements, awards and the milestone of this organization will be brief out in this chapter.

In Chapter 3, we will state the problem and discuss in detail the importance of the problem. It is necessary to retain the contribution of the product without increasing the selling product to sustain the market share. We need to reduce the cost of a chain case to retain the vehicle contribution is our problem. Also, we will describe the reputation of a chain case before making the cost reduction approach. So we will clearly explain the scope, historical perspective, cause and effect and criticality of the problem in this chapter.

In Chapter 4, we are going to discuss a few topics which are most relevant to this project. Also, we have surveyed the results from various research articles and case studies in the precise topic. Literature on automotive industry and need for cost reduction, value analysis and value engineering, functional analysis, metal to plastic conversion and Qc techniques.

In Chapter 5, the vast amount of data will be gathering which are related to our project. Data gathering will be useful for two main purposes of process improvement and cost-effective solution. Finally, it will guide us to find the best cost-effective solution for process optimization, material selection across a different area of application.

In Chapter 6, we will discuss the choice of techniques which is required for our problem discussion. We will discuss the function analysis with VE, function tree, function cost and finite element analysis. We will provide an analysis of plastic and metal. Also, we elaborate the scope of our in this project.

In Chapter 7, we will give a justification that plastic will be the better one than metal. Again, we will choose the type of plastic that will suit for the chain case more and will help to reduce the manufacturing cost of chain case. Design of chain case is very important, so we will be attempted to redesign the already existed chain case. For improvising the design, we redesign the internal design clearance, and we provide a procedure to overcome the chain cover rubbing also. Not only these changes, also we will improve the moulding design, gating design, cooling system and cooling fixture. We explain in detail about the process, packing improvement and validate the concept and selection.

In Chapter 8, we discuss the overall results of this project in a different scenario. Validate the test result in the initial stage and try to find the fault in the process. After identifying the fault, we adopt the necessary actions and rectify the problem. At the end of the stage, we implement the changes in the vehicle and test the output. If everything is working properly, then we will get approval and validate the status of the product. The expected time, cost, effort, and overall expected benefits are described to validate the result. Mainly it focuses on the achievement from this project and methodology adopted during its implementation.

In Chapter 9, we will summarise the project, discuss the limitation and gains of our study. Also deliberate the scope of future wok in this chapter.

M. Manikandan
K. Karthika

CONTENT

CHAPTER 1

Introduction

1.1 INTRODUCTION OF SUBJECT

India will become the 3rd largest automotive market by the end of 2021. The Automobile industry in India is one of the largest employers with an ecosystem of more than 50 manufacturers and supporting ancillaries across various categories of vehicles. Although the year 2019 was a challenging year for the Indian Automobile market, things are gradually transforming and expected to boost sales.

The two - wheeler market in India is forecasted to expand at a CAGR of 7.33%, and reach a sales volume of 24.89 million units by 2024, from 21.19 million in 2019. The Indian automobile sector is experiencing a slowdown since September 2018, which is likely to ease by the second half of FY 2020.

In the global competition, companies are struggling to achieve a competitive edge. The Indian government's unforeseen announcements regarding the norms of BS - VI transition and the electrification of two -wheelers by 2025 have made the market volatile. However, the automobile sector is expected to recover by mid - FY 2021 as per speculations of industrial experts.

Another major aspect is increasing of the cost of two – wheeler spare parts. As costs associated with manufacturing automobiles continue to increase as a result of the fluctuating prices of raw materials and the need for manufacturers to keep pace with industrial and technological advances, many manufacturers are putting a greater emphasis on cost reduction in order to increase their competitiveness, sustainability, and overall profits.

1.2 PROBLEM BACKGROUND

The automobile industries are facing the problem to manage the cost of all kinds of two - wheeler spare parts because the costs of merchandise are increasing tremendously in the market. The high price of raw materials is one of the biggest issues in the automotive industry, accounting for almost half of the total cost of manufacturing a vehicle. Vehicle manufacturers' dependence on these raw materials especially steel leaves them vulnerable to the negative effects resulting from global fluctuations and hike in prices. Also use of aluminium, which is twice as expensive as steel but considerably more lightweight, reducing the cost of materials will become even more important.

From the above discussion, we understood that raw material cost plays one of the important cost drivers for chain cover cost. The chain cases are manufactured using high - cost materials like plastic, various synthetic rubber, aluminium, steel, copper, silver, tungsten, etc. The usage of high - cost material has to be optimized or alternative material to be explored for reducing the cost of material and their by increasing value to the customer. The problem behind the situation is, commodity prices are not controllable and it is market - driven. A challenge to TVS - M is to do cost management to ensure acquisition cost or material cost within the specified target and that should be improved.

1.3 PROBLEM ON HAND

In this current scenario, we are now in the position to find a solution to the challenges in the cost increasing of two - wheeler spare parts. In this project initially, we are deciding to renovate the material of chain case from metal to plastic and at later stage redesign the chain case structure using QC technique, VAVE and functional analysis. We hope that will help us to achieve the cost reduction of chain case from available chain case cost of Rs. 120 to our target price of Rs. 94.

1.4 IMPORTANCE OF THE PROBLEM

- Material cost reduction.
- Improve vehicle contribution and EBDITA.
- New feature of chain cover.
- Choosing alternate material.
- Optimizing the moulding design of chain cover.
- Injection moulding process.

1.5 AIM, OBJECTIVE AND SCOPE OF THE PROJECT

Global competition made industries to focus on competitive edge for achieving company goal by improving value to customer. Manufacturing high quality products with low cost will facilitate in achieving competitive edge to the organization. The main aim of this project is to reduce the chain case cost by 21% in two - wheeler products using VAVE and FA.

The objectives of this project are described below.

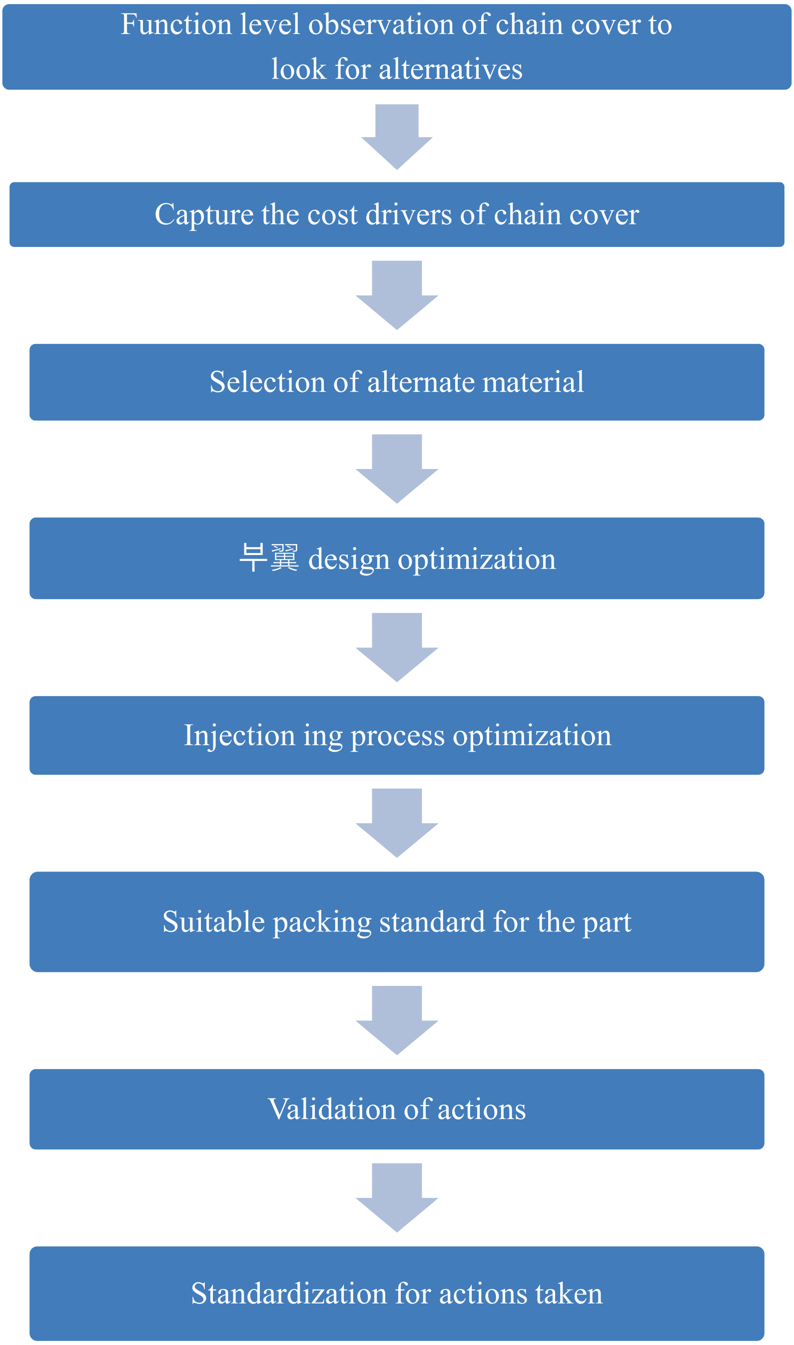
- To study in detail about the TVS organization.
- To study how the automotive industry plays a major role in economic growth for our country.
- To implement VAVE in this project and study how this will contribute much to the cost reduction of the automotive industries.
- To analyse the plastic chain case.
- To analyse the type, material and image of different kinds of two – wheeler's chain cases.
- To describe the project approach.

Plastic plays a major role in benchmark products. The scope of this project is to reduce the cost of making the chain case in two – wheeler industry, by the way of changing the material of chain case from metal into plastic. To optimize the process of manufacturing chain cover is described below.

- Function level observation
- Cost drivers
- Function tree & cost
- Selection of materials
- Product redesign
- Design improvement
- Mould development
- Injection moulding process
- Design verification & validation
- Quality improvement.

1.6 PLAN OF WORK

The portfolio features included in the presentation of project are,



In Table 1.1, P – represent for plan, and A – represent for action.

Activity		July - 20	Aug - 20	Sept - 20	Oct - 20	Nov - 20	Dec - 20
Function level observation	P						
	A						
Asses the cost drivers of chain cover	P						
	A						
Function tree diagram	P						
	A						
Evaluate the function cost	P						
	A						
Selection of alternate material	P						
	A						
Product design optimization	P						
	A						
Mould design optimization	P						
	A						
Mould development	P						
	A						
Process optimization	P						
	A						
Packing standard optimization	P						
	A						
Design verification with tooled up samples	P						
	A						
Test results validation	P						
	A						
Conduct trails and check	P						
	A						
Standardization	P						
	A						
Conclusion	P						
	A						

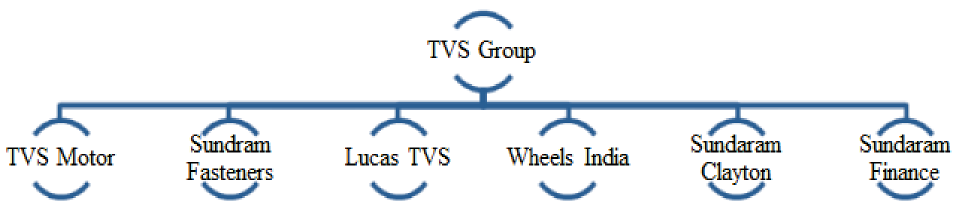
Table 1.1: Development time plan

CHAPTER 2

DETAILS OF THE ORGANIZATION

2.1 INTRODUCTION OF ORGANISATION

Group holding company TV Sundram Iyengar & Sons controls the TVS Group and flagship units such as TVS Group, with group revenues of more than US$8.5 billion, is an automotive conglomerate company, specialising in the manufacturing of two-wheelers, three-wheelers, auto-components, hardware electronics, high tensile fasteners, die casting products, brakes, wheels, tyres, axles, seating systems, corrosion management, fuel injection components, electronic and electrical components and many more. TVS Motor Company Ltd (TVS Motor), a member of the TVS Group, is the largest company of the group in terms of size and turnover.



2.2 THE ORGANISATION

T.V. Sundaram Iyengar began with Madurai's first bus service in 1911 and founded T.V.S, a company in the transportation business with a large fleet of trucks and buses under the name of Southern Roadways. The growth of the TVS group is discussed below.

2.2.1 PRODUCTS

TVS Motor will be one among the top two two-wheeler manufacturers in India and one among the top five two-wheeler manufacturers in Asia. TVS Motor will have profitable operations overseas especially in Asian markets, capitalizing on the expertise developed in the areas of manufacturing, technology and marketing. The thrust will be to achieve a significant share for international business in the total turnover. TVS Motors has always signed very effective brand ambassadors for its different range of products and few products of the organization are listed below with the invention of the year.

- 1972, 76 – Sundaram Clayton was founded, Hosur plant manufactured mopeds.
- 1979 – Moped Division at Hosur to manufacture TVS 50 mopeds.
- 1980 – India's first two-seater moped rolled out in Hosur.
- 1982 – Technical assistance agreement with Suzuki Motor Co Ltd of Japan.
- 1985 – Lakshmi Auto Components Pvt Ltd was founded.
- 1986 – The company was changed from Indo Suzuki motorcycles to TVS Suzuki Ltd.
- 1992, 93 – Launched two modes motorcycles, Samurai and Shogun, TVS Scooty.
- 1999 – 2000, TVS Suzuki Ltd was amalgamated with Sundaram Auto Engineers Ltd.
- 2001 – Removed the word "Suzuki" and named as TVS Motor Company Ltd.
- 2002, 03 – Launched TVS Scooty Pep and the upgraded version of Fiero.
- 2003, 04 – Launched TVS Centra, New Victor GL, Fiero F2 & Fx and Scooty Pep.
- 2004, 05 – Launched TVS Star, New Victor GLX, GX and Scooty Pep 'Splash' series. 2006, 07 – Established a new plant in Himachal Pradesh and Karawang in Indonesia. Also launched StaR City ES, StaR Sport, Scooty Teenz and 99 Colors on Scooty PEP.
- 2007, 08 – Launched TVS Flame, Apache RTR, StaR Sport&City 110 cc, Scooty TeenZ Electric.
- 2008, 09 – Launched Scooty Streak, Scooty Pep+ and Apache RTR RD.
- 2009, 10 – Launched TVS JIVE and TVS Wego. They exported TVS Apache to Brazil.
- 2014 – Launched StaR HLX 125 Motorcycle in Tanzania and TVS StaR City+.

- 2015 – TVS & Kangra Central Co-operative Bank in Himachal Pradesh sign MOU.
- 2016 – They entered into a partnership with Snapdeal to sell online.
- 2017 - Launched TVS Apache RR 310.
- 2018 - Launched TVS NTORQ 125, TVS SmartXonnect (India's first connected scooter), TVS Apache RTR 160 4V, 110cc commuter motorcycle - TVS Radeon.
- TVS is expected to launch 7 bikes in the year 2020-2021. TVS Victor, TVS Apache RTR 310 and TVS Apache RTR 200 Fi E100 are launching soon in India at an estimated price of Rs. 56,622, Rs. 1.99 Lakh and Rs. 1.20 Lakh, respectively [1].

2.2.2 PROCESSES

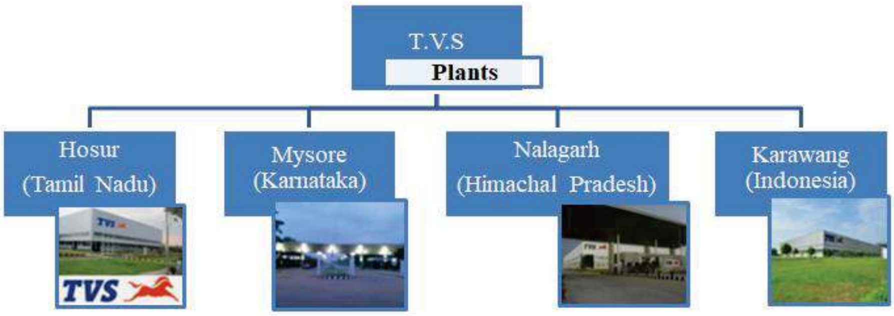
TVS Motor will be responsive to customer requirements consonant with its core competence and profitability. TVS Motor will provide total customer satisfaction by giving the customer the right product, at the right price, at the right time. The company is divided systematically into several departments. Each department has a specific part of the organization process to do.

- Marketing department will collect data from society and give its input to R&D (Research & Development).
- Business planning people will study the data of marketing and account details of the finance department and they will decide the production target of the year and profit to be achieved.
- Based on the above data PED (Production Engineering) will plan for increasing the line capacity.
- HRD (Human Resources & Development) will plan for manpower requirements.
- Factory production department will plan the monthly production based on marketing data.

- The quality department will assure produced the products.
- After assurance of quality, product will be moved to warehouse.

2.2.3 FACILITIES

TVS Motor Company (T.V.S) is an Indian multinational motorcycle company headquartered in Chennai, India. The company has manufacturing plants located as seen below.



The facilities of the organization are discussed below

- **Infrastructure:** Infrastructure plays an important role in the economic growth of any country. It has a very good lean manufacturing setup. TVS Motor has strong in-house product and technology capabilities for the assembly of vehicles, in-house and it has been furnished with multipurpose CNC machines and high-tech processes.
- **Environment:** The Company's manufacturing facilities have been certified under the Integrated Management System (IMS). ISO 14001 (Environment Management System) and ISO 45001 (Occupational Health & Safety Management System) standards are integrated into a common system that meets the requirements of each of the standards. It has introduced the following
  a) Utilization of non-renewable energy
  b) Conservation of water
  c) Material conservation

d) Waste minimization

e) Effluent treatment.

- **Health & Safety:** Implementation of ISO 45001:2018 has helped to improve occupational health and safety performance by proactively preventing work-related injury and ill – health. As part of continual safety improvement, around 643 proactive hazard control measures have been implemented across plants. The Company has achieved a reduction of 33% in the frequency rate of accidents compared to the previous year.
- **Cutting Edge:** TVS Motor will hone and sustain its cutting edge of technology by constant benchmarking against international leaders.
- **Total Quality Management (TQM):** TVS Motor is committed to achieving a self-reviewing organization in perpetuity by adopting TQM as a way of life. TVS Motor believes in the importance of the process. People and projects will be evaluated both by their end results and the process adopted.
- **Cost Management:** The Company continues to focus on all the elements and drivers of cost. Raw materials, components and conversion cost constitute major elements of material cost. In the area of fixed cost, a similar systematic approach of deployment of cost reduction is being done.
- **Research and Development:** The Research and Development (R&D) team continued its focus on in-depth customer understanding, technology development and design innovations.
- **Information Technology:** Company has developed new products with connected technologies and developed skills to take them to the next phase.
- **Human Resource Development (HRD):** Constituents of the Human Resources Development framework followed at the Company include Workforce planning, Employee engagement, Performance & Compensation management, Learning and

Development, Career & Succession planning and Organization Development. Towards sustenance and delivering improved results, these constituents have a structured approach, policies and standard operating procedures which are reviewed and updated periodically.

- **Corporate Social Responsibility (CSR):** CSR activities have already been textured into the company's value system through Srinivasan Services Trust (SST), established in 1996 with the vision of building self - reliant rural community.

2.2.4 ORGANIZATION STRUCTURE

The structure of the organization is as seen in Fig. 2.1, in a hierarchy, third, fourth and fifth stages will be remain the same for the remaining HOD's

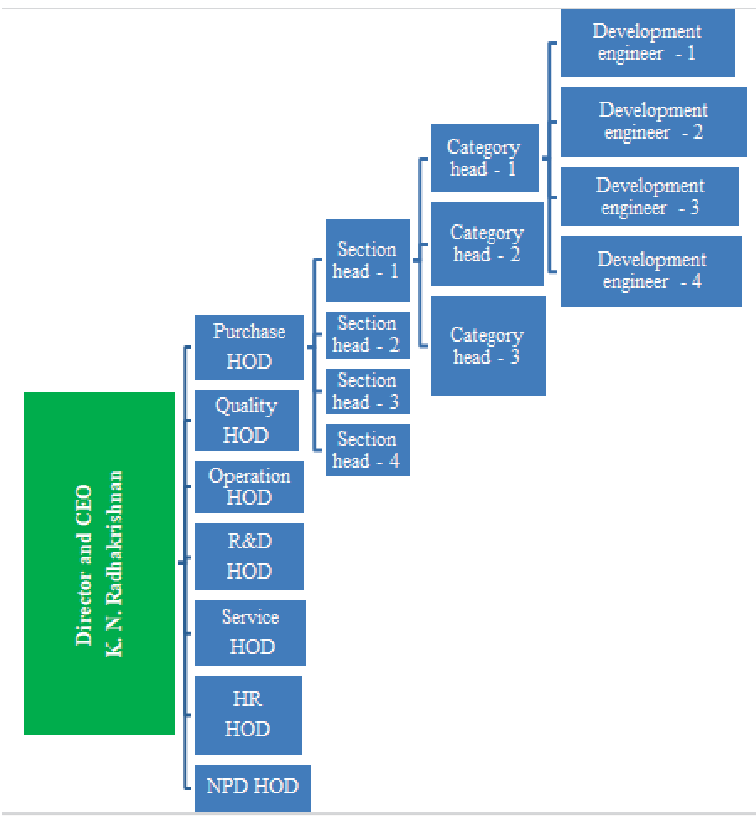


Fig. 2.1: TVS organization structure

2.3 ORGANIZATIONAL BUSINESS PROFILE

TVS Motor has footprints globally, including geographies like the Middle East, Africa, SE Asia, Indian subcontinent, Latin & Central America. TVS Motor Company is the third largest 2-wheeler company in India with revenue of over ₹18,217 cr (over US$2.9 billion). It has an annual sale of more than 3 million units and an annual capacity of over 4.95 million vehicles.

TVS Motor is also the 2nd largest exporter in India with exports to over 60 Countries. A member of the TVS Group, it is the largest company of the group in terms of size and turnover. TVS Motor manufactures the largest range of 2-wheelers, starting from mopeds, to scooters, commuter motorcycles, to racing inspired bikes like the Apache series and the RR310. Whatever your requirement is we have one for everyone.

TVS Motor's strength lies in its extensive research and development, resulting in products that are industry leading in terms of innovation. We at TVS deliver total customer satisfaction by anticipating customer needs and presenting quality vehicles at the right time and at the right price. TVS has always stood for innovative, easy-to-handle, and environment – friendly products, backed by reliable customer service. More than 33.5 million customers have bought a TVS product to date. TVS products give you only reasons to smile [2].

TVS group earned many prestigious awards for various categories. Few awards will be listed in this section. TVS plays a major role in the automobile industry, will initiate many new things. Also, we discuss the milestone of the organization in detail in this section.

2.4.1 AWARDS OF TVS GROUP

TVS Motor won many prestigious awards [3].

- 2007 - Team Tech, SAPACE Awards.
- 2010 - SAP ACE Award for Consumer Excellence, Silver EDGE award

- 2012 - CII ITC Sustainability Awards.
- 2013 - Silicon India Mentor Graphics Best VLSI / Embedded Design - Automotive Award. 2014 - Network for Quality Award.
- 2015 - Two – wheeler manufacturer of the year.
- 2016 - Most Appealing Executive Scooter, Highest in Customer Satisfaction, Most Appealing Premium Motorcycle, Best Executive Scooter, Most Appealing Economy Motorcycle,
- 2017 - Indian Motorcycle of the year
- 2018 - Highest in Customer Satisfaction by J.D. Power Asia Pacific Awards, Most Appealing Premium Motorcycle, Highest Ranked Economy Motorcycle in Initial Quality, Most Appealing Economy Motorcycle, NDTV Car & Bike 2018, Most Appealing Executive Scooter, Motor beam - Bike manufacturer of the year – 2018.
- 2019 - Two – wheeler manufacturer of the year.

2.4.2 ORGANIZATION INITIATIVES

Several initiatives taken as part of the policy management process has facilitated implementing breakthrough initiatives.

- BS-VI transition, Cost reduction, International business market growth.
- Daily Work Management for retirement people.
- The Company has enhanced information security by adopting new cyber security tools.
- Renewable energy resulted in a CO_2 emission reduction of about 60,000 tonnes during 2019-20.
- The company has invested in group captive mode to the tune of 35 MW wind power and roof top solar power of 5.9 MW.

- Towards IT & IOT initiatives, ambient air quality, ambient VOC and stationary emissions are monitored through online systems.
- Corporate Social Responsibility Committee for overseeing CSR.
- Good practices cited in reduction, recycling, and reuse initiatives benchmarked against industry best practices.

2.4.3 MILESTONE OF TVS MOTOR COMPANY

The Company registered sales of 30.9 lakh units of two - wheelers in 2019-20. The two – wheeler industry declined by 14.4% majorly impacted by on – road price increase in a domestic market due to an increase in motor vehicle insurance, mandatory safety norms and tepid demand due to lower GDP growth estimated at 4.7%. The Company's performance was better than the industry with a 11% decline in the first half of the FY 2019-20. In the second half, the Company transitioned into BS-VI emission norms, well ahead of the competition and successfully positioned the entire portfolio with the BS-VI product line up by January 2020 (3 months before the deadline). Exports of two-wheelers in 2019-20 were at 6.79 lakh units with a growth of 9.2% over 2018-19. Sales revenue of spare parts grew by 6%. The total two - wheeler sales in Million, export grew in % and total revenue in Cr is discussed in Table 2.1 – 2.3 [4].

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Sale	1.15	6.6	1.34	1.53	1.28	8.4	1.34	2	2.7	3.14	1.99

Year	2015	2016	2017	2018	2019
Sale	2.41	2.57	2.858	3.367	3.76

Table 2.1: Sales table

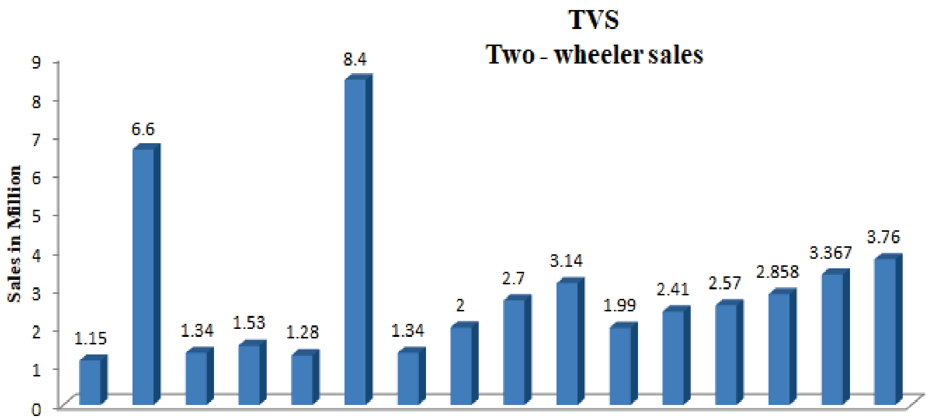


Fig.2.2: Two – wheeler sales of TVS group from the year 2004 – 2019

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Export	176	78	48	30	32	44	1	34	29	22.1	17
Year	**2015**	**2016**	**2017**	**2018**	**2019**						
Export	33.7	1	2.4	2.7	26.4						

Table 2.2: Export grew

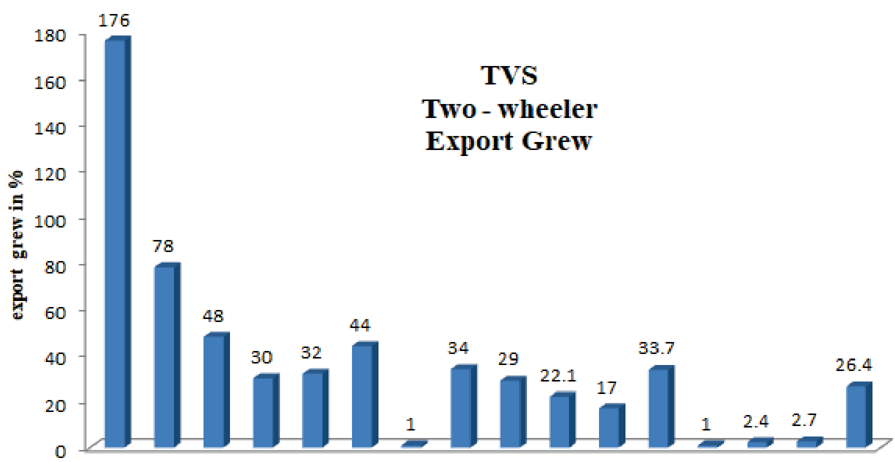


Fig.2.3: Two – wheeler export grew of TVS group from the year 2004 – 2019

Year	2004	2005	2006	2007	2008	2009	2010	2011
Revenue	28566	2955	3306	3928.19	3310.35	3741.18	4484.68	6298.66

2012	2013	2014	2015	2016	2017	2018	2019
7147.91	7088.84	7193.09	10130.83	11295.18	13363	15274.44	18217.46

Table 2.3: Revenue table

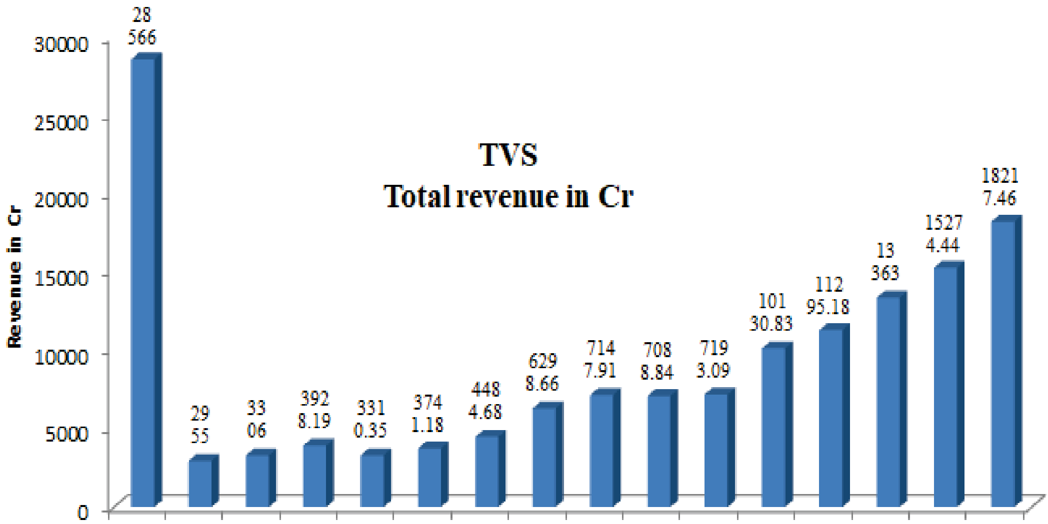


Fig.2.4: Two – wheeler revenue of TVS group from the year 2004 – 2019

Model	Type	Segment	July'19	Aug'19	Sept'19	Oct'19	Nov'19	Dec'19	Jan'20	Feb'20	Mar'20
Zest	Scooter	100-110cc	6,549	9,076	5,101	6,680	4,111	5,116	3,050	378	801
Pep+	Scooter	<100cc	11,228	9,565	9,007	8,027	8,439	7,135	5,136	502	532
iQube	e-Scooter	EV									18
Jupiter	Scooter	100-110cc	57,731	57,849	69,049	74,560	41,007	36,184	38,689	31,440	21,001
Wego	Scooter	100-110cc	1,463	2,152	1,664	906	302	263	266	264	103
Ntorq	Scooter	~125cc	23,335	25,578	27,814	23,842	27,390	21,026	20,644	22,804	9,194
Victor	Motorcycle	100-110cc	4,231	4,053	4,226	3,658	1,370	655	126	11	0
Star City	Motorcycle	100-110cc	5,862	7,028	8,027	8,331	5,105	1,221	10,476	8,209	2,478
Radeon	Motorcycle	100-110cc	13,454	15,330	18,379	17,265	9,045	16,411	6,055	9,314	2,794
Sport	Motorcycle	100-110cc	8,113	6,393	12,360	14,960	7,123	3,186	2,882	8,615	2,585
Apache	Motorcycle	~150-160cc	25,094	26,402	29,889	34,059	29,668	20,302	23,157	32,033	21,764
RR310	Motorcycle	~250-300cc	234	290	326	222	112	76	1	312	27
XL Super Moped	Moped	<100cc	51,192	55,812	57,321	60,174	57,550	45,669	52,525	55,802	32,808

Table 2.4: Different brand of TVS sales report from July 2019 to March 2020

2.5 CONCLUSION

As we know that TVS Motor Company, the flagship company of TVS Group, is the third largest two – wheeler manufacturer in India. The company manufactures a wide range of two – wheelers from mopeds to racing inspired motorcycles. TVS group has flagship not only in the automobile industry. Some of the key initiatives were undertaken by the Company to support the society in fighting COVID - 19. The Company has spent $ 32.33 Cr towards COVID – 19 relief measures, which includes a contribution to Prime Minister's dedicated National Fund "PM CARES" and Tamil Nadu Chief Minister's Public Relief Fund.

CHAPTER 3

THE PROBLEM ON HAND

3.1 INTRODUCTION

Considering the existing market scenario and various factors, those are continuously impacting the cost of the automobile product. It is necessary to retain the contribution of the product without increasing the selling product to sustain the market share. We need to reduce the cost of a chain case to retain the vehicle contribution.

3.2 DETAILS OF PROBLEM

We have to concentrate on the cost reduction of chain cover. Achieving cost reduction is very important in this competitive market. Typically during the product design, quality improvement along with cost reduction techniques can be adopted. We need to understand that the function and importance of the chain case on the vehicle and how it is evolving over the period. It is necessary to retain the purpose of the chain case while doing cost reduction. We need to reduce the cost of the chain case to meet the vehicle contribution without affecting the function of the chain case. So, we deliberate this section in the following manner.

- Automotive industry and need for cost reduction.
- Historical perspective.
- Cause and effect relationships.
- The criticality of the problem.

3.2.1 AUTOMOTIVE INDUSTRY AND NEED OF COST REDUCTION

The automotive industry is a term that covers a wide range of companies and organizations involved in the design, development, manufacture, marketing, and selling of motor vehicles, towed vehicles and mopeds. It is one of the world's most important economic sectors by revenue [5]. The need for cost reduction is discussed under Section 3.2.1.1 to 3.2.1.6, Government initiatives are discussed in 3.2.1.7 and suggestions for how to rejuvenate the automobile industry are given in Section 3.2.1.8.

3.2.1.1 The Current Scenario of Two – Wheelers in Automobile Industry

India has become an established ground space for automotive companies for their growth and development. The Indian automobile industry is one of the driving forces of the economy, contributing about 49% of the country's manufacturing GDP (gross domestic product) and 7.5% to its overall GDP. In the last decade, while the production of two-wheelers in India has nearly trebled, 2019 was a challenging year for the auto industry, which witnessed headwinds due to the slowing economy in the last 6 years. The industry is expected to close with a drop in wholesale dispatches of 12% – 14% in 2019 vis-à-vis 2018.

According to the report, the Indian passenger vehicle market is expected to grow at a compound annual growth rate (CAGR) of 12% to 5 million units by 2020. The two-wheeler market is also expected to grow at the same pace to 29.5 million units, while the commercial vehicle market will grow at a CAGR of 7% to 1.175 million units [6].

3.2.1.2 Market Share in the Automobile Industry

The two - wheeler segment has dominated the market share. Its share in production increased from around 54% in 1970 – 1971 to 80% in 1990 – 1991, close to 75% in the 1990s, 81% in 2017 – 2018.

3.2.1.3 Low Penetration

India has overtaken China to become the world's largest two-wheeler market, mainly due to a faster rate at which India's two-wheeler market is growing as compared to China, which is witnessing a de-growth. The two-wheeler sales in India has grown at a CAGR of ~8% during FY14-18 period with FY18 witnessing a 14.8% YoY growth. The scooter segment grew by 19.9% YoY and motorcycle segment grew by 13.7% YoY. The faster growth in two-wheeler sales is mainly due to rising income levels, growing infrastructure in rural areas and the rising trend of scooterization (especially among women commuters). However, despite India being the world's largest two-wheeler market, India still has a very low penetration level of two wheelers. In India, about 110 out of 1000 people have two-wheelers, which is less than half of penetration levels in Indonesia (281) and Thailand (291).

3.2.1.4 Commodity Prices

In two – wheeler industry, raw material cost is close to 70-75% of the overall revenue of OEMs and as a result, it is a key variable impacting their profitability.

During CY18, the prices of key raw materials such as steel, aluminium and crude-based materials like plastic have seen sharp volatility, which resulted in variation in profitability of these companies despite favourable demand scenario and improvement in realizations.

A majority of two-wheeler OEMs have seen their raw material cost inching up in the last four quarters, which has affected their operating margins, which fell by ~200 bps between Q2FY18 to Q2FY19. However, many companies have resorted to partial pass on of inflation in raw material cost to consumers as the demand momentum was strong until the changes in regulation related to insurance and liquidity crunch owing to an NBFC default impacted the demand scenario. However, many commodities, which are direct raw material like steel and aluminium to the industry, has seen sharp correction towards the end of CY18. Similarly, prices of indirect raw materials like Brent crude oil, lead and rubber also witness correction in CY18. We believe, the recent price hike taken by companies coupled with moderation in raw material prices are likely to help two-wheeler companies to improve its operating performance and thereby their overall profitability.

3.2.1.5 The Key Challenges for Automobile Sector

- Clubbing of various Government regulations leading to an increase in costs and thereby impacting affordability.
- Alternative fuel vehicles, global consolidation, the automotive supply chain, reconnecting with shoppers.
- Low consumer sentiments thereby impacting demand.
- Customers are required to pay a higher upfront insurance premium for two – wheelers.

3.2.1.6 Government Regulation Leads to Hike the Cost of Two – Wheeler

The price of owning a two-wheeler for a common man has increased by 30% in 1.5 years because of the following reasons.

- BS - VI -Indian two-wheeler industry has been witnessing ups and down in recent past, mainly due to changes in regulatory requirements. In March 2017, the Supreme Court ruled to stop selling vehicles, which are not compliant with BS-IV emission standards after 31 March 2017 that coupled with GST implementation related hiccups led to a slowdown in demand for two wheelers post March 2017. Making a two – wheeler BS - VI means re-working the engine components, exhaust setup and this, in turn, results in a significant increase in costs as well.

- AHO - to make roads safer for two-wheelers in India, the government has reportedly decided to mandate 'Automatic Headlamp On' (AHO) in two-wheelers from 2017.
- DRL - From April 2017, two-wheelers in India, like some of the high-end bikes and the daytime running lights (DRLs) will come with headlights that stay on as long as the ignition is on.
- Insurance norms - However, two-wheeler sales once again hit the slow lane, as there was a mandate that third-party insurance to be increased to five years and premium to be collected upfront for two-wheelers
- IRDAI - In addition to this, the Insurance Regulatory and Development Authority of India (IRDAI) in a circular dated September 20, 2018 had made the mandatory increase in the compulsory personal accident cover for two-wheelers from Rs.0.1 mn to Rs.1.5 mn.
- CPA - However, effective from January 1, 2019, IRDAI has unbundled the compulsory personal accident (CPA) cover and permitted the issuance of a stand-alone policy, which is likely to reduce the cost of ownership of a vehicle.
- CBS & ABS - The two - wheeler industry is also likely to see another change in regulation, where all existing models of two wheelers having an engine capacity higher than 125cc are mandatory to have anti-lock braking system (ABS) and for two-wheelers below that capacity are mandatory to have combined braking system (CBS) from April 1, 2019. This move is also likely to increase the cost of a two-

wheeler going ahead as a result we may witness some pre-buying ahead of the implementation of this norm, which may drive the volume growth for two-wheeler companies in the near term.

- HSRP - According to MoRTH, the notification mandates that HSRP, including the third registration mark and the dealers, shall place a mark of registration on such plates and affix them on the vehicle.
- Ad- Hoc- In recent times, the two-wheeler industry has seen ad-hoc changes in the policy environment, which has resulted in disruption in demand scenario and thereby affecting the profitability of these companies. If the uncertainty in the policy environment continues for a longer period then the industry may witness subdued interest for new investments and may affect the long-term sustainable growth of the industry.

3.2.1.7 Government Initiatives

The government incentives to buy vehicles and steps taken to address liquidity crunch, economic growth and infrastructure spending would boost the auto industry's prospects. The sales of two-wheelers are set to get a boost with the government providing tax relief to the middle class and income support to farmers. TVS Motor Company chairman Venu Srinivasan expressed confidence that the budget would support demand for two-wheelers. The budget of the current financial year has empowered and increased the buying capacity of every sector and segment of people. He said they are expected more buyers of two-wheeler vehicles and in turn help the industry’s growth [7].

Finance Minister said that to boost demand in the automobile sector several temporary relief measures will be introduced including an increased depreciation cost for automobiles for corporates and businesses, however, she stopped short of giving a GST cut for automobiles, something the industry has been lobbying for.

- All BS-IV vehicles purchased up to March 2020 will remain operational for their entire period of registration.
- An additional 15% depreciation will be provided on vehicles acquired from now till March 2020, taking the total depreciation to 30 %.
- Further, the increase in the one-time vehicle registration fee, which the government had earlier mooted, will be deferred until June 2020. The automobile industry had argued that an increase in the vehicle registration fee would further hurt demand.
- The automobile industry has been demanding a reduction in GST rate from the current 28 per cent to 18 per cent.
- The auto industry has sought measures, such as a reduction in GST rates on vehicles and abolition of duty on import of lithium-ion battery cells, to encourage electric mobility.
- The industry, which has been facing a downturn for almost a year now, has also sought an incentive-based scrap page policy and an increase in re-registration charges of vehicles to discourage the use of old vehicles [8].

3.2.1.8 Rejuvenations of India' S Automobile Industry

The automotive industry is one of the ripest industries in India. But that does not stop it from being fraught with challenges and issues. Overcoming these challenges will enable the Indian automotive industry to become one of the biggest disruptors in the global market. TVS Motor Company foresees some challenges due to migration to BSVI norms in 2020 and due to the international trade environment. From April 1, 2020, the industry will undertake a significant change in migrating from BSIV to BSVI emission norms. Hence, in the second half of 2019-20, BSVI transition will pose some challenges and the company is gearing itself to meet the same. TVS Motor Company has announced the launch of the Bharat Stage VI (BS6) compliant TVS Jupiter 110 cc scooter, TVS Apache RTR 160 4V & RTR 2004 .

According to Venu Srinivasan, chairman, TVS Motor Company, the measures will provide the immediate relief that the industry was seeking. The government's prompt response has not only been reassuring for just industry, but for the common man as well because the steps will boost liquidity in the market. While there are indications of a global slowdown, this government has demonstrated its resolve to mitigate the impact of that in India through these measures. This is the stability and proactiveness that industry wants. Lobby groups in the sector like Society of India Automobile Manufacturers (Siam), Automotive Component Manufacturer Association of India (ACMA) and Federation of Automobile Dealers Associations (FADA) had also been urging the government to ease financing options for dealers and customers and reduce Goods and Services Tax on two and three-wheelers.

3.2.2 HISTORICAL PERSPECTIVE

Motorcycle has now become one of the most important vehicles for transportation among all. Motorcycles were introduced many years back. We are also familiar with different parts of motorcycles. Motorcycle chain is one of the most important pieces among all. The chain connects the engine and the rear tire of a motorcycle for speed and to run the bike. We all use motorcycles for better transportation and communication and without chain a motorcycle cannot even run at the roads so it has great importance because a chain is linked directly with the engine. Core work of the motorcycle chain is to provide speed and run the bike after ignition.

This piece of a motorcycle requires great take care of its usage. During bike riding because of extra oil or other lubricants used over the chain, it gets dirty and that dirt spread to rider or pillions body. In fact that dirt is also deadly for the chain. To get rid of this problem chain cover is invented. From the 80s motorcycle chain covers are in use. It is mainly necessary for the safety of chains. But nowadays we saw chain covers are used for the safety, few motorbikes didn't even have chain covers, and few have half covers (only the front part) etc. For ensuring the safety of both motorcycle and the rider chain covers are used. Now from bellow, the lines let us know about the advantages of motorcycle chain cover.

- At the 80s motorcycle users used chain cover to get rid of dirt and to remain their clothes neat and clean. To protect clothes from oil and dirt which spread from the chain by using it, chain covers were made.
- In our country chain covers are massively seen at commuter bikes because in our country dust, muds, water on the roadside are common things because of the weather. To get relieved of them and to constant, the effectiveness of the chain covers are necessary at our country basis.
- Extra oils and lubricants which are used over the chain for smoothness can make the tire, rim, riders clothes grimy in this type of situation chain cover gives protection.
- Without these legs can be cut if it gets closer to the chain during the bike is running, pillion shoes can be stuck with the chain, clothes can be trapped with the chain uncertainly etc. problems can be created. That's why chain cover is used.
- Because commuter bikes can carry pillions on it, that's why chain cover is needed for the safety.

3.2.3 CAUSE AND EFFECT RELATIONSHIPS

As the cost of metal is high, it will affect the manufacturing of two - wheeler spare parts. As the volumes are increasing & new mould to be made, it is the right opportunity to look for alternate raw material & get cost benefit. The production volume of the motorcycle (Product A), selected for the project, is high (1200/day) and any cost saving on that will result in substantial benefit to the company. Price of steel has been an increasing trend (10% to 13% YOY). This has been affecting the product contribution, as the selling price of the vehicle cannot be increased continuously as there is intense competition in the market. There is a need for capacity enhancement, considering the increase in demand and current production levels. Hence it is the right time to implement possible improvements if any.

3.2.4 CRITICALITY OF THE PROBLEM

For any organization, profitability is one of the critical measures and it reflects the performance of a company. Also, it will directly improve the brand image and sales. The recent price hike was taken by companies with moderation because of raw material prices. Raw materials are likely to help two - wheeler companies to improve their operating performance and thereby their overall profitability. The prices of metals will be one of the witnesses of the price hike taken be companies on the two wheelers, because they need a profit of their product. It will be the better choice of changing the material metal into plastic because plastics have seen sharp volatility, which resulted in variation in profitability of these companies despite favourable demand scenario and improvement in realizations.

3.3 CONCLUSION

In this section, we have stated the problem and discussed in detail about the importance of the problem in detail. Also, we have understood the reputation of a chain case before to do the cost reduction approach. So we clearly described the scope, historical perspective, cause and effect and criticality of the problem in this chapter.

CHAPTER 4

RELEVANT LITERATURE REVIEW

4.1 INTRODUCTION

In this chapter, we are going to discuss a few topics which are most relevant to this project. Also, we have surveying the results from various research articles and case studies in the precise topic. Literature of review will be sectioning in the following manner.

- Automotive industry and need for cost reduction.
- Value analysis and value engineering.
- Functional analysis.
- Metal to plastic conversion.
- Qc techniques

4.2 AUTOMOTIVE INDUSTRY AND NEED OF COST REDUCTION

In 1997, J. Luis Guasch [9] had provided an overview of the costs and benefits of regulation throughout the world. They have highlighted the potential gains from the reform of regulation and deregulation in developed and developing countries. Also, they had provided some fundamental lessons from the experience with government regulation and make suggestions for improving regulation in developing countries.

In 2010, Susanne Müller [10] described a cost benefit analysis (CBA) of the Materials Off-Shore Sourcing (MOSS) project. The project focused on improving the operation of US inbound intercontinental supply chains of automotive parts. The MOSS project sought to reducing transit time, transit-time variability and inventory by providing a collaborative environment engaging original equipment manufacturers (OEM), suppliers, ocean carriers, logistics service providers, freight forwarders, and customs brokers. MOSS developed an innovative approach to resolving the significant problems of visibility, data quality, and customs compliance. The benefit analysis explains how MOSS contributes to reduce transit-times and transit time variability, and what benefits could be derived from it. The costs analysis considers one-time investments as well as recurring costs of deploying MOSS conforming software as ‘Software as a Service'. The results of the CBA indicate an economically feasible investment with a payback period of 3 months and give support for managers’ preparation of a possible investment decision. Difficulties for MOSS deployment are discussed, with emphasis on collaboration problems within a supply chain.

In 2019, Smita Miglani [11] discussed India’s national policy in light of these developments. The role of government policy, infrastructure, and other enabling factors in the expansion of the automobile and automotive component sectors and the direction they are likely to take for growth path in the next few years are discussed. The author discussed the structure and makeup of the Indian automobile industry, the growth of the sector over the past decades, while the third section discusses the role of government, other enabling factors in the growth of the industry, initiatives in upgrading and innovation.

In 2019, Himanshu Shekhar et al. [12] had studied the battery technologies, its components and functioning, theoretical parameters, the rationale behind the selection of technology and other important technical factors. Also, they had outlined the EV battery value chain in India and the opportunities and challenges in each stage of the chain. They had a deal with the reviewing the EV policies in different countries – Norway, China, Sweden, Germany, The United States, The United Kingdom – and in India (both at the central and state level) and listing and ranking the identified cost-reduction strategies

4.3 VALUE ANALYSIS AND VALUE ENGINEERING

In this section, we are going to present previous studies in the field of value engineering / value analysis. This will provide us theoretical background which will be useful in cost reduction of automotive products. Value engineering (VE) was first conducted by Lawrence Miles in 1947 at General Electric Company, USA. VE is a systematic and organized approach to providing the necessary functions in a project at the lowest cost. This promotes the substitution of materials and methods with less expensive alternatives without sacrificing functionality. It is focused solely on the functions of various components and materials, rather than their physical attributes. Value engineering is also called value analysis [13].

4.3.1 VAVE IN DECISION - MAKING PROCESS

Value Engineering is used at the design stage of a product or process in order to avoid unnecessary costs. A design is scrutinized using the value methodology to establish whether any function can be fulfilled more cost effectively.

Value Analysis is used on existing products or processes to reduce costs. Change is a constant and unless products and processes are continually re-evaluated for more cost effective ways of providing the desired function, a firm is likely to be left sorely behind.

4.3.2 APPLICATION OF VAVE IN AUTOMOTIVE INDUSTRIES

VE can be applied across all stages of the decision - making process, so it can be used to reduce costs across a vast range of functions and systems. These functions and systems are classified as either product or process focused. Although purchasing falls into either or both of these categories, it is considered pertinent to focus on it separately given that the initial application of VE was in fact within the purchasing function and that it remains a key area for cost reduction using the methodology.

4.3.3 VAVE IN PRODUCT DESIGN

VAVE can achieve significant cost benefits in terms of both new product design and product re-engineering. This is best achieved by doing a complete product strip-down and then examining the function of each component in order to identify any potential areas for cost reduction. In the context of the automotive components industry, however, there is limited scope for VA/VE from a product perspective. OEM's have stringent design requirements and thus any design changes have to be approved by foreign parent companies before being implemented. Furthermore, even if approval is granted, it usually takes a significant amount of time and thus, with regular model changes, the time over which the cost saving is realized is often limited thereby significantly reducing the value of the cost benefit.

4.3.4 VAVE IN PURCHASING FUNCTION

A strong emphasis of VAVE as a method of cost reduction is its use in the purchasing function. Not only does the purchasing department have specialised knowledge of markets, materials, standard parts, processes and costs but it can also bring the skill and knowledge of specialised suppliers into the firm's domain.

4.3.5 VAVE IN PROCESSING

The structured methodology of VE provides a firm framework from which to make strategic and operational decisions from a cost cutting perspective, in that it brings order to the often-haphazard approach to cutting costs. Closely examining the desired function of a strategic or operational concept provides a valuable base from which to develop a cost effective strategy and plan for implementation.

4.3.6 INDIAN AUTOMOTIVE INDUSTRIES

The VAVE has two dimensions worth and cost. In Indian automotive industries VE approach is not fully utilized. This is the most effective approach available to identify and eliminate unnecessary costs in design, testing, manufacturing, operations, process, materials, maintenance, etc. It's application to product design and development, specifications and practices are less well known, its effectiveness in these areas has been proven by Ali Mostafaei pour in 2016 [14].

4.3.7 SUMMARY OF VAVE

The use of VAVE in cost reduction is discussed above in detail. We have summarized the application of VAVE in cost reduction with a suitable example.

- Leverage Cost – Effective Processes for New Products.

For example, you can take advantage of VE during the product development stage to evaluate the cost savings of using substitute metals.

- Assess Your Existing Products' Components & Procedures.

For example, if your analysis reveals that your machining processing is costing you more than it would if you were using more fabricated components, you can then modify your manufacturing process to include more fabricated parts and less machining.

- Use Pro-VAVE facilities,

For example, the most complete metal fabricators run facilities that offer full-service custom metal fabrication capabilities, including welding design, finishing, cutting.

4.3.8 RESEARCH ARTICLES IN VAVE

In 2013, Hemanth et al. [15] proposed the problem to reduce material cost in the fabrication part of two -wheeler through VA technique.

In 2007, Ugo Ibusuki et al. [16] had done a case study using VAVE. The proposed approach was validated in a case study focused on the engine-starter system of a vehicle, aimed at improved product cost, functionality and quality accomplishment, in accordance with customer needs and the company strategy.

Ajitanath Patil 2010, [17] QUEST 'Value Engineering team' achieved 38% of savings indirect material cost and reduced part count by 34% in their project. Having a Paint brush does not make one a painter. While they had strived to implement the different VAVE tools, they have realized that the years of experience in product design & development is very essential to achieve the desired objective.

In 2012, Chougule et al. [18] had done a case study in the use of value analysis technique for cost reduction in the production industry.

4.4 FUNCTION ANALYSIS

Functional analysis has similarities to value engineering in that it is applied during the development stage of a new product, but it uses the functions of a product (or service) as the basis for cost management.

"Functional analysis is concerned with improving profits by attempting to reduce costs and/or by improving products by adding new features in a cost effective way that are so attractive to customers that profits actually increase".

CIMA Official Terminology: " Functional analysis is an analysis of the relationship between product functions, their perceived value to the customer and their cost provision ".

4.4.1 FUNCTIONAL ANALYSIS IN AUTOMOTIVE INDUSTRIES

In this current competitive automotive world, cutting down the cost & improving the function for the same cost is the key to winning over the competition. Value Engineering & Value Analysis with a classical VAVE approach through Functional Analysis, FAST methodology, Cost/worth for each function and identification of function for cost reduction & brain storming for idea generation with a cross – function team of design, manufacturing experts for identified functions/parts.

Functional Analysis is a fundamental tool of the design process to explore new concepts and define their architectures. When systems engineers design new products, they perform Functional Analysis to refine the new product's functional requirements, to map its functions to physical components, to guarantee that all necessary components are listed and that no unnecessary components are requested and to understand the relationships between the new product's components.

4.4.2 PURPOSE OF FUNCTIONAL ANALYSIS

There are numerous purposes behind the Functional Analysis which can be seen through developing the Function Analysis Systems Technique (FAST) diagram. They are listed as follows.

- Assuring proper relationships between functions.
- Provides a good basis for classifying the functions.
- Arrangement of the functions can help identify missing functions.
- Clarification of the meaning of function can result from the diagramming of the functions.
- Finding duplicate functions becomes more evident and marks those that may be eliminated or combined with others with the same result.
- FAST can help avoid coming up with the right solution to the wrong problem. Thus expecting to possibly reduce the total cost of the products or services.
- To set the scope of the project undertaking.

4.4.3 ISSUES TO BE CHECKED FOR FUNCTIONAL ANALYSIS

- Function
- Material Specification and Content.

- Material and Manufacturing.
- Standardization.
- Direct Labour Costs.
- Tolerances and Finishes.
- Costs of material

4.4.4 CUSTOMER BENEFITS – FUNCTIONAL ANALYSIS

Customers have benefited with a variety of ideas like Alternate materials/manufacturing process/assembly process etc., & cost savings running into millions (when implemented across huge product volume).

4.4.5 ALTERNATE MANUFACTURE PROCESS – FUNCTIONAL ANALYSIS

When the work which is usually performed in a process can be done in another process, the latter process is called Alternative Process. Such an alternative process is often used when an overload occurs in a process. There will be two alternate manufacture process.

- Cost Reduction
- Easy for welding – further operation

Cost Reduction

Cost reduction is the process used by companies to reduce their costs and increase their profits. Depending on a company's services or product, the strategies can vary. Every decision in the product development process affects cost. Companies typically launch a new product without focusing too much on cost. Cost becomes more important when competition increases and price becomes a differentiator in the market.

Easy for welding – further operation

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by using high heat to melt the parts together and allowing them to cool, causing fusion. Welding is distinct from lower temperature metal-joining techniques such as brazing and soldering, which do not melt the base metal. Choose the easier method for welding.

4.4.6 ALTERNATE MATERIAL – FUNCTIONAL ANALYSIS

The material of chain case can be changed from Sheet metal to Plastic.

- Weight Reduction by 60%
- With injection moulding of mounting features, 6 assembly operations reduced
- With the integration of parts like mounting brackets, about 7+ parts reduced.
- Implemented for more than 5 programs

4.4.7 RESEARCH ARTICLES IN FUNCTIONAL ANALYSIS

In 2015, Ainul Farahin Binti Abdullah et al. [19] presented one of the tools used in Value Analysis Value Engineering (VAVE) methodology; Functional Analysis and its implementation during the New Product Development (NPD) phase. Current vehicle outer door handle has been redesigned through its functions in order to meet customer requirements of having higher value vehicle, by increasing performance while trying to decrease the cost without scarifying the quality, saleability and maintainability. An analysis has been made and discussed using the Function Analysis System Technique (FAST) diagram to achieve product optimization.

Campean et al. [20] developed and implemented a structured approach for functional analysis of a complex system, which focuses on the identification and characterization of interfaces. The proposed approach is based on the principle of separation of the functional and physical domains and development of function decomposition through iteration between functional and physical domains. This is achieved by integrating some existing / known engineering tools such as Boundary Diagram, State Flow Diagram, Function Tree and an enhanced interface analysis within a coherent flow of information. The approach is illustrated with a case study on system level design analysis of an electric powertrain for a full electric light commercial vehicle.

In 2019, Jakhotiya [21] had presented the following. Indian automobile companies and their foreign counterparts operating in India should regularly conduct the following five exercises which should define the next or higher milestones of comprehensive reforms. Analysis and measurement of organizational effectiveness Regular review of the strategic plan to ascertain the quality and quantum of strategy execution and plan for alternate strategies. Review cum audit of PMS to ascertain the relevance of various employee-related policies, processes and programs. Technology Audit to measure the overall effectiveness of present technology in place and the scope for improving or replacing it. Indian automobile companies, their foreign counterparts in India and their business associates can prove to be

(i) growth engines for Indian economy

(ii) global hub for automobile research and experimentation

(iii) providers of indicators of the growth in various sectors of the economy

(iv) change makers in technology, human performance and the overall ecosystem

4.5 METAL TO PLASTIC CONVERSION

Plastic is aiding the driving force to make products lighter, stronger, easier to process, and available in more complex shapes - specifically in the form of composite and high-end polymers. In other words, plastics are still the future. The auto industry has been one of the biggest drivers of metal-to-plastic conversion, as two wheeler makers look for ways to lower the weight of their vehicles and increase fuel efficiency in order to comply with federal mandates. Carbon fibre-reinforced plastics are particularly popular here, as they offer more lightweight options for parts like side panels, and certain polymers can trim weight without compromising the performance of under-the-hood components.

4.5.1 HISTORY

Bakelite, developed in 1907 [22], was considered the first full-synthetic polymer. While other thermoplastics were around before this, Bakelite was a thermoset. Thermosets form strong bonds that cannot be remoulded and can provide relatively strong parts but are difficult to recycle. One option to recycling a thermoset is to simply grind it up and use it as an aggregate in a new part. Adversely, remoulding is possible with thermoplastics. In September 2013, the American Society of Mechanical Engineers estimated, in general, companies can expect to achieve an overall cost savings of 25% to 50% by converting to plastic parts. Plastics can offer indirect benefits in the automobile industry.

4.5.2 DESIGN CAPABILITY AND COST

You do not have to watch the sheet metal fabrication process for very long to take away the fact that metal can difficult to work with and shape. Even with today's technology, metal's inherent characteristics prohibit complex part designs or shapes, such as compound curves or fluid designs from either a material capability or cost limitation.

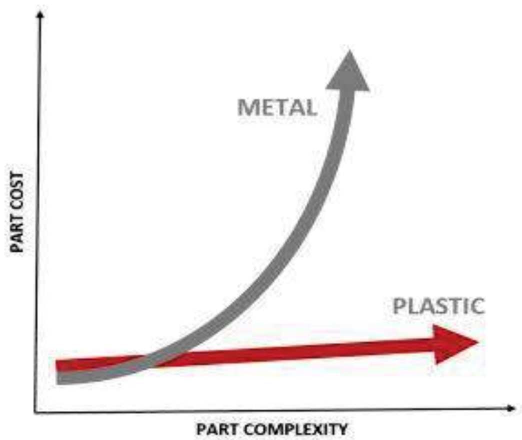


Fig. 4.1: Comparison between part complexity and part cost of metal and plastic

Shaping a metal part can require to die work, welding, grinding, rework, or bending on each individual part produced to achieve design specifications and desired look. In addition, to greatly increasing production and lead times as mentioned above, as part design complexity increases, part cost increases at an exponential rate.

4.5.3 PRODUCTION/LEAD TIME

Whether you are trying to meet a deadline or fill orders for an increase in demand, time to market can be an essential factor to the success of any project. With a dramatically less labour intensive process, plastic injective can save production time, energy, labour, and cost compared to manufacturing components from metal processes.

Plastic Injective Process	Metal Fabrication Process
• Melt the material. • Inject the molten material into a mould. • Let them into cool to a solid state. • Remove the hardened material from the mould.	• Fixture/die construction. • Programming. • Cutting, bending, welding. • Cleaning welds, finishing. • Paint preparation. • Painting.

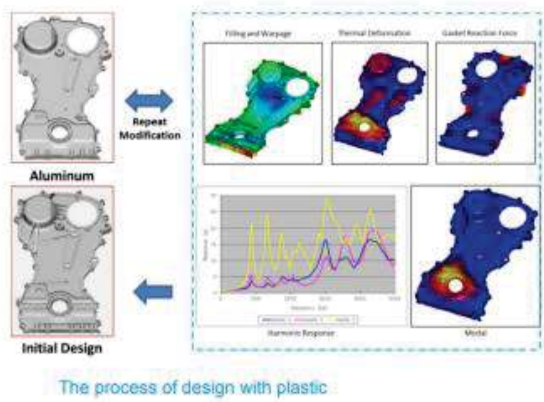
Table 4.1: Plastic vs metal process

4.5.4 RESEARCH ARTICLES

In 2014, Kwang - Ho Oh et al. [23] had presented, the key aspects of the plastic timing chain cover as well as its advantages. They had discussed the design solution and the CAE analysis provided to achieve weight saving benefits in addition to an improvement in NVH performance on the timing chain cover of a 2.0 litter gasoline engine from Hyundai Motor Company.

Fig. 4.2. The process of replacing an aluminium design with plastic

Fig. 4.3 shows the first plastic timing chain cover design after several CAE and the additional parts required for a plastic part replacing aluminium.



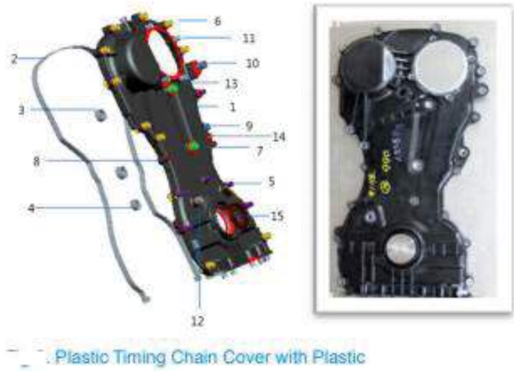


Fig. 4.3 Plastic chain case

In 2004, D. C. Pereira [24] has presented the development of a plastic valve cover system (PVCS) using finite element analysis (FEA). This approach results in a shorter development period and reduced costs. The numerical methodology was divided into two steps. First, a two-dimensional analysis is of the rubber components (gasket, grommet) determines the load-deflection response and the system equilibrium for the complete range of component tolerances. These curves are utilized in a second step. Applied to a three-dimensional model of the cover, the analysis determines the valve cover optimal design. The paper describes other relevant issues related to PVCS's such as

- influence of strain damage on elastomeric response.
- element type, size and order selection for optimum moulding.

This paper described the numerical methodology to develop a plastic valve cover system that provides a leak proof seal to the cylinder head under engine temperature.

Valve Cover System

Fig. 4.4: Valve cover

Light weighting is a critical objective in the automotive industry to improve fuel efficiency. But when redesigning parts for light weight, by changing from metal to plastic, the resulting design gives NVH issues due to differences in part mass and material stiffness. Many parts were not converted from metal to plastic because of NVH issues that could not be solved. Many engine parts such as cylinder head cover, air intake manifold, oil pan and etc. previously made of metal have since long been replaced with plastic. But timing chain cover has not been replaced because of the aforementioned issue. Sealing performance due to the dynamic characteristics of the application is another challenging factor.

In two wheelers mudguard is provided to prevent the dirt's and sand particles in tire from entering and damaging other parts. Presently most of which are made from ABS/Polypropylene plastics. They are of high cost and not completely degradable. In 2017, Baskaran et al. [25] had attempted to use strong and abundantly available sisal plant fibbers as reinforcement in epoxy resin to make low cost, high strength and less weight substitute for mudguards. Model of mudguard is depicted in Fig. 4.5.


Conceptual model of mudguard

Fig. 4.5: Model of mudguard

4.6 QC TECHNIQUES

In this section, we present the techniques which will be used for the result and discussion in this project. These techniques are used accurately to find a solution to the problems and provide a great opportunity for us to improve the performance in a well efficient manner. Also, we provide few research articles using these techniques.

4.6.1 IDENTIFICATION

This step consists of identifying the problem – opportunity and elaborating the scope of the project. Through a wide range of opportunities will identify the correct one and improve the performance. Elaborating the scope of the problem will help to the improvement of the project.

4.6.2 NOTE

This step seeks to raise as much data and information as possible about the problem. Quality checklist tool can help to collect the new data. After collecting the data, validate these using Scatter Diagram, Histogram, and Control Charts etc.

4.6.3 ANALYSIS

This step aims to find the root causes of the problem. While in the previous phase the problem was analysed, here the root causes will be analyzed. To discover them, then prioritize them, analysis the techniques of the problem.

4.6.4 ACTION PLAN

This step is designed to elaborate a plan of action that contains the solutions that will solve the problem. Using the previous step discover the root cause and exposed the problem in this step.

4.6.5 ACTION

This step is pure execution putting the action plan elaborated in the previous stage into practice. Improvement solutions are already known to combat and eliminate the problem and thereby achieve the goal. Based on them - contained in the action plan, those responsible for all proposed and pending tasks should follow as planned and execute them.

4.6.6 VERIFICATION

This step is intended to compare the result achieved with the expected results of the implemented solutions. This stage will ensure that the expected results are actually achieved.

If any one of the tasks did not achieve the desired result, the responsible parties should evaluate what were the reasons that interfered in this process and if this impediment can be solved.

4.6.7 STANDARDIZATION

This step refers to standardizing the process that the problem contemplated. When you get here it means that the goal of the project has already been achieved - at least that was the goal.

4.6.8 CONCLUSION

This step is linked to finally completing the project, reviewing the method used and the context of the problem. This is the last stage where all those responsible for solving the relevant problem should discuss more sustainable practices for applying the problem solving methodology, as well as leaving recommendations for future projects that include the same scenario like the one that the problem was involved.

4.6.9 RESEARCH ARTICLES

In 2014, Varsha M. Magar et al. [26] had reviewed the systematic use of 7 QC tools. They had provided an introduction of 7 QC tools and shown how to improve the quality level of manufacturing processes by applying it. In 2016, Deepak et al. [27] had presented a study which is aimed toward reducing the rejection of Bicycle rims by application of Quality Control (QC) tools. A case study has been conducted in a bicycle industry in Ludhiana to improve the quality of the bicycle rims.

In the automotive industry, the development of new products, involve complex engineering processes subject to time pressures and fierce competition on the automotive market. The companies have to adapt their products precisely to customer needs, and therefore parameters of manufactured products are adjusted to the individual requirements of customers.

An important role in the development of such projects is a user of the modern quality tools in the development of new products. Existing tools and methods have become inadequate because they do not meet all additional requirements in. It is therefore necessary to look for new solutions or improve old and trusted methods. In this context, the use of modern quality methods such as the Quality Assurance Matrix (QAM) and the Quality Control Story (QC Story) is opportune [28-29]

QAM and QC Story are tools of IATF 16949. In October 2016, the IATF will publish a revised automotive industry standard, and the first edition will be referred to as IATF 16949. This new standard will supersede and replace the current ISO/TS 16949:2009, defining the requirements of a quality management system for organizations in the automotive industry. IATF 16949 is aligned with and refers to the most recent version of ISO's quality management systems standard, ISO 9001:2015, fully respecting its structure and requirements. The customer has specific prescribed processes, tools, or systems for problem solving, the organization shall use those processes, tools, or systems unless otherwise approved by the customer [30].

In 2017, G M Sicoe et al. [31] had presented a paper, which has focused on possibilities that offer the use of Quality Assurance Matrix (QAM) and Quality Control Story (QC Story) to provide the largest protection against nonconformities in the production process, throughout a case study in the automotive industry. There is a direct relationship from the QAM to a QC Story analysis. The failures identified using QAM are treated with QC Story methodology. This method will help to decrease the PPM values and will increase the quality performance and customer satisfaction.

4.7 CONCLUSION

In this chapter, we have surveyed the relevant information regarding Automotive industry and need of cost reduction, Value analysis, value engineering, Functional analysis, Metal to plastic conversion and QC story from the various text book, research articles and case studies.

CHAPTER 5

DATA COLLECTION AND ANALYSIS

5.1 INTRODUCTION

Information gathering in this project is done based on the standard dissertation process. In the first stage, the vast amount of data gathering is required and a literature review helped for the same. Data gathering is done for two main purposes of process improvement and cost effective solution. Finally, it will guide us to find the best cost effective solution for process optimization, material selection across a different area of application.

5.2 THE TYPE OF DATA NEEDED

The required data are listed below.

- Data related to different types of vehicles and brand name.
- Different kinds of chain case type, material and its images.
- Data related to different kinds of materials and ASTM test results.
- The ASTM test results based on, Tensile Strength, Flexural Modulus of Elasticity, Izod Impact, Heat Deflection Temperature, Water Absorption per units.
- Weight comparison between metal and plastic.
- The rank of materials based on density.
- Strength – to – Weight Ratio chart for different kinds of metals and plastics.
- Strength – to - Stiffness Ratio chart different kinds of metals and plastics.
- Material's prices vs volume cost
- Cost comparison between different kinds of metals and plastics.

5.3 THE SOURCES FOR THE COLLECTION OF DATA

- Books.
- Articles.
- Websites.
- Production department, HR department, Company documents.

5.4 THE DETAILS OF THE DATA COLLECTED

The data which is required for this project is discussed in this section. In the beginning of this section, we will provide the data for various chain cases for different kinds of brand and its images. Also, we mention the type of vehicles and materials. We will provide the data which describe the properties of some specific metal and plastic materials. Also, we discuss the importance of metal to plastic conversion in the automobile industry.

5.4.1 BENCHMARKING

Benchmarking involves a structured comparison between similar products, services or processes on some dimensions of performance. For example, it can be used to compare the availability and delivery of features in a product and in this form often provides the basis of consumer tests and reviews. These look at products and services and provide recommendations based on which is best or some form of ranking amongst competitors.

It is particularly useful when comparing not only performance but also practice – in other words, what do the different organizations do to enable that performance to be delivered? And applied in this way it is a powerful tool in process innovation sin e studying how the 'best' achieve their performance can provide powerful clues for changing the way processes operate.

Process benchmarking of this kind can operate at several levels:

- Between similar processes in the same factory or service branch.

• Between different factories or service branches.

• Between different competing organizations.

• Between different sectors using the same process.

Whilst it offers a significant learning opportunity benchmarking between competing organizations is harder than the other three because competitors do not want to disclose their process information since it is a source of competitive advantage to them. So benchmarking of this kind often involves a third party who can collect the data, make the comparison and provide feedback but all on a confidential basis. Based on this we have provided the varieties of vehicle's chain case are described in the following table for a few specific brands.

- TVS Motor Company Ltd.
- Hero Motocorp Ltd.
- Honda Motorcycle & Scooter India (Pvt) Ltd.
- Bajaj Auto Ltd.
- India Yamaha Motor Pvt Ltd.
- Royal Enfield (Unit of Eicher Ltd).

S. No	Brand Name	Vehicle	Chain Case		
			Type	**Material**	**Image**
1.	TVS Motor Company Ltd	Star Sport	O. E. M	Plastic	
		Apache RTR	O. E. M	Plastic	
		Star City	C. C	Iron CRC sheet	

2.	Hero Motocorp Ltd	Glamour	C. C	Plastic	
		Splendor 100cc	C. C	Steel	
		I Smart	O. E. M	Plastic	
3.	Honda Motorcycle & Scooter India (Pvt) Ltd	Shine	O. E. M	Plastic	
		CD 110	O. E. M	Plastic	
		CG125 / AX100 / GS125 / GN125	O. E. M	Plastic	
4.	Bajaj Auto Ltd	100, 112, 135 150CC M ST.	O. E. M	Plastic	
		Platina	O. E. M	Plastic	
		Pulsar 220	O. E. M	Plastic	
5.	India Yamaha	SHINNY	C. O	Iron	

	Motor Pvt Ltd	YAMAHAFZ1	O. E. M	Aluminium	
		Yamaha XS650	Drilled	Steel	
6.	Royal Enfield (Unit of Eicher Ltd)	Classic	O. E. M	Brass	
		Rickman	O. E. M	Steel	
		Uce Classi 500CC, EFI.	O. E. M	Plastic	

Table 5.1: Benchmarking

5.4.2 MECHANICAL PROPERTIES OF DIFFERENT METALS

Metal properties like steel yield strength, density, hardness and other parameters are important factors when designing a mechanical part or selecting the right material for CNC machining services, here we present a simple table of properties of some common metals and detailed metal mechanical properties chart. We provide different kind of properties and its explanations. Those properties which are required for further discussion.

Property 1: Tensile Strength

The load at which a plastic test specimen fails when it is pulled from both ends.

Property 2: Yield strength

The stress a machined component or material can withstand without permanent deformation or the stress of the yield point at which the part starts plastic deformation

Property 3: Flexural Strength

The load at which a plastic test specimen fails in flexure.

Property 4: Izod Impact

The energy that it takes to break a plastic test specimen. An indication of the toughness of a material.

Property 5: Heat Deflection Temperature

The temperature at which a plastic test specimen will bend a specified distance under a specified load.

Property 5: Water Absorption

The % increase in the weight of a plastic when it is immersed in water for a specified period of time.

Mechanical Properties Chart

Types of Metals	Tensile Strength (PSI)	Yield Strength (PSI)	Hardness Rockwell B-Scale	Density (kg/m^3)
Stainless Steel 304	90,000	40,000	88	8000
Aluminum 6061-T6	45,000	40,000	60	2720
Aluminum 5052-H32	33,000	28,000		2680
Aluminum 3003	22,000	21,000	20 to 25	2730
Steel A36	58-80, 000	36,000		7800
Steel grade 50	65,000	50,000		7800
Yellow Brass		40,000	55	8470
Red Brass		49,000	65	8746
Copper		28,000	10	8940
Phosphor Bronze		55,000	78	8900
Aluminum Bronze		27,000	77	7700-8700
Titanium	63,000	37, 000	80	4500

Table 5.2: Mechanical properties of metals

Properties	Carbon Steels	Alloy Steels	Stainless Steels	Tool Steels
Density (1000 kg/m3)	7.85	7.85	7.75-8.1	7.72-8.0
Elastic Modulus (GPa)	190-210	190-210	190-210	190-210
Poisson's Ratio	0.27-0.3	0.27-0.3	0.27-0.3	0.27-0.3
Thermal Expansion (10-6/K)	11-16.6	9.0-15	9.0-20.7	9.4-15.1
Melting Point (°C)			1371-1454	
Thermal Conductivity (W/m-K)	24.3-65.2	26-48.6	11.2-36.7	19.9-48.3
Specific Heat (J/kg-K)	450-2081	452-1499	420-500	
Electrical Resistivity (10-9W-m)	130-1250	210-1251	75.7-1020	
Tensile Strength (MPa)	276-1882	758-1882	515-827	640-2000
Yield Strength (MPa)	186-758	366-1793	207-552	380-440
Percent Elongation (%)	10-32	4-31	12-40	5-25
Hardness (Brinell 3000kg)	86-388	149-627	137-595	210-620

Table 5.3: Properties of steel

Grade	UNS No.	Common form	Treatment	Tensile strength MPa (min.)	Yield strength (0.2% offset) MPa (min.)	Elongation % in 50mm (min.)	Hardness (max) (Note 2)
Austenitic stainless steels							
253MA	S30815	Plate	Annealed	600	310	40	95 HRB
301	S30100	Sheet or coil	Annealed 1/4 to full hard	515 860 - 1275	205 515 - 965	40 25 - 9	95 HRB
302HQ	S30430	Wire 2.5mm dia. and over	Annealed Lightly drawn	605 max. 660 max.	-	-	-
303	S30300	Bar	Cold finished Condition A				262 HB
304	S30400	Plate	Annealed	515	205	40	92 HRB
304L	S30403	Plate	Annealed	485	170	40	88 HRB
304H	S30409	Plate	Annealed	515	205	40	92 HRB
309S	S30908	Bar	Annealed	515	205	40	95 HRB
310	S31000	Plate	Annealed	515	205	40	95 HRB
316	S31600	Plate	Annealed	515	205	40	95 HRB
316L	S31603	Plate	Annealed	485	170	40	95 HRB
317L	S31703	Plate	Annealed	515	205	40	95 HRB
321	S32100	Sheet	Annealed	515	205	40	95 HRB
347	S34700	Plate	Annealed	515	205	40	92 HRB
904L	N08904	Plate	Annealed	490	220	35	70 - 90 NRB typical

Table 5.4: Mechanical properties of stainless steel grades and alloys

5.4.3 TYPICAL PROPERTIES OF DIFFERENT PLASTICS

Table 5.5 explore the property group, sort, or compare two or more plastic materials. Also, we can use this table to assist with the material selection process based on requirements.

S. NO.	Materials	Tensile Strength	Flexural Modulus of Elasticity	Izod Impact	Heat Deflection Temperature	Water Absorption
	Units	**psi**	**psi**	**ft-lbs/in**	**°F**	**%**
	ASTM Test	**D638**	**D790**	**D256**	**D648**	**D570**
1.	ABS	4,100	3,04,000	7.7	200 177	0.3
2.	Acetal	10,000	4,20,000	1.5	336 257	0.25
3.	Acrylic	10,000	4,80,000	0.4	- 195	0.2
4.	Aluminium Composite Material (ACM)	-	-	-	-	-
5.	CAB	5,221	2,30,000	4.4	196 181	1.4
6.	CE Canvas Phenolic	9,000	15,00,000	1.5	-	-
7.	DuPont™ Vespel® Polyimide	*	4,50,000	0.8	- ~680	0.24
8.	ECTFE	7,500 - 8,300	232,000 - 261,000	no break	195 160	<0.10
9.	Engravable Sheet	5500	-	1.1	175	-
10.	ETFE	6,100	1,45,000	no break	-	0.007
11.	EVA	3,580	2,470	-	-	-

12.	Expanded PVC	1,975 - 2,900	1,65,000	0.7	- 181	0.15 - 0.30
13.	FEP	4,350	95,000	no break	-	<0.01
14.	Fluted Polypropylene Boards	-	-	-	-	-
15.	Foam Boards	-	-	-	-	-
16.	G10/FR-4 Glass Epoxy	38,000	24,00,000	12	-	-
17.	GPO-3 Thermoset	8,000 - 11,000	15,00,000	8.0 - 9.5	-	-
18.	HDPE	4,000	2,00,000	-	172 -	0.1
19.	High Impact Polystyrene	3,500	3,10,000	2.8	- 196	-
20.	KYDEX® Thermoplastic Sheet	6,100	3,35,000	18	- 173	0.05 - 0.08
21.	LDPE	1,400	30,000	no break	122 -	0.1
22.	LE Linen Phenolic	9,000	12,00,000	1.1	-	-
23.	Noryl®	9,600	3,70,000	3.5	279 254	0.07
24.	Nylon	12,400	4,10,000	1.2	- 194	1.2
25.	PAI	21,000	7,11,000	2.3	- 532	0.3
26.	Paper Boards	-	-	-	-	-

27.	PBT	8,690	3,30,000	1.5	310 130	0.08
28.	PCTFE	4,860 - 5,710	200,000 - 243,000	2.5 - 3.5	259 -	0
29.	PEEK	14,000	5,90,000	1.6	- 306	0.5
30.	PET	11,500	4,00,000	0.7	240 175	0.1
31.	PETG	7,700	3,10,000	1.7	164 157	0.2
32.	PFA	*	90,000	no break	-	<0.03
33.	Polycarbonate	9,500	3,45,000	12.0 - 16.0	280 270	0.15
34.	Polycarbonate Film	*	3,30,000	-	288 270	0.35
35.	Polyester Film	*	-	-	-	0.4
36.	Polypropylene	5,400	2,25,000	1.2	210 -	slight
37.	PPS	12,500	6,00,000	0.5	400 200	0.02
38.	PPSU	10,100	3,50,000	13	- 405	0.37
39.	PSU	10,200	3,90,000	1.3	358 345	0.3
40.	PTFE	1,500 - 3,000	72,000	3.5	250 -	<0.01
41.	PVC	7,500	4,81,000	1	- 158	0.06
42.	PVDF	7,800	3,10,000	3	300 235	0.02
43.	Sentry Glas® Interlayer	5,000	50,000	-	110 -	-
44.	Surlyn®	2,100 - 5,400	4,300 - 7,500	-	-	-
45.	TPE	1,740	-	-	-	-

Table 5.5: Typical properties of different plastics

5.4.4 METAL VS PLASTIC

Plastic is aiding the driving force to make products lighter, stronger, easier to process, and available in more complex shapes - specifically in the form of composite and high-end polymers. In other words, plastics are still the future. We will compare metal and plastic with various manners.

5.4.4.1 Weight Benefits

Plastic parts are typically 50% lighter than their metal counterparts, and provide more production quantity — that is, you get more per pound with plastic versus metal. Below is a comparison of the specific gravity values of the two materials, which shows how drastic the difference in weight can be:

Metals	Weight
Aluminium	2.5 – 2.8
Brass	8.4 – 8.7
Copper	8.8
Zinc	6. 9 - 7.2
Steels	7.7 – 7.83
Polycarbonate	1.2 – 1.4
Nylon	1.2 – 1.7
Polyethylene	0.92 – 0.95
Polypropylene	0.90 – 1.04
ABS	1.02 – 1.4

Table 5.6: Materials weight

Materials Rank by Density (gm/cc)

Material	d	Material	d
Air	0.001	Aluminum	2.7
Water	1.0	Titanium	4.5
Plastics	1.1	Zinc	7.1
Carbon fiber composite	1.3	Iron	7.2
Glass fiber composite	1.8	Steel	7.9
Carbon fiber	1.8	Nickel	8.8
Magnesium	1.8	Copper	8.9
Glass Fiber	2.5	Lead	11.3

Table 5.7: Materials rank

The rank with respect to density is shown in the following chart

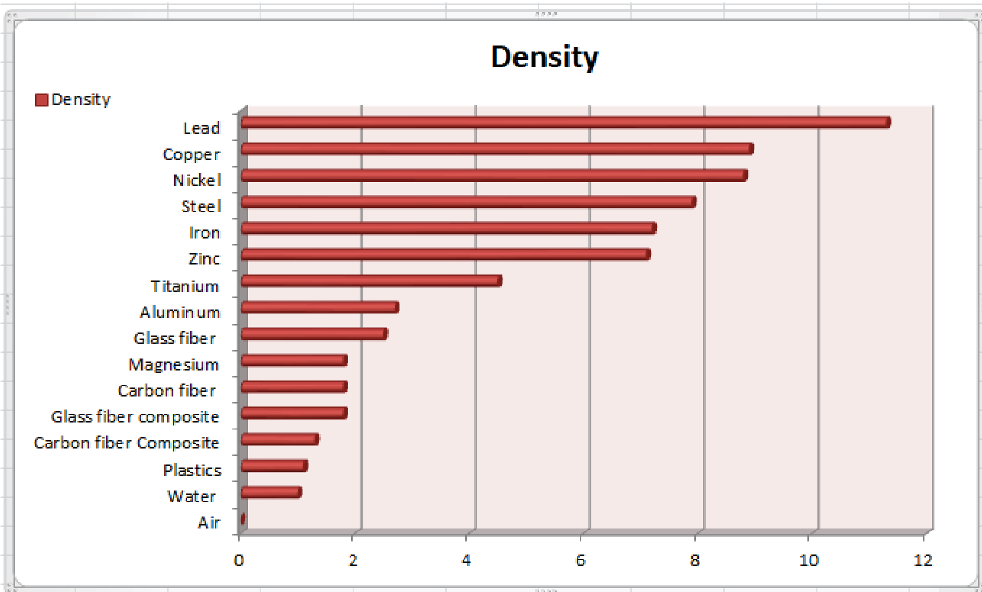


Fig. 5.1: Materials rank

5.4.4.2 Strength – to - Weight Ratio

It is also known as specific Strength, is a material's strength (force per unit area at failure) divided by its density. When referencing the chart below note that examples of thermoplastic reside in the composite and polymer categories and that this data may not include all thermoplastic material products, many of which are specially formulated to compete with metal and alloys in strength and stiffness. Data for these materials can be found on thermoplastic material manufacture websites.

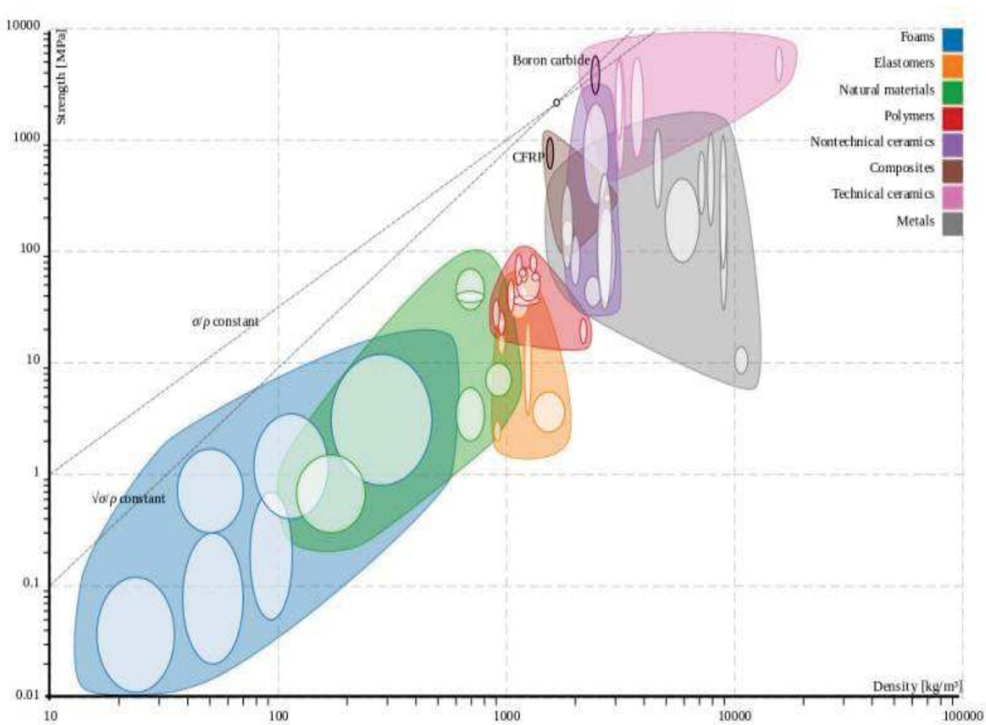


Fig. 5.2: Strength and stiffness

5.4.4.3 Strength – to - Stiffness Ratio

It is also called Specific Modulus, is a material's property consisting of the elastic modulus per mass density of a material.

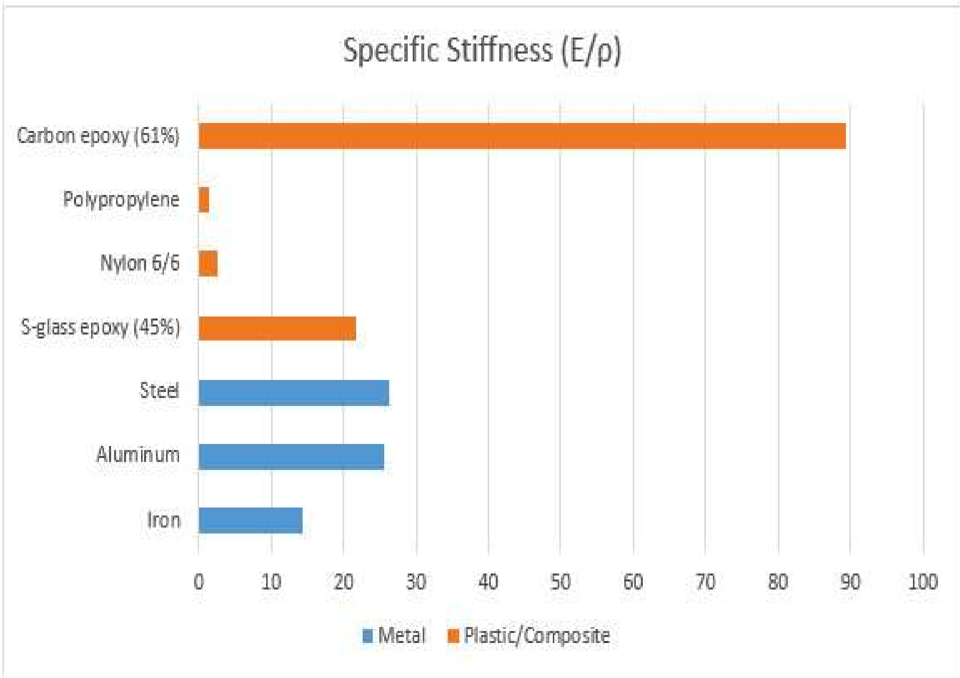


Fig. 5.3: Metal and plastic stiffness

5.4.4.4 Cost Benefits

One of the biggest drivers of change across any industry is the cost of production. If there are lower cost alternatives that provide the same or better results, naturally a company should pursue those. When it comes to metal-to- plastic conversion, perhaps the biggest advantage of plastic parts is their ability to potentially provide an overall cost savings of 25-50% over metal. A typical cost comparison between various materials is as seen in Fig. 5.4.

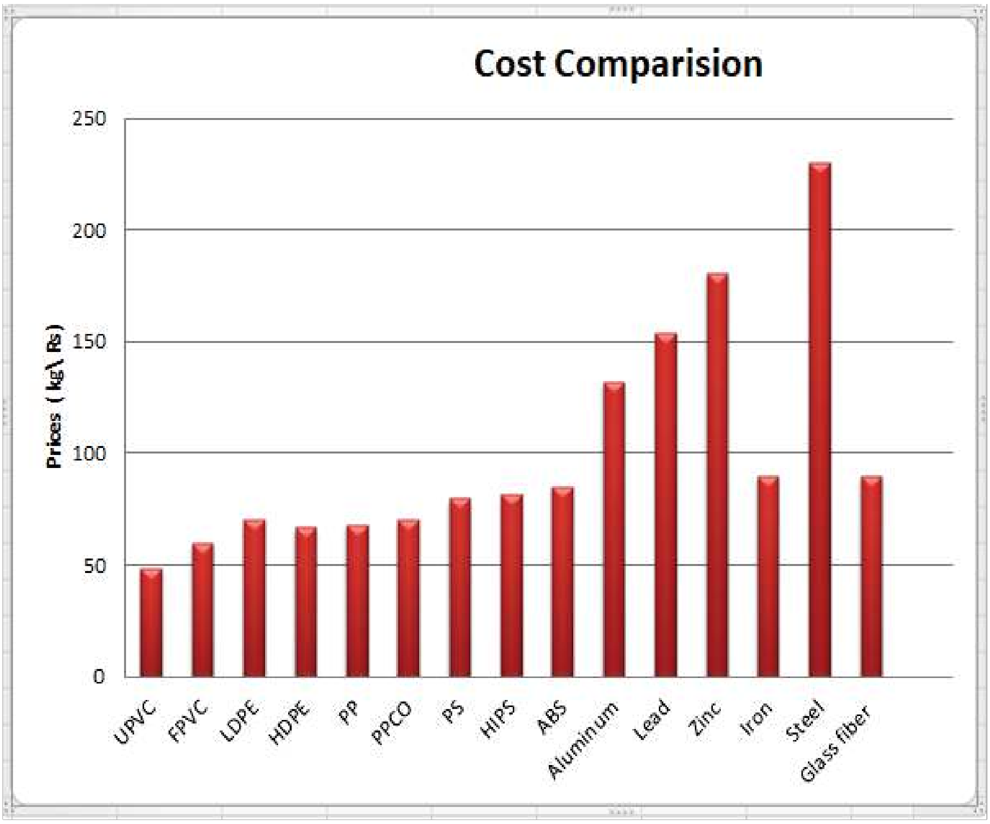


Fig. 5.4: Cost comparison between various materials

Materials	Prices (kg\ Rs)	Materials	Prices (kg\ Rs)
UPVC	48	ABS	85
FPVC	60	Aluminium	132
LDPE	70	Lead	154
HDPE	67	Zinc	181
PP	68	Iron	90
PPCO	70	Steel	230
PS	80	Glass fibre	90
HIPS	82		

Table 5.8: Cost comparison between various materials

A typical cost comparison between various plastic materials prices and volume cost as shown in Fig. 5.5.

Materials	Density (g\ cc)	Prices (kg\ Rs)	Volume Cost
UPVC	1.38	48	66.24
FPVC	1.25	60	75
LDPE	0.92	70	64.4
HDPE	0.96	67	64.32
PP	**0.90**	**68**	**61.2**
PPCO	0.905	70	63.35
PS	1.05	80	84
HIPS	1.05	82	86.1
ABS	1.05	85	89.25
Aluminium	2.702	132	356.664
Lead	11.35 g/cc	154	154
Zinc	7.13	181	1290.53
Iron	7.2	90	648
Steel	**7.9**	**230**	**1817**
Glass fibre	1.8	90	162

Table 5.9: Density, price, volume cost comparison between various materials

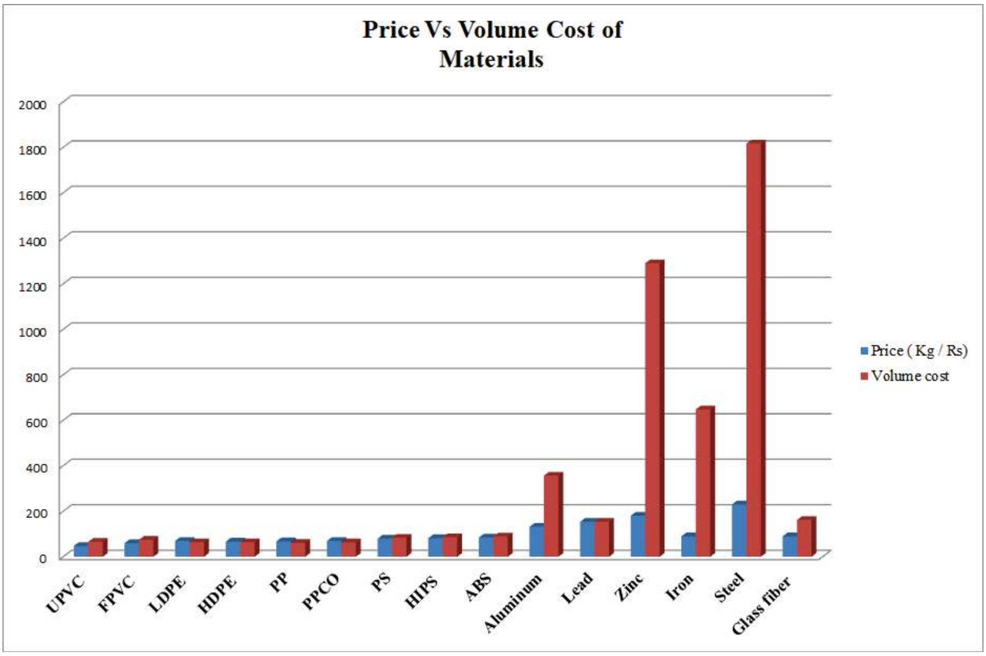


Fig. 5.5: Price vs volume cost of various materials

5.4.4.5 Design Capability and Cost

You do not have to watch the sheet metal fabrication process for very long to take away the fact that metal can difficult to work with and shape. Even with today's technology, metal's inherent characteristics prohibit complex part designs or shapes, such as compound curves or fluid designs from either a material capability or cost limitation.

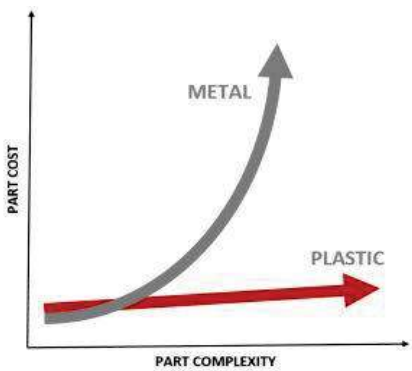


Fig. 5.6: Design capability and cost

Shaping a metal part can require die work, welding, grinding, rework, or bending on each individual part produced to achieve design specifications and desired look. In addition to greatly increasing production and lead times as mentioned above, as part design complexity increases, part cost increases at an exponential rate.

5.5 PROCESSING OF THE DATA FOR ANALYSIS

We had collected the data from various sources. Also, we discussed the necessary properties related to the project. We can validate the data using the chart and excel sheet. After collecting the required data is sorted and then validated by the respective department. This validation is required to check it correctness of the data for further processing. Also, we can form tables whenever it is necessary. The calculated data from the table is then further processed for data presentation as chart, diagram, bar diagram etc. Representing data as figures will help us to understand the concept very easily.

5.6 CONCLUSION

In this chapter, we have provided various types of data were collected from various sources. Also, we have done the analysis using those data for strengthening our problem. By supporting this data analysis, we can get a conclusion and validate plastic is better than steel chain cover based on the density, price, volume cost and design also.

CHAPTER 6

ANALYSIS OF DATA

6.1 INTRODUCTION

Nevertheless, data collection does not produce any meaningful and actionable results without adequately analysing it. You will only end up with numbers and figures with no basis. In this section, we will discuss the choice of techniques which is required for further discussion. We will discuss the function analysis with VE, function tree, function cost and Finite element analysis. We will provide an analysis of plastic and metal. Also, we elaborate the scope of our in this project.

6.2 CHOICE OF TECHNIQUES

We have explored various techniques will be described below.

1. **Part Count reduction**

Part count reduction (PCR) is one of the typical motivations for using additive manufacturing (AM) processes. However, the implications and trade-offs of employing AM for PCR are not well understood. The deficits are mainly reflected in two aspects, lifecycle-effect analysis of PCR is rare and scattered and the second one is current PCR rules lack full consideration of AM capabilities and constraints.

2. **Alternate material**

Consider the choice of materials, form/size of various pieces of the vehicle, durability, target market, and ease-of-use. Choose the alternate material, which one will be more suitable for our project.

3. Alternate process / Process optimization

Once the process optimizer has an idea of what kind of material we can choose, then we should move onto implementation. This is where amendments are made to the process. Usually, the implemented changes will cause positive results. If they don't, then another round of process optimization may be in order. What's useful to know is that process optimization isn't some lengthy, time-consuming act – it can all be done rather quickly. Seeing as this is the case, there's no excuse to optimize your processes.

4. Combining functions

When we wanted to compute a heating cost from a day of the year, we created a new function that takes a day as input and yields a cost as output. The process of combining functions so that the output of one function becomes the input of another is known as a composition of functions.

5. Yield improvement

A yield (and profit) improvement strategy consists of making measurements at critical stages, as early as possible in the assembly process, and adjusting the process parameters to achieve optimal performance.

6. Communication

Constant communication with customers ensures that they are aware of issues, proposed approaches to solving them, and progress on achieving the desired solutions. Often, customers provide additional insights into processes that may confirm or expand our process understanding and facilitate optimal problem resolution. Consultation with customers is also important to confirm that no changes to a process will cause downstream issues.

7. Alternate source

We can go for alternate source instead using the traditional sources. Which should better than the previously available source and should have more advantages.

8. Alternate design

Alternative Design is dedicated to providing an ethical and rewarding environment for the corporate family including customers, employees, shareholders, vendors and the community.

9. Weight reduction

Over the decades, harmful vehicular emissions have shown a negative impact on the environment and human health. The increasing air pollution from the transportation sector has led many government agencies to lay strict regulations on automobile manufacturers to curb the harmful emissions under permissible limits. Weight reduction has played a major role in a vehicle's design process. An automobile on an average comprises of 200 such motorized movable parts that could be replaced with lightweight smart materials, which can further be used to achieve potential weight savings.

10. Supplier ideas

Suppliers will be the most probable future industry scenarios – ones in which multiple player categories are likely to benefit or, in more extreme cases, ones in which one player type. They will then need to create a path for themselves that considers their strategic aspirations, the shape of their presence in the market, their partnerships and position within the value chain, and the tools that enable and deepen their relationships with their customers. We can accept a good idea of the supplier, which will form a good relationship while working with them.

Out of this, we have used the following guidelines in this project.

1. Alternate material
2. Alternate process / Process optimization
3. Alternate design
4. Weight reduction

6.3 FUNCTION ANALYSIS

Function analysis means breaking down and meticulously investigating the product or service functions that are targeted by VE activities to determine whether each function is necessary. Thus, the objective of functional analysis is to improve product or service functions so that all functions are both necessary in nature and appropriate degree. For every purpose, we have an upper level function and lower level function. We are now in a position to choose the alternative materials for our problem. For this, we are planning to apply the functional analysis to choose the better material.

6.4 FUNCTION TREE

The purpose of a function tree is to illustrate all the functions that a product, a process or a project must do and the links between them, in order to challenge these functions and develop a better response to the client's needs.

The functions are linked together in a logical way and the model resulting from this diagram illustrates what will be done by the product, starting with a statement on the mission of the product, and presenting all the functions.

The functional tree allows splitting the higher level functions, which stem from the mission objectives/upper level system requirements, into lower level functions and eventually it allows identifying the basic functions that have to be performed by the future product.

Higher level functions are complex functions that have to be decomposed into simpler functions, that is lower level functions, in order to accomplish the analysis.

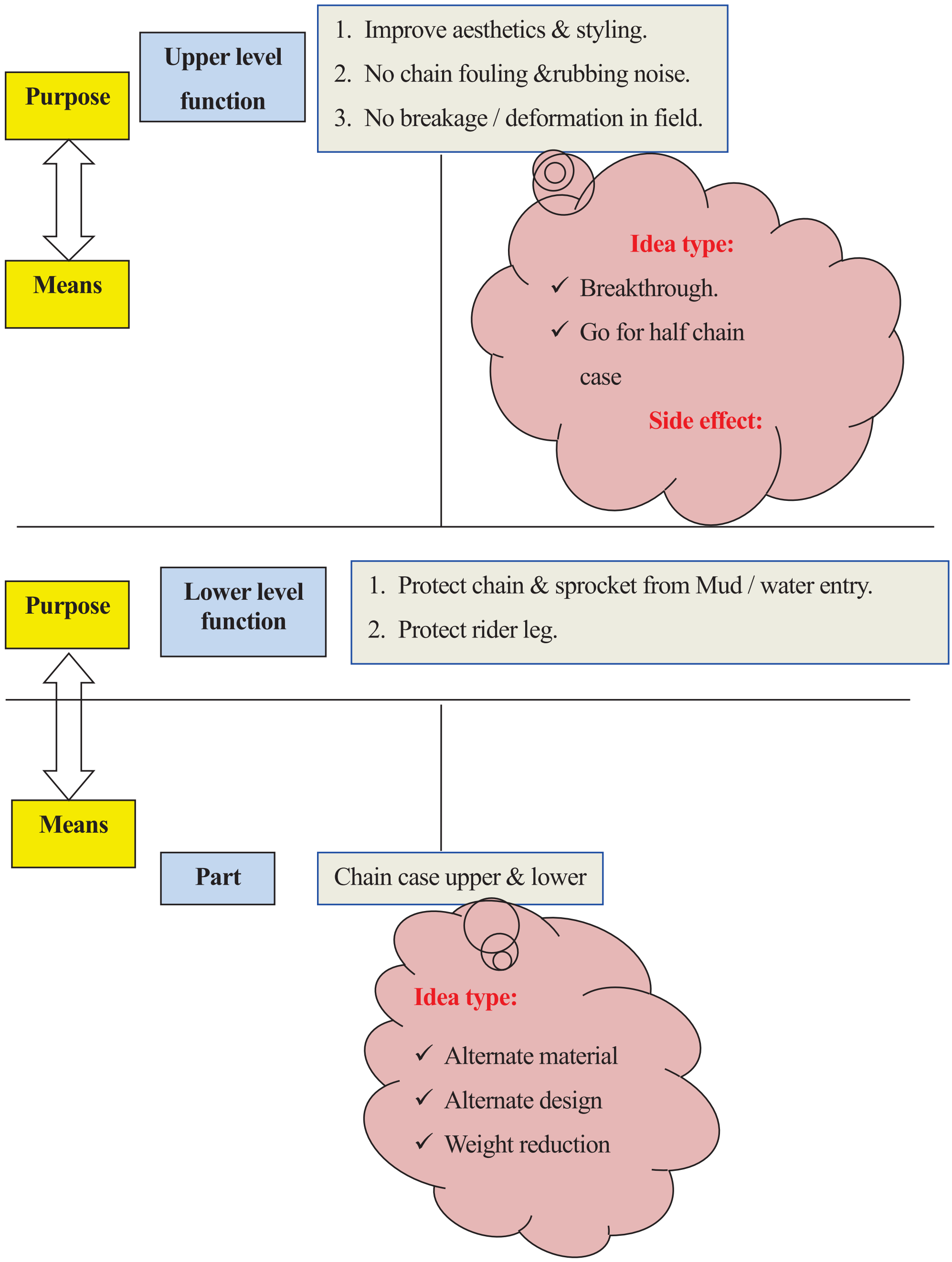


Fig. 6.1: Function tree

6.5 FUNCTION COST

The functional cost analysis is a value engineering method that aims to increase the difference between the cost and the value of a product. The cost is the amount that is incurred in the production and delivery of the product. This expense can include the price of parts, labour, overhead (e.g., building, power), packaging, shipping, and advertising, among others. What the product is worth in the eyes of the customer is considered the value. When completing a functional cost analysis, remembering this definition of value is extremely important. The design team may not perceive a certain product feature to be valuable, however if it is important to the customer, then that feature must be regarded as valuable.

Evaluation of Function Cost

$$\nabla = \frac{\text{function}}{\text{cost}}$$

$$\nabla = \frac{\text{function (To cover, protect chain and sprocket)}}{\text{cost of chain case}}$$

Our Targeted Cost of Chain Cover = Function = 94

Current Chain Cover Cost = cost of chain case = 120

$$\nabla = \frac{\text{function}}{\text{cost}} = \frac{94}{120}$$

$$\nabla = 0.78$$

∇ should be more than 1.

$\nabla = 0.78 < 1$.

6.6 FINITE ELEMENT ANALYSIS

Stress optimization is one of the key factors for structural design in a wide range of engineering problems. Its importance relies upon obtaining mechanical structures that are free of or present less stress concentrations. Topology optimization has shown to be a powerful tool for structural conception. If stress is not taken into account in the concept of the structural component, the design is susceptible to postprocessing or rework, leading to unexpected costs. The selected material was checked for Stress levels for design optimization. Stress levels at critical zones were optimized as per SOP.

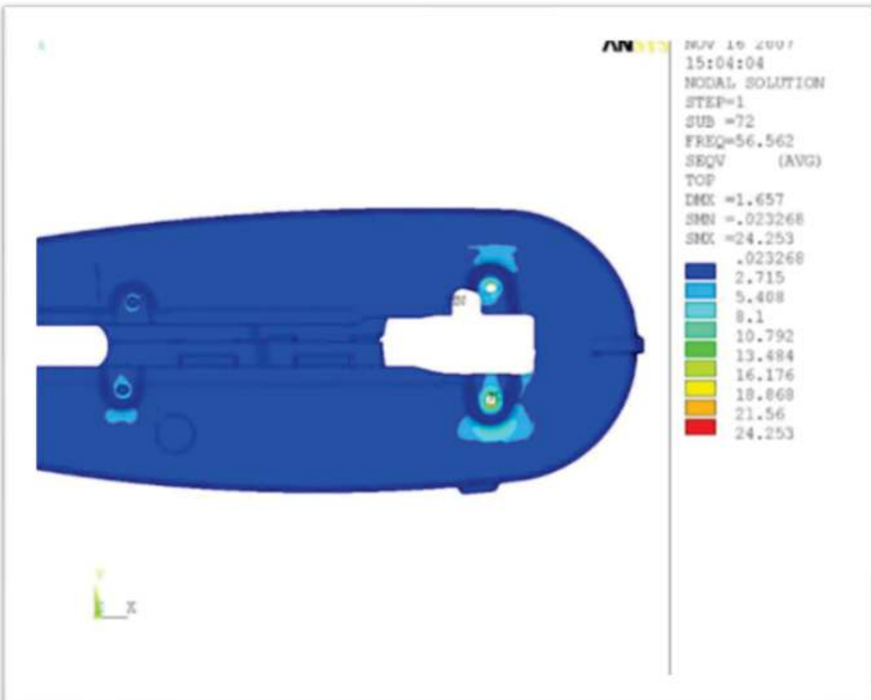


Fig. 6.2: Finite element analysis - Chain cover with polypropylene

6.7 FUNCTION LEVEL OBSERVATION

Despite present - day constraints and issues, the world is full of possibilities. Yet the greater awareness of these possibilities are the more pressure there is to choose one. Thus, it is impossible to experience a uniform world; rather one can only anticipate the outcome during the selective process. This is experienced as a paradox: one is both free but simultaneously forced to choose. The possibilities – suspended for the benefit of a choice – mark the limits in the present. This, in turn, helps to sustain freedom in the future. From a social perspective, however choice decisions process the paradox of freedom and constraint by expanding it in time without solving it. Eventually, decisions react to the possibilities provided by previous decisions. In this project, we have two levels of observations, which will discuss below.

6.7.1 FIRST LEVEL OBSERVATION

Chain case (Vehicle level function)

1. Protect chain and sprocket from the accumulation of dust, mud, water etc.,
2. Provide good styling and Improve vehicle aesthetics.
3. To avoid lubricant oil splashing on passenger & vehicle.

6.7.2 SECOND LEVEL OBSERVATION

Chain case (Part level function) requirement

1. Should cover sprocket & chain
    - Avoid entry of foreign particles (mud, dust, rain water)
2. Should meet assembly requirement
    - Easy of assembly.
    - Easy of service.
3. Should give good aesthetic to vehicle

- Avoid visibility of sprocket and chain

4. Durable and reliable

    - To withstand environment conditions (Heat, Sunlight, Water, Cold etc.)
    - To withstand vehicle and road induced vibrations.

6.8 GAINING CONFIDENCE WITH PLASTICS

Among the plastic compounds are fibre – reinforced plastics, these come in two main variants with either short fibre reinforcement made with chopped fibre or long fibr reinforcement made from continuous fibre. Fibre reinforcement can provide a tremendous amount of structural integrity and raise the tensile strength of the entry-level engineering polymer nylon 6/6 (polyamide 6/6) six times from 8,000 psi (55 MPa) up to 48,000 psi (331 MPa). This puts plastic strength in the same performance realm as metals like die-cast magnesium and aluminium.

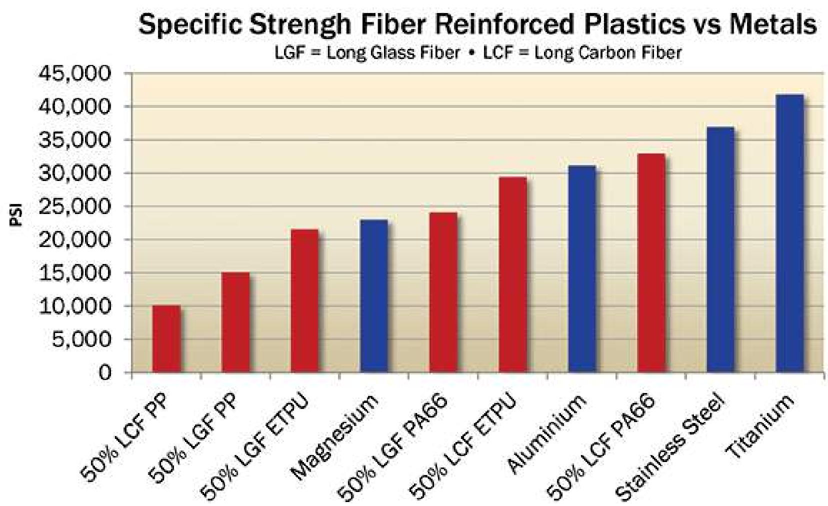


Fig. 6.3: Specific strength – Plastic Vs Metals

6.8.1 PLASTIC IN THE AUTOMOTIVE INDUSTRY

The automotive industry has an important relationship with the chemicals sector while remaining an instrumental force on the global economy as an employment-intensive sector. In a fast-changing world, the automotive manufacturing is susceptible to unique challenges. While vehicle manufacturers are impacted by material prices, trends impacting the market ripple upstream. The industry consumes significant volumes of plastics, resins, rubber, and paints. Despite the slowdown of recent years, auto production is still identified as a growth area for many as the focus on sustainability and opportunities to lightweight vehicles increase.

6.8.2 STEEL COMMODITY MARKET PRICE TREND

A notable characteristic of world steel prices is that they are highly cyclical. As can be seen in Fig. 6.4, prices move from peak to trough every few years. Looking at pricing for a typical steel product such as hot rolled coil (HRC), the latest prominent peaks occurred in March 2005, August 2008, May 2011 and May 2018. For steel reinforcing bar (rebar), recent price peaks were evident in May 2004, August 2008, August 2011 and April 2018. Across these products, the average peak-to-peak time works out at ~54 months; meaning that the next price peak can be expected around October or November 2022. Steel price in India is Rs 37850/Ton

6.8.3 METALS VERSES PLASTICS

If you were to take a part made from steel and compare it to the same part made from thermoplastic, the plastic part could be more than 6 times lighter. Take that same part, now manufactured with aluminium, and the plastic version would be approximately half the weight. The weight and cost comparison of two different chain cases is discussed in Fig. 6.5 (We take randomly two different products and compare them.)

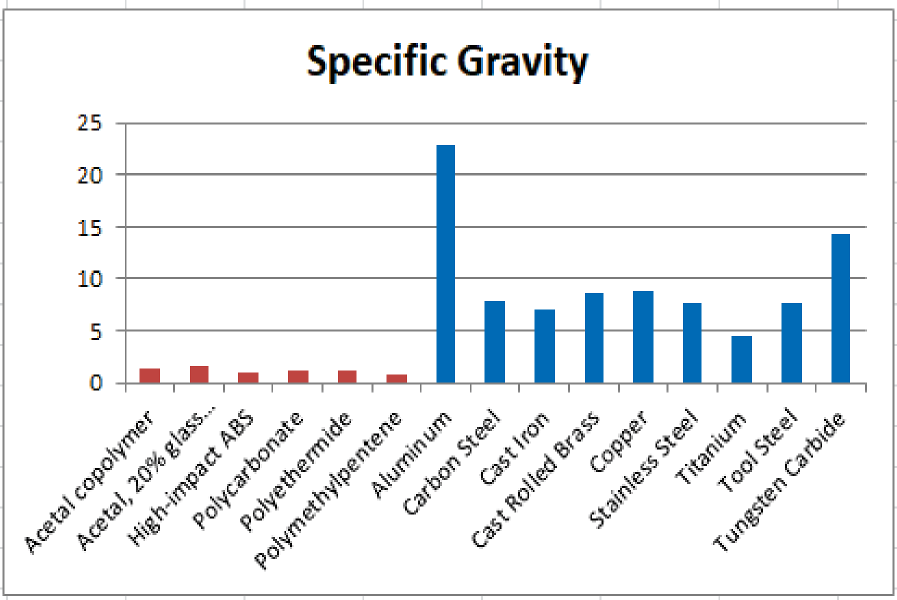


Fig. 6.5: Gravity – Plastic Vs Metals

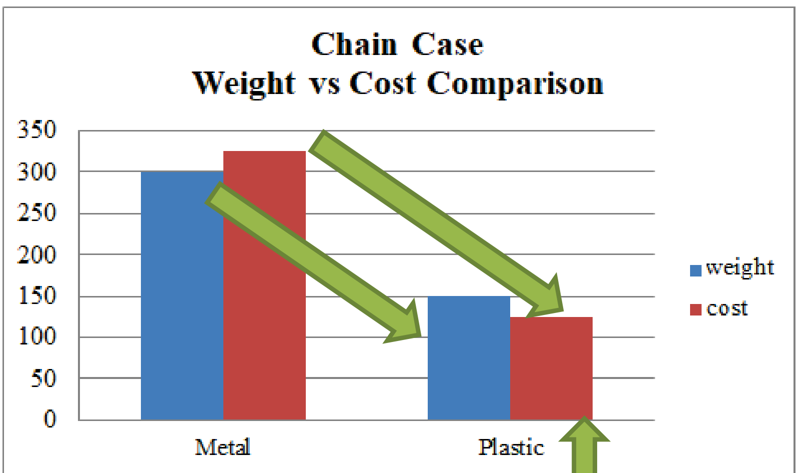


Fig. 6.6: Cost and weight comparison – Plastic Vs Metals

	Metal	**Plastic**
Weight	300	150
Price	325	124

Plastic chain case weight and the price is 61% lower

6.9 COST DRIVERS

Raw material cost is one of the important cost drivers for chain cover cost. So to get cost saving we need to work on the raw material alternatives to get the savings. On selecting the alternate material Polypropylene there is a weight reduction observed due to the difference in the density. We will elaborate on the material selection criteria in Chapter 8. This will contribute to an additional savings of 10% due to the density difference. We can see this in Fig. 6.7.

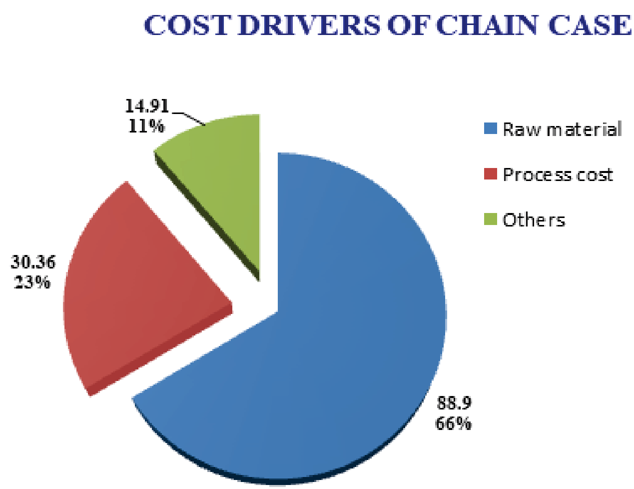


Fig. 6.7: Cost drivers of the chain cover

Raw material price comparison, part weight comparison and weight & density comparison is described in table 6.1 – 6.3.

Chain Case Cost	RM	RM price Rs\ per Kg	Input weight Kg	Cost (Rs)	%
120	ABS	146.94	0.605	88.90	74

Table 6.1: Raw Material Price Comparison

Current Part weight (Kg)	Plastic RM	Proposed Plastic RM	Proposed weight (Kg)	Weight reduction (Kg)	%
0.605	ABS	PP	0.544	0.061	10%

Table 6.2: Part Weight Comparison

Material	Density (gm/cc)
ABS	1.04
PP	0.94

Table 6.3: Weight and density comparison

6.10 SCOPE OF WORK

To optimize the process of manufacturing chain cover

- To eliminate quality complaint of chain cover rubbing.
- To study the gap in the vehicle layout between the drive chain and chain cover.
- To further look for any scope for increasing the same for better clearance between drive chain and chain cover for the chain movement.
- To change the material specification for healing cost reduction per part.
- By reducing the thickness and eliminate heavy wall thickness areas.
- To improve the mould design by mould flow analysis,
    - Better and easy filling by gate design optimization.
    - Better cooling efficiency.

- By optimizing the injection moulding process to arrive
  - Injection time.
  - Holding time.
  - Gate freeze time.
  - Cooling time.
- To decide on packing standard
  - To overcome post warpage effect on the chain cover.
  - To overcome transit & storage warpage, as parts are stacked one over the above.

6.11 HISTORICAL PERSPECTIVE

Today's economy has forced many Automobile companies to put a larger emphasis on cost reduction while still upholding the same performance quality and standard. One solution in which many manufacturers are now incorporating is replacing metal like steel into other materials with engineered thermoplastics or high - performance plastic resins. This is a key strategy in the automotive industry, because.

- Plastics are lighter in weight, providing for ease of use and reduction in transportation cost for both parts and raw materials.
- It will provide resistance to corrosion, chemicals, and rust, reducing the need for secondary coatings and sprays.
- Ability to mould complex geometry and multiple parts reduce the amount of metal components and/or secondary operations and assembly
- A single plastic injection moulded part can often replace multiple metal pieces, reducing the amount of fixtures and handling required to assemble those metal parts together.

- The specific gravity of plastic resins is much less than metal, reducing material required.
- Increased speed to market due to shorter cycle and processing times.
- Many plastic materials can be recycled, reused, or reprocessed, helping to further reduce waste and cost.

6.12 CONCLUSION

Using QC techniques, VE, VA and FA we analysis our results. We had shown how to reduce the chain case cost using various steps involving in functional analysis. We had provided a vehicle level observation and part level observation of the chain case.

CHAPTER 7

RECOMMENDATIONS

7.1 INTRODUCTION

In this current scenario, we are now in the position to find a solution to the challenges in the cost increasing of two - wheeler spare parts. In this project initially, we are converting the material of chain case from metal to plastic and give a justification that plastic will be the better one than metal. Again we will choose the type of plastic that will suit for the chain case more and will help to reduce the manufacturing cost of chain case. Design of chain case is very important, so we will be attempted to redesign the already existed chain case. For improvising the design, we redesign the internal design clearance, and we provide a procedure to overcome the chain cover rubbing also. Not only these changes, also we will improve the mould design, gating design, cooling system and cooling fixture. We explain in detail about the process, packing improvement and validate the concept and selection.

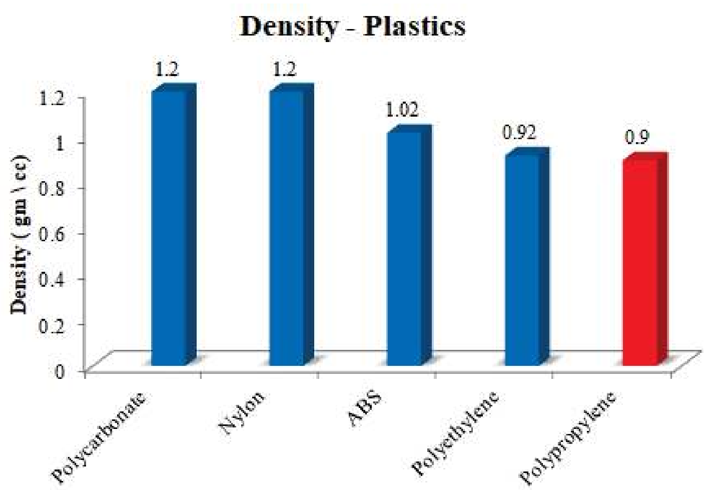
7.2 BRIEF DESCRIPTION OF RECOMMENDATIONS

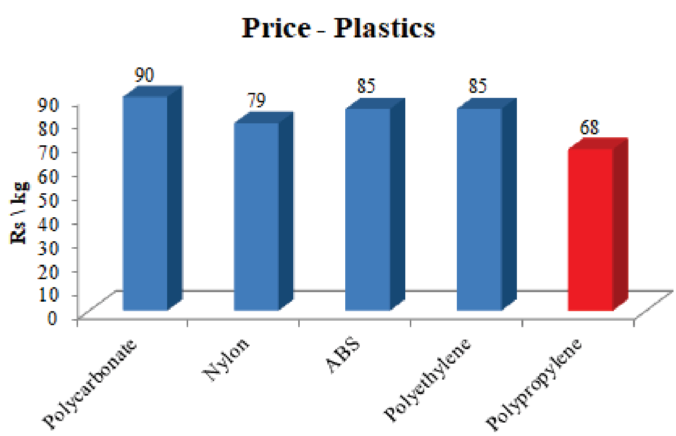
We will precede this chapter in the following manner.

- Choose alternate material.
- Study the properties of specific material.
- Economic comparison.
- Product design optimization.
- Design improvement.
- Process & packing improvement.

7.3 CHOOSE THE ALTERNATE MATERIAL

One of the main targets of this project is choosing alternate material. We will provide a justification of the alternate material is a better choice of already existed one. In this situation, we have a plan to alternate the different kind of metals with plastic materials. The properties of different kinds of materials are already discussed in Chapter 5. From Chapter 5 and 6, we confirmed that plastic is better than metal. We have gone through the properties, prices and density of many types of plastics. We could not showcase everything here, so we can choose a few types of plastics for comparison and choose the better one. For that, we will pick Polycarbonate, Nylon, ABS, Polyethylene, Polypropylene and its density, price and Izod impact.





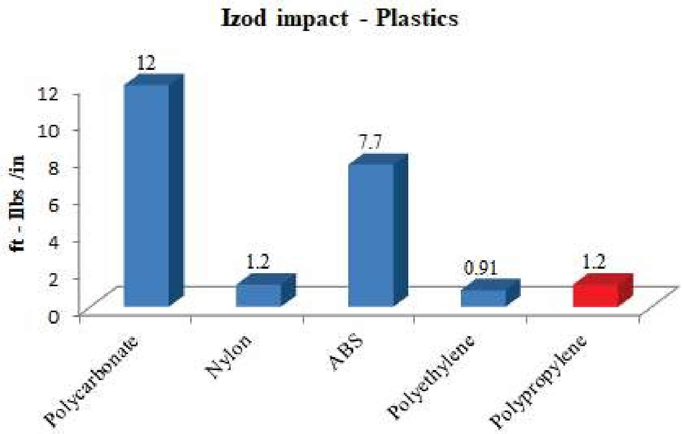


Fig. 7. 1 Comparison between various type of plastics

Materials	Density (gm / cc)	Price (per/Kg)	Izod impact (ft – Ilbs / in)
Polycarbonate	1.2	90	12
Nylon	1.2	79	1.2
ABS	1.02	85	7.7
Polyethylene	0.92	85	0.91
Polypropylene	**0.90**	**68**	**1.2**

Table 7.1: Comparison between various type of plastics

We came across the above discussion when compared to the other plastic materials, pp will be the better choice of our project. Furthermore, there are some notable advantages of polypropylene. It is a relatively inexpensive material, easily repaired from damage, very resistant to moisture. It has a low coefficient of friction, good chemical resistance over a wide range of bases and acids, good fatigue resistance, good impact strength and good resistance to electricity and is thus a good electrical insulator.

7.4 PROPERTIES OF PP

Property	Test Method	Units	Nominal Value	Units	Nominal Value (SI)
Tensile Strength	ASTM D638	psi	3770	MPa	26
Tensile Elongation		%	12	%	12
Flexural Modulus	ASTM D790A	psi	160000	Mpa	1100
Notched Izod impact	ASTM D256	ft.lb/in	2.2	j/m	120
Temp of Defection Under Load	ASTM D648	°F	203	°C	95
Melt mass – Flow rate	ASTM D1238	g/10 mts	3	g/10 mts	3

Table 7.2: Typical properties of REPOL MI3530

Typical Properties		Units	ASTM Test	PP
Tensile strength	73°F		D792	**0.91**
Tensile modulus of elasticity	73°F	psi	D638	**5,400**
Tensile elongation	73°F	psi	D638	-
Flexural strength	73°F	%	D638	-
Flexural modulus of elasticity	73°F	psi	D790	-
Compressive strength	73°F	psi	D790	**2,25,000**
Hardness	73°F	psi	D695	-

Izod impact	73°F	scale as noted	D785, D2240	**Shore D 75**
Coefficient of friction		ft-lbs/in	D256	**1.2**
Coefficient of linear thermal expansion			Dynamic	**-**
Heat deflection temperature	66psi / 264psi	in/in/°F x 10^{-5}	D696	**5**
Max continuous service temperature in air		°F	D648	**210**
Dielectric strength		°F		**180**
Water absorption	Immersion 24 hours	V/mil	D149	**-**
Light transmittance	Transparency / Clarity	%	D570	**slight**

Table 7.3: Material Property

Using Table 7.3, we can conclude that the properties of PP are meeting the product requirement as the part class C item that doesn't have any load acting on it. Based on the properties, the material as we have chosen meets the basic design and process requirements.

7.5 ECONOMIC COMPARISON (EXISTING VS PROPOSED)

Polypropylene (PP) demand in India grew at a CAGR of around 8.51% during 2015-2019 and is expected to achieve a healthy growth rate during the forecast period. In addition, demand for Polypropylene from the automotive sector remained lull in Q4FY20 due to plant shutdowns and lack of buying sentiments.

However, the restart of automobile plants with ease in lockdown restrictions has led to a gradual pick up in the PP volumes produced and procured. With major players like RIL, IOCL and OPAL ambitiously expanding their polyolefins sectors, India's PP industry is expected to witness tremendous growth heightened by new capacity additions which are scheduled for the next five years.

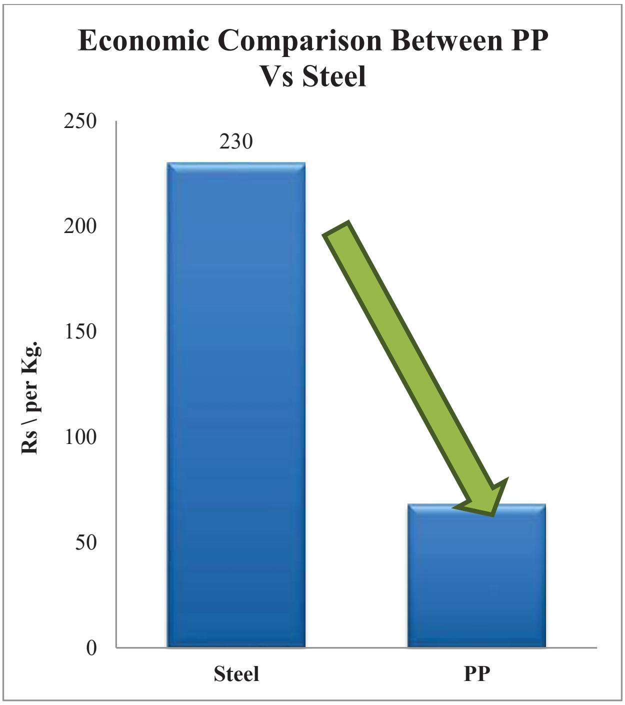


Fig. 7.2: PP Vs Steel - cost comparison

Material	Cost (1 kg/ RS)
Steel	230
PP	68

Note that, the cost of PP is **70.43%** lower than steel. So, Cost wise, PP material will be the better one.

7.6 PRODUCT DESIGN OPTIMIZATION FOR PROPOSED MATERIAL

In this section, we proposed the product redesign of chain case. Especially, to overcome the chain cover rubbing, internal design clearance was redesigned.

- Chain case width increased at critical zones, to reduce chain rubbing.

- Chain case width increased at critical zones, to reduce chain rubbing.

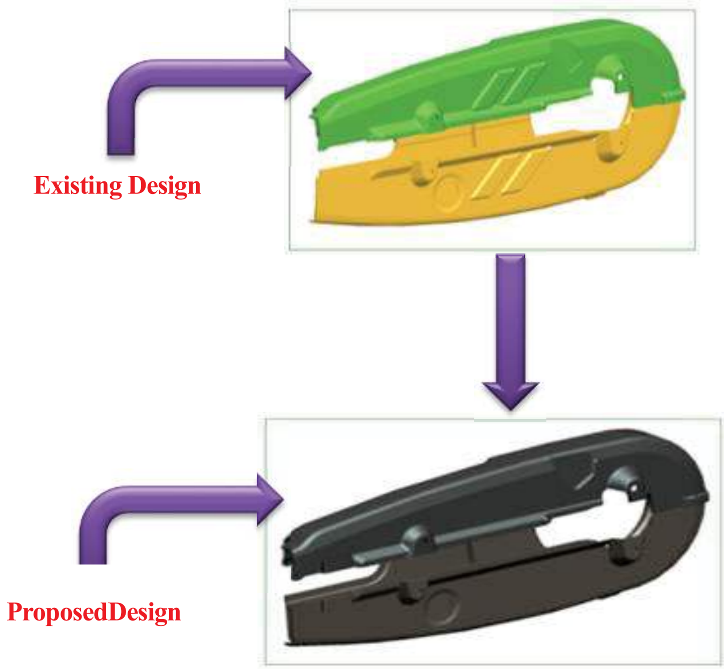


Fig. 7.3: Chain case proposed design

Product design change areas are highlights in red colour.

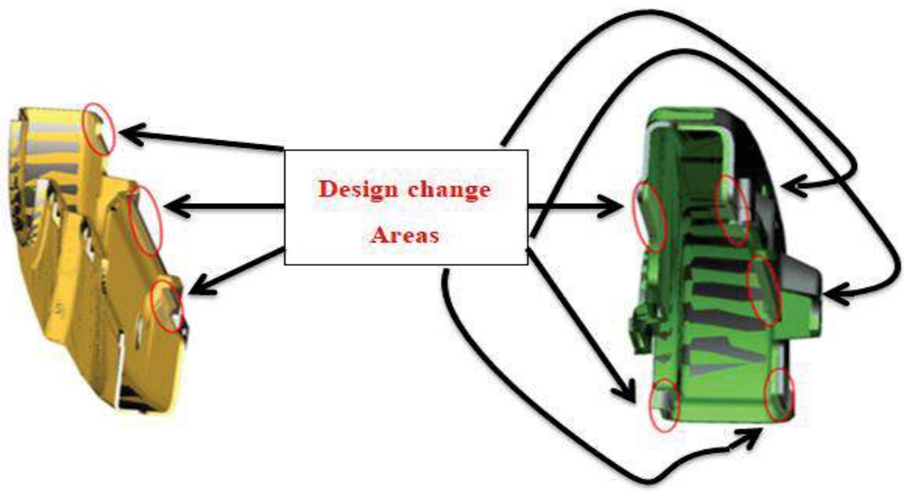


Fig. 7.4: Design changes areas

Redesigned proposed chain cover as shown in Fig. 7.5.

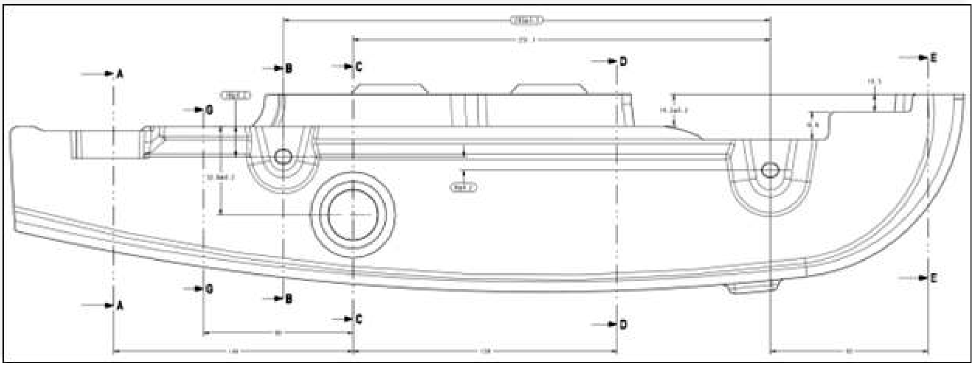


Fig. 7.5: Proposed chain cover

7.7 DESIGN IMPROVEMENT

For better chain case we have to improve the mould design, gating design, cooling system and cooling fixture.

7.7.1 MOULD DESIGN

The existing design of the mould is having following concerns

- Warpage
- Higher cycle time

Hence it is required to redesign the mould to overcome the above.

For that, we need to redesign the following aspects.

- Gating system
- Cooling systems
- Ejection systems

Various options were tried and simulated in mould flow analysis to ensure that we get the desired results after making the mould.

7.7.2 GATING DESIGN

Single edge gate was having an injection time of 4.4 seconds. With double edge gate the time was drastically reduced to 1.35 seconds. The following figure indicates the injection time improvement between 2 different options.

Gating design

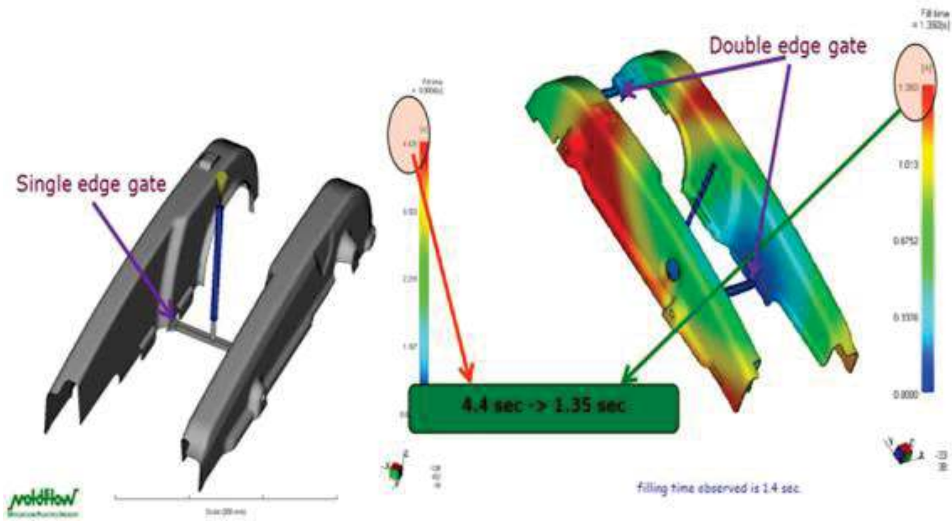


Fig. 7.6: Chain cover gating improvement

7.7.3 COOLING SYSTEM

The cooling system was taken farther away from the part profile and not integrated along the part. This in turn resulted in higher cooling time required for the part to cool which influence the part warpage.

In the existing chain case, chain rubbing is the major complaints and the warpage of the plastic chain case is also will lead to chain rubbing.

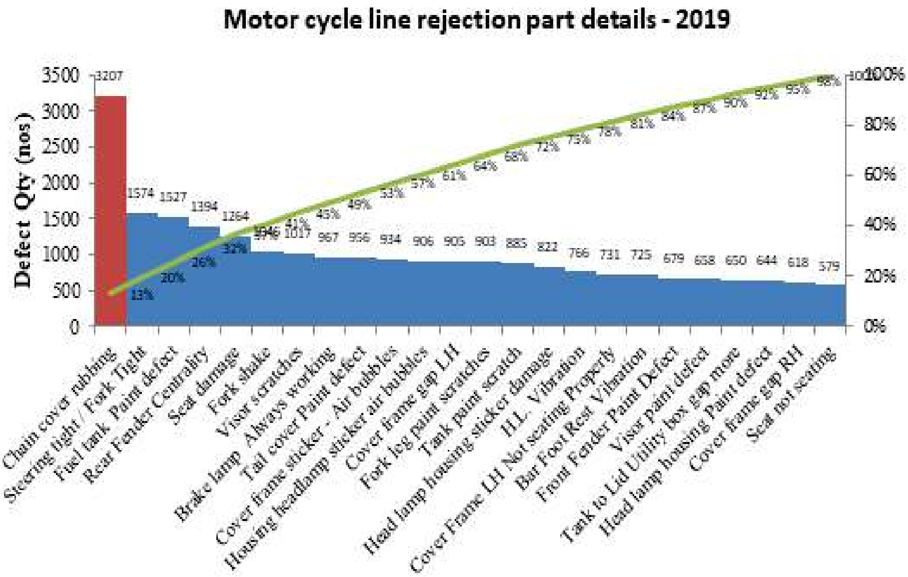


Fig. 7.7: Rejection details

Hence the cooling circuits were redesigned to be integrated with the part profile. This has resulted in get the mould temperature profile to the accepted levels. The following picture represents the improvement.

<u>**Cooling Circuits**</u>

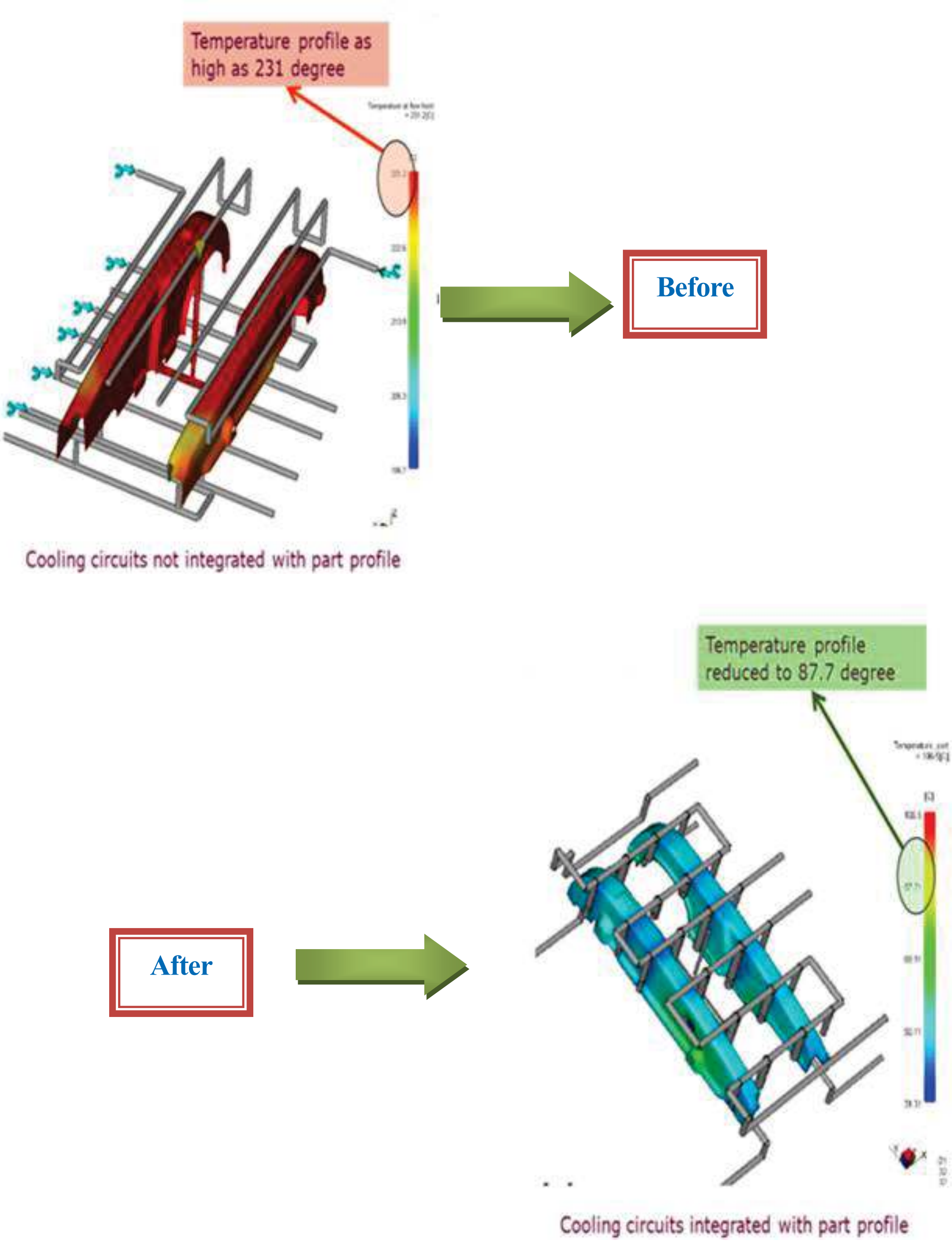


Fig. 7.8: Chain cover - Cooling circuits improvement

To reach the deep core sections action taken to accommodate baffle cooling. By doing so the ejection system changed from pin ejection to block ejectors. This has assisted for better balanced ejection. This we can refer in Fig. 7.9.

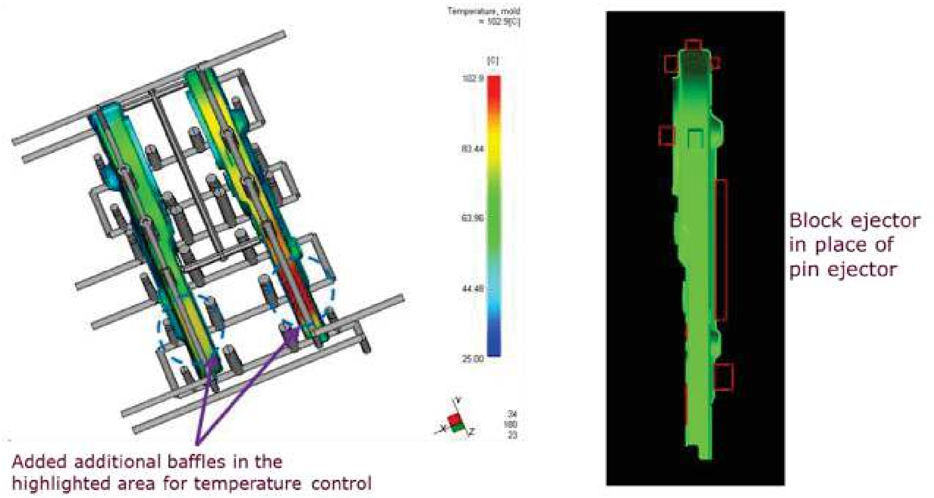


Fig 7.9: Chain cover - Cooling circuits improvement

7.7.4 COOLING FIXTURES

Chain cover being a U section, it has got all tend to have post warpage towards the inner section. This will in turn restrict the free movement of the chain during vehicle running condition. This is one of the pareto defect discussed in the earlier chapter. The anticipated deflection was evident in the deflection report of mould flow. To overcome this post cooling fixture was designed for

- Setting the component in enlarged condition for 120 seconds. The cooling fixture was made 28 mm bigger to overcome the spring back effect.
- Making the cooling faster at that set condition in a chilled condition that will set the component at the required dimension. The cooling fixture is circulated with chilled water of 18 degrees. We can see this in Fig. 7.10.

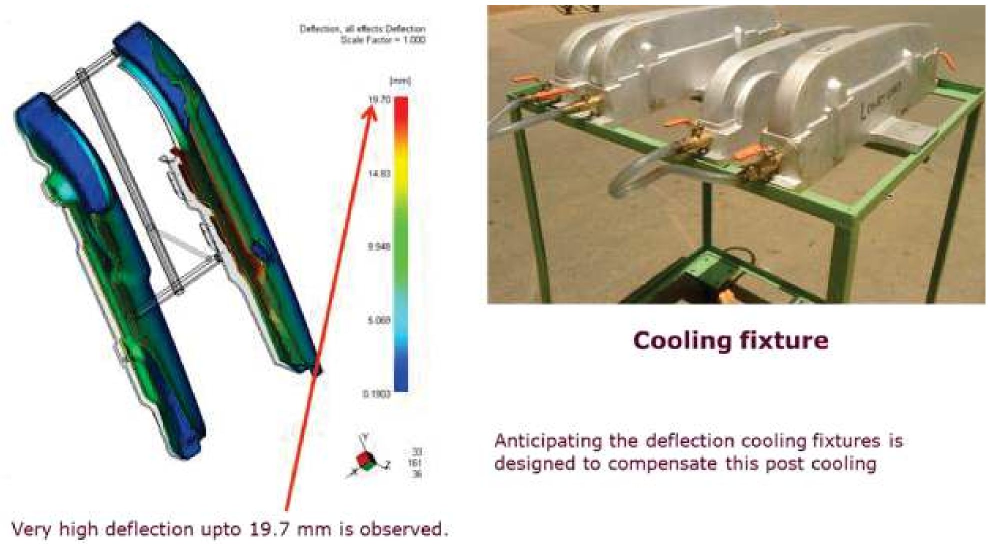


Fig. 7.10: Cooling fixture

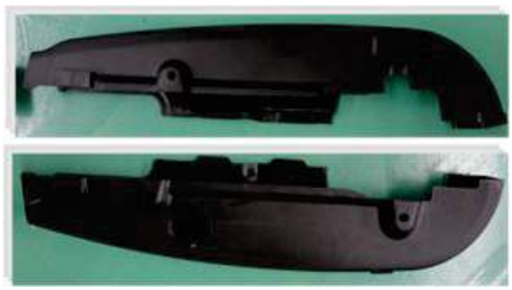


Fig. 7.11: Chain cover sample photo

7.8 MOULD DEVELOPMENT PLAN

Based on the design improvement actions, mould was development was started. All improvement actions were incorporated. Refer to the development plan attached below. There was a certain delay in between. Later during the mould progress actions, was taken to over-come the delay.

Part Name: Chain case upper and lower

Part No.: N8090910 / N8090900

In Table 7.4, P, A and w represents plan, action and week respectively.

Activity	P	Aug - 20		Sept - 20				Oct - 20					Nov - 20		
	A	w 34	w 35	w 36	w 37	w 38	w 39	w 40	w 41	w 42	w 43	w 44	w 45	w 46	w 47
Feasibility study	P														
	A														
Mould design	P														
	A														
Raw Material purchase	P														
	A														
Mould base manufacturing	P														
	A														
Roughing	P														
	A														
Cooling holes and boring	P														
	A														
Profile roughing – CNC Mill	P														
	A														
Profile finishing – CNC Mill	P														
	A														
Electrode machining	P														
	A														
EDM - Wire cut	P														
	A														
EDM – Sparking	P														
	A														
Polishing	P														
	A														
Bench work	P														
	A														
Assembly	P														
	A														
T0 Trials	P														
	A														
Mould debugging	P														
	A														
T1 Trials	P														
	A														
Approval	P														
	A														
PPAP run and approval	P														
	A														

Table 7.4: Mould development plan

7.9 PROCESS & PACKING IMPROVEMENT FOR PROPOSED MATERIAL

In this project for processing, we are going to use injection moulding. Injection moulding is a manufacturing process for producing parts by injecting material into a mould. Injection moulding can be performed with a host of materials, including metals, glasses, elastomers, confections, and most commonly thermoplastic and thermosetting polymers. Material for the part is fed into a heated barrel, mixed, and forced into a mould cavity where it cools and hardens to the configuration of the cavity. For moulding engineering, we refer in website and from the following text books, Mr. Douglas M. Bryce, 1999, [32] and Mr. Hebert Rees, 2002, [33].

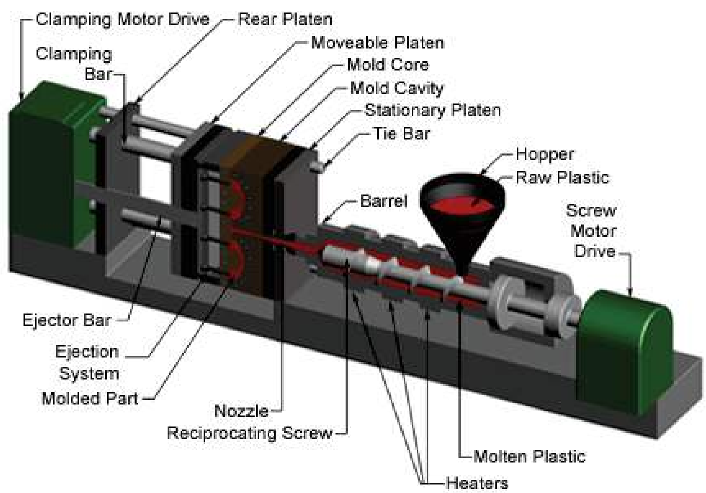


Fig 7.12: Schematic diagram of the injection moulding machine

Purpose: To get consistency in the moulded part quality.

Scope: Injection moulding process

Following three parameters are determined for process validation.

a) Viscosity curve

b) Gate freeze

c) Process window

7.9.1 VISCOSITY CURVE

1. Set the melt temperatures to those recommended by the manufacturer. If there is a range, set the temperatures to the centre of the range.
2. Set all the holding phase parameters to zero. This means that there will not be any holding phase and only injection.
3. Set the injection pressure to the maximum available.
4. Set the cooling time to a safe value such that the part will be cooled and has reached the ejection temperature before mould opening.
5. Set the injection speed to 'slow' and make a part. The part should be short. If not adjust the transfer position to make the part such that it is filled only about 50%.
6. Increase the speed in steps and make sure that the parts are still short. Mould a part with close to the maximum injection speed and make sure that it is still short. If it is full, then adjust the transfer position, such that it is about 95 % full part. If it is less than 95 % full, then also adjust such that the part is 95% full. This means that at close to the maximum injection speed you have a 95% full part with no holding time or pressure.
7. Make another shot and record the fill time and the peak hydraulic pressure required to fill the part. Note: The peak hydraulic pressure will be the pressure required to move the screw at the set injection speed. This is taken from the available pressure from the machine. For example, the machine is set to 2200 psi but may require only 1850 psi to move the screw at the maximum speed of 5 in/sec.
8. Next, lower the speed by a small amount, for example from 5 in/sec to 4.5 in/sec or from 90% to 80%. Note the fill time and the peak injection pressure.
9. Repeat the above step all the way till you get to the lowest injection speed possible. Divide the available injection speed range into about 10 - 12 speeds so that you get as many data points.

10. Find the Intensification Ratio of the screw from the machine manufacturer. If this number is not available, pick it to be 10. It does not really matter since this is a constant used in the equation and will factor the viscosity proportionately.

$$\text{Viscosity} = (\text{Peak Injection Pressure}) \times (\text{Fill Time}) \times (\text{Screw Intensification Ratio})$$

In Table 7.5,

A - Machine set velocity (distance / sec) (injection speed)

B - Hydraulic peak pressure

C- Intensification ration

D- Fill time

E - Relative viscosity

F - Shear rate = 1/ E

S. No.	A	B	C	D	Relative viscosity $E = B \times C \times D$	F	Optimum setting
1.	10	33	12.54	13.5	5586.6	0.07	Short fill
2.	15	39	12.54	11.5	5624.2	0.09	Short fill
3.	20	40	12.54	10.5	5266.8	0.1	Short fill
4.	25	43	12.54	8	4313.8	0.13	Short fill
5.	30	44	12.54	6	3310.6	0.17	Short fill
6.	35	53	12.54	4.2	2791.4	0.24	Short fill
7.	40	54	12.54	3.8	2573.2	0.26	Short fill
8.	45	55	12.54	3.6	2482.9	0.28	Short fill
9.	50	56	12.54	3.5	2457.8	0.29	95% fill
10.	55	58	12.54	3.4	2472.9	0.29	95% fill

Table 7.5: Viscosity

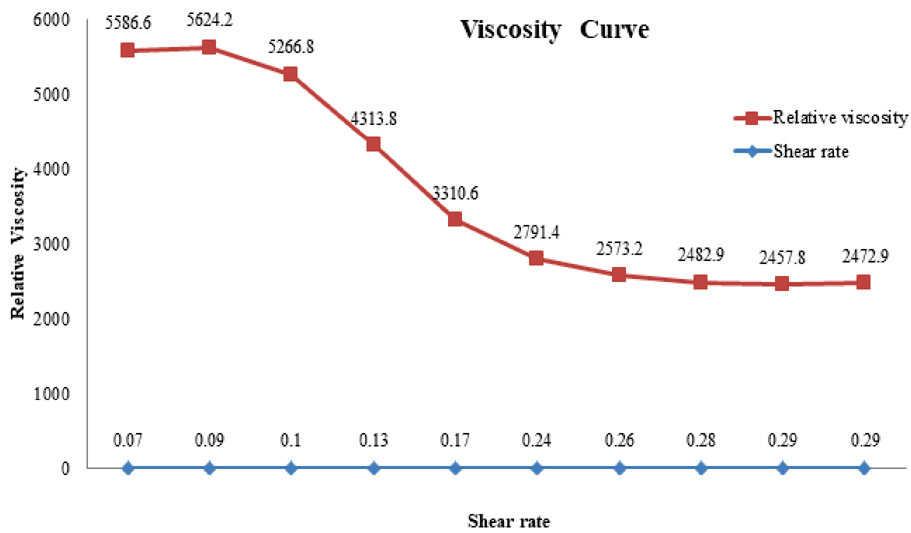


Fig. 7.13: Viscosity curve

7.9.2 GATE FREEZE

Set the injection speed to the value obtained from the viscosity curve experiment. Set the process at the centre of the process window from the process window study. Set the cooling time to a value to ensure that the part is cooled before ejection. Drop the holding time to zero and start moulding. Mould approximately 5 to 8 shots. Increase the holding time to one second and collect a shot. Increase the holding time to two seconds and collect a shot. Similarly, collect shots at increments of one second. Weigh the shots and plot a graph of part weight versus time. Determine the gate seal time.

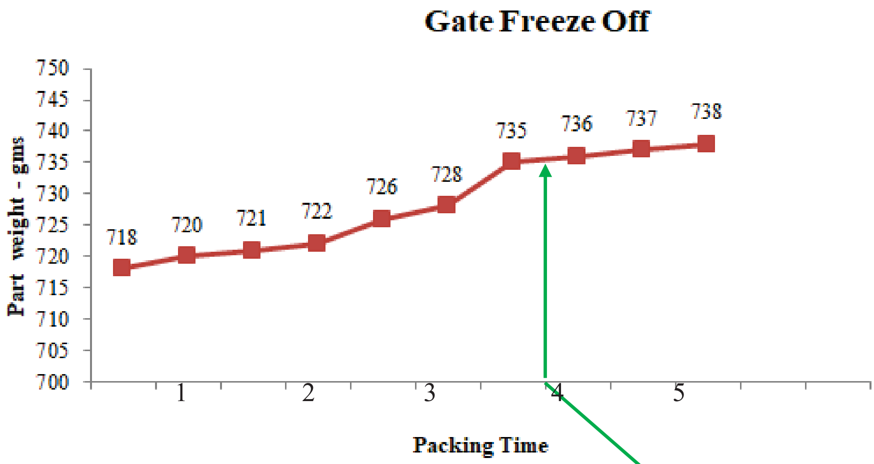


Fig. 7.14: Gate freeze graph

Gate freeze of should be set just after the curve levels

7.9.3 PROCESS WINDOW

1. Set the barrel temperatures to attain the lower value of the recommended melt temperature.
2. Set the injection speed to the value obtained from the viscosity curve experiment.
3. Set all holding times and pressures to zero
4. Set the cooling time to a value more than what would be typically necessary. E.g. If the estimated cooling time is 10 seconds, set the cooling time to 20 seconds.
5. Start moulding and adjust the transfer position to make a part 95 t o98% full.
6. Let the process and the melt stabilize by moulding the parts for about 5 to 8 shots.
7. Now set the hold time to a value such that you are sure the gate is frozen. For the experiment, we would set the hold time to 6 to 10 seconds.
8. Increase the holding pressure in small increments and note the pressure where an acceptable part is made (no shot fill, flash, etc. …).
9. Note down this pressure as the 'Low Temperature - Low Pressure' corner.

10. Increase the pressure further in similar increments and note down the pressure where there is evidence of an unacceptable situation such as part sticking in the mould or flash, warpage, etc. Note down this pressure as the 'Low Temperature - High Pressure' corner.

11. Repeat steps (9) and (10), but at the high end of the recommended melt temperature. This time the two extreme pressures would be the 'High Temperature - Low Pressure' and 'High Temperature - High Pressure' corners. Joining these four corners would now generate the process window or the moulding area diagram.

12. Set the process to the centre of this window.

Sample	Packing Pressure at min melt point	Acceptable part quality? Yes/ No
1.	5	N
2.	10	N
3.	15	N
4.	20	N
5.	25	N
6.	30	N
7.	35	N
8.	40	Y
9.	45	Y
10.	50	Y

Table 7.6: Packing pressure at minimum melting point

Sample	Packing Pressure at max melting point	Acceptable part quality? Yes/ No
1.	5	N
2.	10	N
3.	15	N
4.	20	N
5.	25	N
6.	30	N
7.	35	Y
8.	40	Y
9.	45	Y
10.	50	N

Table 7.7: Packing pressure at maximum melting point

	Pressure		Temperatures
	Min	**Max**	
Low	45	35	180
High	55	45	230
Range	10	10	50
¼ of range	2.5	2.5	12.5
Proc low	47.5	37.5	192.5
Proc High	52.5	42.5	217.5

Table 7.8: Pressure and temperature

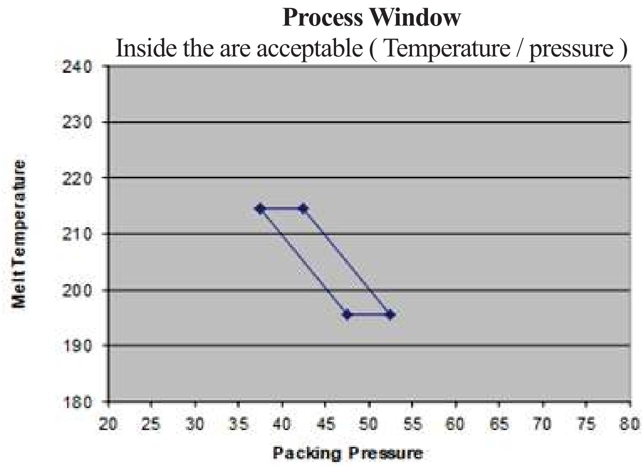


Fig. 7.15: Process Window

7.9.4 CYCLE TIME

By optimizing the process parameters product volume requirement was met. The cycle time breakup will discuss in Table 7.9.

Cycle time breakup **Before** **After**

S. No	Parameters	Time (Seconds)	Time (Seconds)
1.	Mould closing time	5	5
2.	Injection time	4.5	3.5
3.	Holding time	4	3.6
4.	Cooling time	45	25
5.	Opening time	8	8
6.	Ejection time	12	10
7.	Total cycle time	78.5	55.1
8.	output / day with OEE 85%	877	1250
9.	Requirement / day	1200	1200
10.	**Gap**	**- 323**	**50**

Table 7.9: Cycle time comparison

7.9.5 PACKING STANDARD

Warpage behaviour of injection moulded parts is crucial in determining the polymer dimensional accuracy. Warpage is known to be related to the existence of residual stresses related to heterogeneous temperature and cooling rate distributions, non-symmetric processing-induced morphology and orientation patterns through the part thickness. Warpage is one of the major hurdles that need to be taken care of this part chain cover. As far as the part mounted on to the vehicle, we have a mounting position on the swing arm of the vehicle which will hold part intact after assembly. But the part needs to intact till it gets assembled on to the vehicle, Jerry M. Fischer, 2003 [34].

7.9.6 CONCEPT PROPOSALS

To overcome this phenomenon, the different proposal was thought off. Following are the 2 concepts. Refer the pictures of the trolley concept and buffer and bin concept in Fig. 7.16.

- Buffer stacked in the part & stored in bins
- Customized trolley with square bars permanently fixed.

Trolley concept

Buffer & bin concept

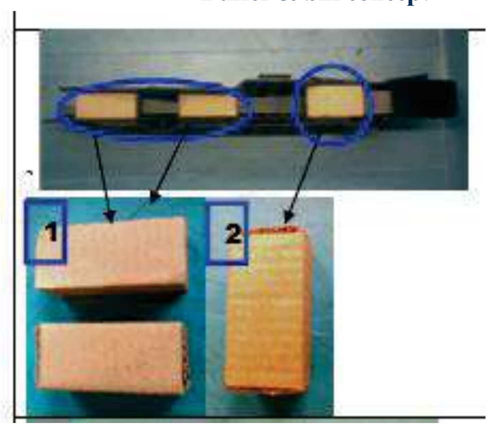


Fig. 7.16. Packing standard concept

7.9.7 CONCEPT VALIDATION AND SELECTION

Pros and cons of both concepts were weighed on weightage rating matrix to arrive at the final recommendation. Decided to opt for buffers stacking.

S. No.	Criteria	Validation Comments	Weightage	Trolley	Bins with buffer
1.	Dimension stability	Dimension control is better in case of buffers as one of the buffer can be made bigger.	20	2	4
2.	Handing scratches	Trolley bars prone to have hustling scratches on the component.	10	2	4
3.	Storage space	Bins can be stacked high one above the other.	15	1	3
4.	Freight cost	As bins can be stacked high, fright cost is less when compared to the trolley.	15	2	4
5.	Investment	Trolley investment is high (12.5 L). For bins, it is a common bin and hence exclusive investment.	10	2	3
6.	Dust	In trolley dust pick up is high as it is stored in an open condition for easy handling.	10	2	5
7.	Packing cost	Buffers cost per set comes to Rs 9. This can be eliminated in case of the trolley is designed with permanent bars.	20	5	1
Rating scale: 1 to 5, Low = 1, High = 5			**Final Score**	**245**	**325**

Table 7.10: Trolley Vs Bins decision

7.10 CONCLUSION

For attaining our expectation of reducing the cost chain case we adopted various technologies and improvising the chain case by redesign the gating systems, cooling systems and ejection system. Also, we validated the process by using three important parameters, which as viscosity curve, gate freeze and process window.

CHAPTER 8

DISCUSSION OF THE RESULTS

8.1 INTRODUCTION

In this chapter, we discuss the overall results of this project in a different scenario. Validate the test result in the initial stage and we try to find the fault in the process. After identifying the fault, we adopt the necessary actions and rectify the problem. At the end of the stage, we implement the changes in the vehicle and test the output. If everything is working properly, then we will get approval and validate the status of the product. Overall expected benefits are discussed in in this chapter. Also the expected time, cost and effort are discussed. Mainly it focuses on the achievement from this project and methodology adopted during its implementation.

8.2 OVERALL RESULTS OF THE PROJECT

The overall result of this project is described in this section. We provide results of this project in the following manner.

- Initial test results.
- Quality improvement.
- Necessary actions.
- The status of the actions.
- Part approval.
- Validation status after improvement.
- Standardization.

8.2.1 INITIAL TEST RESULTS

As per the discussion in Chapter 7, we process our project and get tested for validation. On receipt of tooled up samples, following tests was verified and validated on the vehicle.

S. No.	Test details	Requirements	Observations	Test results
1.	Fitment and functions test	Part shall be able to easily assemble in the vehicles	Found difficulty in assembling the chain case.	Not Ok
		Part shall not rub with the chain throughout the length.	Also observed chain rubbing near front portion of the chain case.	Not Ok
2.	Vibration endurance test on Rig.	Part shall not fail during the vibration loads.	Part meets the test requirements.	Ok
3.	Bump test	Part shall not fail during the road induced vibration loads	Part meets the test requirements.	Ok
4.	Material, finish and UV resistance	Part shall meet the material specification as per TSMS.	Part meets the test requirements.	Ok
		Part shall meet the UV resistance as per the specification.		
5.	Dimension	Part shall meet the dimensional and geometrical requirements.	Minor deviations observed, conditionally cleared.	Ok
6.	Thermal cycle test	Part shall not deform due to thermal load	No abnormal observed after the thermal cycle test	Ok
	Development test			

Table 8.1: Part validation status

8.2.2 QUALITY IMPROVEMENT

Chain cover rubbing defect has been controlled substantially. Refer the trend chart below. Moving forward, need to monitor the further improvements require to make this defect zero.

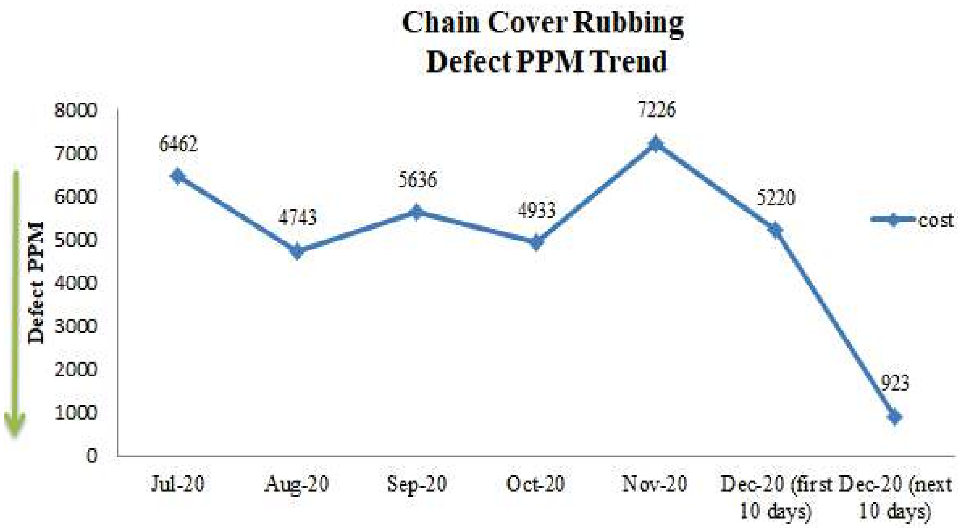


Fig. 8.1: Chain cover rubbing

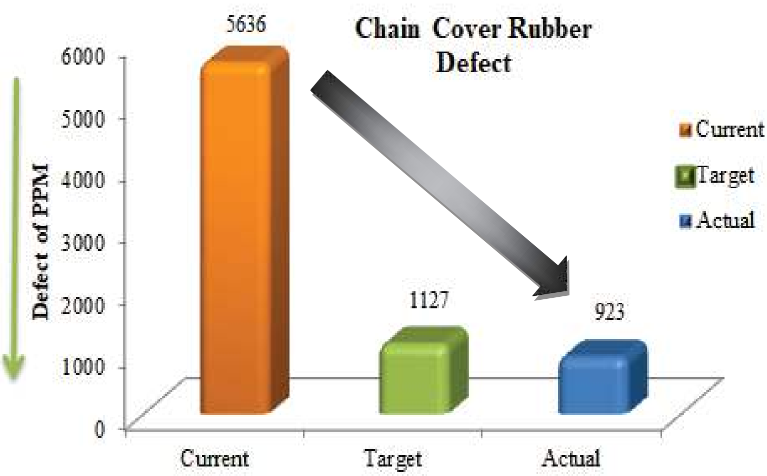


Fig. 8.2: Chain cover rubber defect

8.2.3 NECESSARY ACTIONS

Based on the above test results, need to improve the following 2 areas

- Snap - fit improvement.
- Chain rubbing in the sprocket area.

8.2.3.1 Snap Fit Improvement

Following is the process flow of chain cover assembly in vehicle assembly conveyor

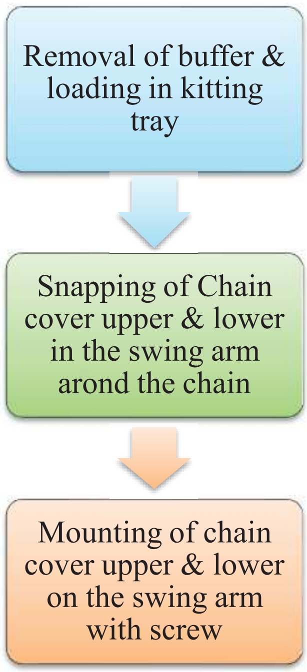


Fig. 8.3: Snip improvement

During the snapping, the part falls off which affects station cycle time & leads to conveyor stoppage. Based on this action was taken to increase the snap strength. Enough care was taken not to make it too tight as it will also affect the station cycle time.

Action taken to improve locking during assembly

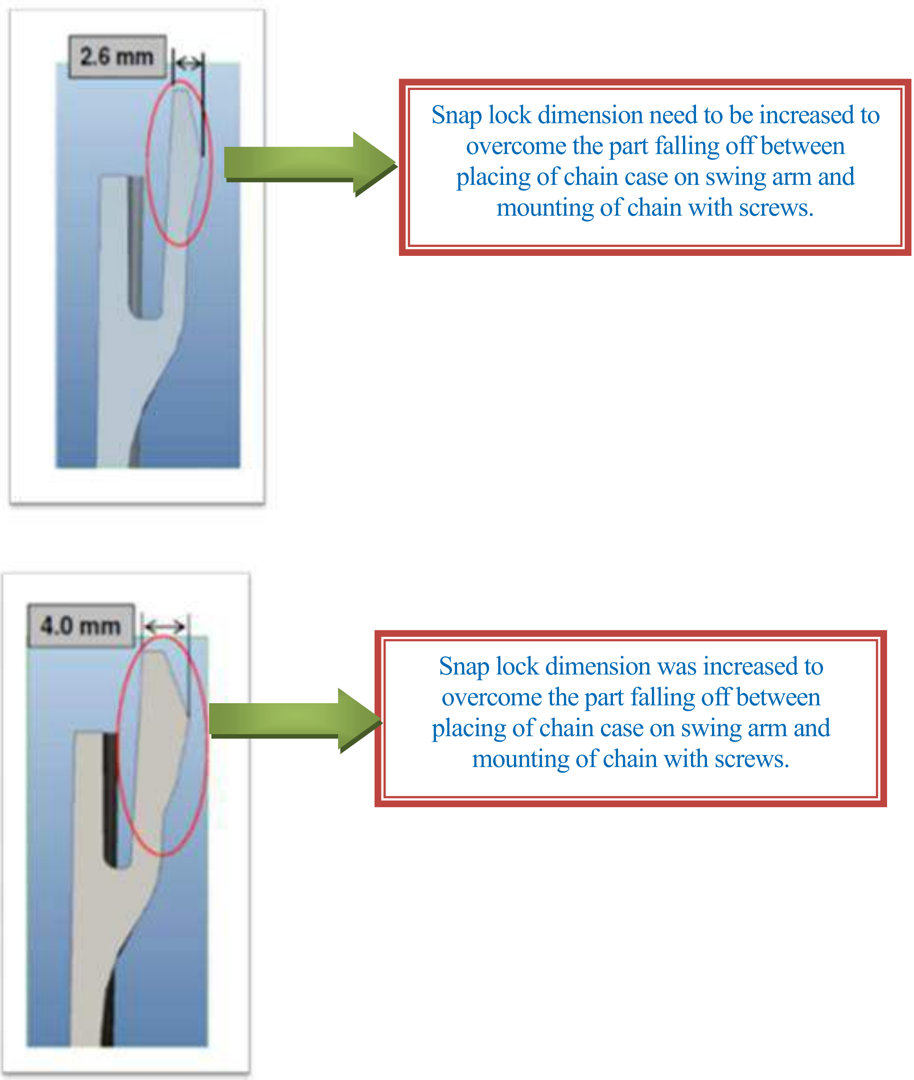


Fig. 8.4: Snap fit improvements

8.2.3.2 Chain Rubbing in the Sprocket Area

The chain cover has 2 mountings and at the farther end towards the sprocket area, there is no mounting due to the vehicle layout constraints. There is a tendency for the chain cover to flex towards inner profile. To overcome this decided to add have a pocket profile.

Action is taken for chain cover rubbing at the sprocket area

Before **After**

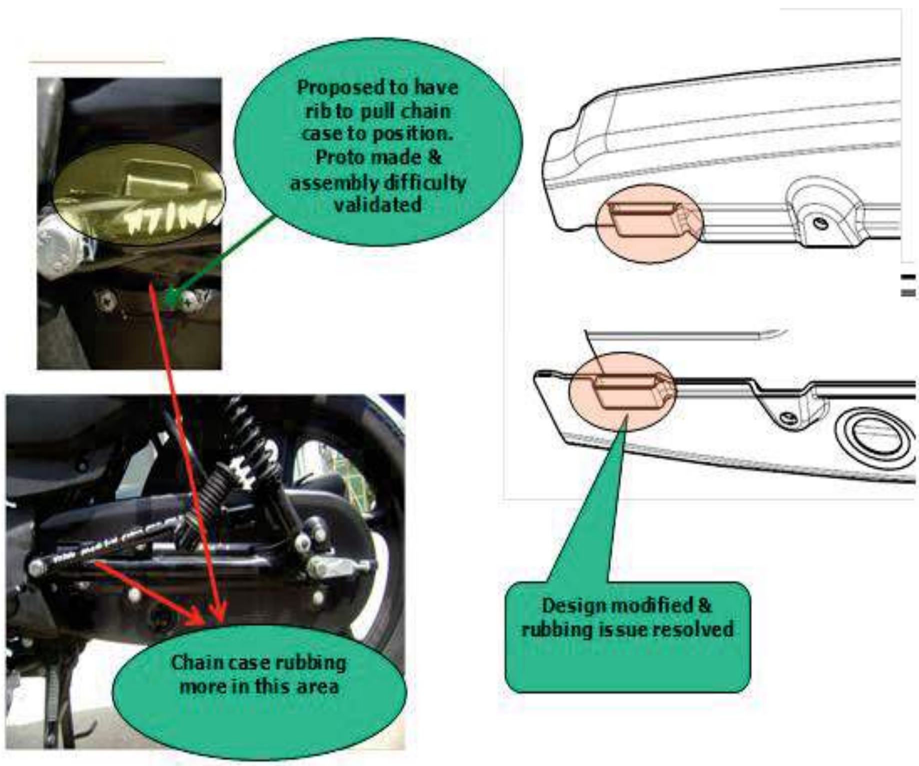


Fig. 8.5: Chain cover rubbing actions

8.2.4 THE STATUS OF THE ACTIONS

Chain cover with improvements

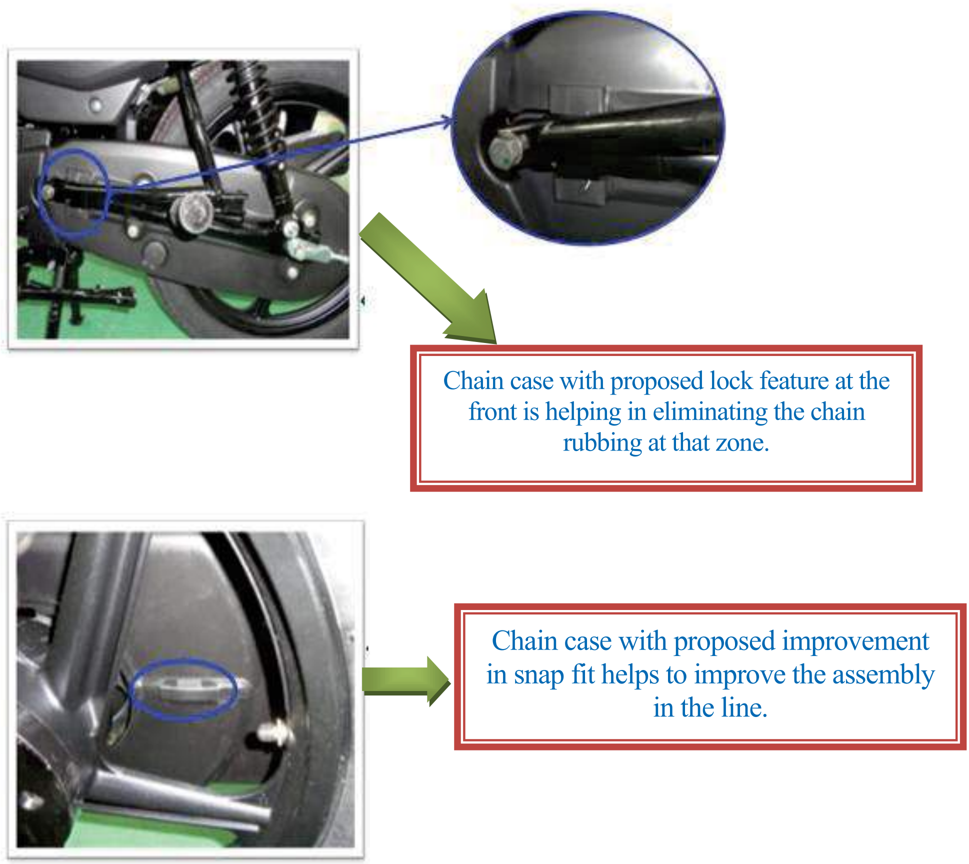


Fig. 8.6: Validation action status

8.2.5 PART APPROVAL

S. NO	Part approval reports	Status
1.	Quality lab approval report for Bump and vibration test	Accepted
2.	Design verification plan approval	Accepted
3.	Sample approval report	Accepted

Table 8.2: Part approval status

8.2.6 VALIDATION STATUS AFTER IMPROVEMENT

S. No.	Test details	Requirements	Observations	Test results
1.	Fitment and functions test	Part shall be able to easily assemble in the vehicles	Chain cover upper and lower snap is good and not conveyor stoppage.	Ok
		Part shall not rub with the chain throughout the length.	Chain cover rubbing in the sprocket area is eliminated.	Ok
2.	Vibration endurance test on Rig.	Part shall not fail during the vibration loads.	Part meets the test requirements.	Ok
3.	Bump test	Part shall not fail during the road induced vibration loads	Part meets the test requirements.	Ok
4.	Material, Finish and UV resistance	Part shall meet the material specification as per TSMS.	Part meets the test requirements.	Ok
		Part shall meet the UV resistance as per the specification.		
5.	Dimension	Part shall meet the dimensional and geometrical requirements.	Minor deviations observed, conditionally cleared.	Ok
6.	Thermal cycle test	Part shall not deform due to thermal load	No abnormal observed after the thermal cycle test	Ok
	Development test			

Table 8.3: Part validation status after improvement

8.2.7 STANDARDIZATION

As part of standardization to have improvement sustenance following activities are completed

S. No.	Get Approval	Approval status
1.	Experimental Job Order approval	Vehicle assembly approval
2.	Engineering change order approval	Approval from concerned departments for ECO release
3.	Engineering change order release	Drawing regularization with the changes
4.	PSW sign off	PPAP approval for the part supplier combination

Table 8. 4: Standardization

8.3 OVERALL EXPECTED BENEFITS

Savings realized per vehicle is Rs28 per vehicle. By fulfilling this company will get an annual savings of Rs 8,40,0000.

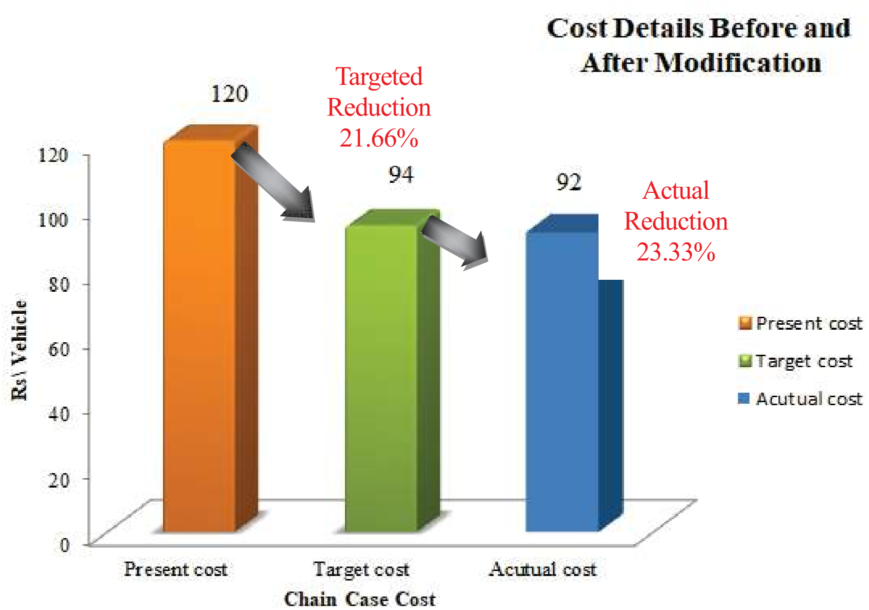


Fig. 8.7: Cost improvements

Function cost $\nabla = \frac{94}{92} = 1.02.$

Total savings achieved Rs. 28 / Vehicle

8.4 OVERALL EXPECTED TIME, COST AND EFFORTS

The overall expected time of the chain case is described in the following table.

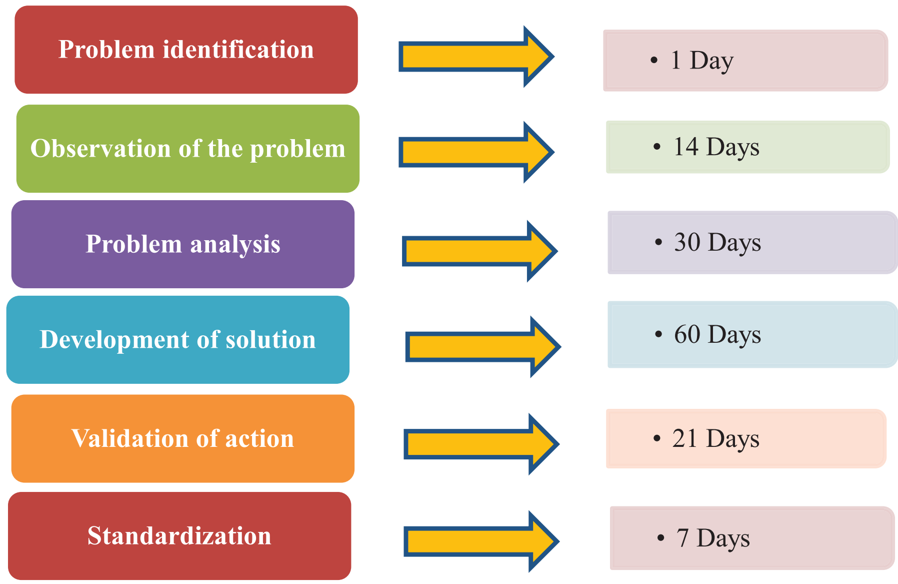


Fig.8.8: Overall expected time

As per the declaration in Section 8.3, the overall expected cost will be Rs28 per vehicle and the company will get an annual savings of Rs 8,40,0000.

The overall effort in this project is we have started activity from product design and established up to mass production. This is equivalent to a complete new product development.

8.5 SUGGESTED SCHEME OF IMPLEMENTATION

We have followed QC story approach with value engineering and value analysis approach (Metal to plastic conversion). This project implementation planned such a way that existing production did not have any disturbance and proper validation before jumping into implementation. After getting sufficient confidence in new proposal changeover planned in the production line.

8.6 PRECAUTIONS

Precautions measures are essential to avoid the damage in the existing vehicle production. We have done an extensive benchmarking study and gone through various literature reviews on value engineering. Separate mould is developed without touching the existing production mould. After complete testing and approval changeover has been planned.

8.7 CONCLUSION

In this chapter, we have done a complete comparison of results with the existing chain case. In the result review, we have compared all aspects like function, quality of the part, cost of the product and capacity of the new mould to meet the production demand.

CHAPTER 9

CONCLUDING REMARKS

9.1 SUMMARY

The intension of this project is to overcome the price hike in the selling price of two – wheeler in the automobile industry. If we reduce the manufacturing cost, automatically vending price will also come down, because increasing the cost of two wheelers in the market is not the motive of the automobile industry. What kind of problems and how the automobile industries struggling are already discussed in this project. However, the chain case cost is extraordinarily little, but each small thing will help us to reduce the price of two – wheeler cost. We have done a vast survey and collected the data from resources to study our problem. After collecting the data, we did a deep analysis, identified the main problem, and tried rectifying the minute problems using VAVE and FA. The main reason we identified is the material of the chain of cases, so we convert the materials metal into plastic especially when we adopt the polymer called Polypropylene. Moreover, we had validated that polypropylene will be the better one among the available materials. Furthermore, in this project we have achieved the intended cost benefit in addition, we have addressed the prevailing quality issue in the product, which resulted in particularly good cost saving and improved the customer satisfaction by resolving the quality issue.

9.2 GAINS OF THE STUDY

- Impact of new norms and regulations in the automobile industry.
- The necessity of the literature reviews.
- Importance of benchmarking.
- Advantage of QC story approach to achieve the desired results.

- A significant impact of VAVE on cost reduction.
- Plastic material penetration in the automobile industry.
- Reputation of improving the quality of the product.
- A novel approach of redesign the product

9.3 LIMITATIONS OF THE STUDY

- We cannot influence government regulation and emission norms.
- Automobile industry.
- Two - wheeler products.
- Plastic material limitation respect to impact load and heat resistance.
- Possibility of plastic metal to plastic conversion.

9.4 SCOPE FOR FURTHER WORK

- Other vehicle chain cases could be change into plastic across the company.
- Vehicle level parts could be explored for metal to plastic conversion considering minimal impact and heat resistance application.

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