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ANALYSING THE EFFECT OF IMPLEMENTATION OF LEAN SIX SIGMA IN MODERN AUTOMOBILES IN INDIA

Shaikh Moinuddin[1], Dr. S.D Deshmukh[2], Ritesh Fegade[3]
[1]Ph.D. Research Scholar, Dr. Babasaheb Ambedkar Marathwada Univesity, Aurangabad (India)
[2]Principal, JNEC, Aurangabad (India)
[3]Assistant Professor, Dept. of Mechanical Engineering, GSMoze, COE, Balewadi Pune (India)

ABSTRACT

Lean Six Sigma (LSS) is a key ingredient of quality management principles, practices, tool and techniques. It is process based improvement methodologies, the combination of both can provide the philosophy and the most powerful tools to solve problems and create rapid transformational improvement at lower cost. Lean Six Sigma have been successfully implement in many manufacturing sector such as Toyota, Honda, Tata Motors, Ashok Leyland, Maruti, etc. Due to commercial competition, enterprises must focus on low cost; eliminate waste and workforce effectiveness to get high profit by satisfying end user.

Lean Six Sigma programs, which comprise statistical approaches with a systematic and quantifiable project-based improvement methodology, are proving to be extremely effective in tracking down the real causes of variation. By adopting this new approach, An Indian companies of all sizes, are now establishing a far better understanding and gaining much tighter control of their development.

Keywords*: *Design of experiment, Electronics control unit, Emission, Fuel Economy, Lean, Six Sigma, Variable valve timing.

I. INTRODUCTION

Lean and Six Sigma have evolved in Toyota, Japan and Motorola, USA respectively. Lean has a reputation of making the organization to drive cost reduction through creating an organization wide war on waste. Lean makes the organization competitive in the long-term. On the other hand, Six Sigma proved itself as the most effective problem solving approach and delivers breakthrough results in the short-term.

An organization can gain both in short-term and long-term by combining the Lean as well as Six Sigma approaches. Lean Sigma program combines the best of American and Japanese quality management practices.

Lean manufacturing is a systematic approach for identifying & eliminating waste in operations through continuous improvement for doing everything more efficiently, reducing the cost of operating the system & fulfilling the customer's desire for max value at the lowest price.

Electronics and software control 70% of modern cars' functionality; studies predict 90% and more tomorrow, however mechanics is still present and important. The induced system complexity makes it increasingly difficult for automotive companies to master interdisciplinary, horizontal issues such as quality, reliability, and functional safety. The holistic nature of these quality requirements and the ever increasing need for shortening development cycles imply that the topics linked to risk aspects have to be addressed in a totally integrated way.

II. BACKGROUND

India vehicular population growing at a rate of over 5% p.a, with the increasing threats of global warming and vehicular pollution the role of emission control becomes mandatory in maintaining the ecological balance. In 1959, California formulated the first emission norms in the world. In 1966, Emission standards were introduced in Japan. In 1970, European countries formulated the ECE regulation.

In 1991, Emission norms were first introduced in India for petrol vehicles and subsequently in 1992 for diesel vehicles with further emission control. In 2000, Bharat stage (BS) Norms start implemented in line with Euro Norms. At present BS-IV norms is prevails in the country.

Major changes took place in vehicle to meet BS-IV norms. Apart from using the emission control devices like catalytic converters to meet the Bharat stage norms there was need to adapt new technologies in modern vehicles to reduce emissions. Some of the new technologies and add-on devices in engine and vehicle as a whole explained in next headings.

III. ADAPTION OF NEW TECHNOLOGIES IN LEAN MANUFACTURING WITH DFSS (DESIGN FOR SIXSIGMA) ON ASSEMBLY LINE

The Indian manufacturers like Ashok Leyland, Tata Motors, Force motors, etc started using lean manufacturing concept and DFSS for further improvements in vehicles. Japanese based companies like Maruti Suzuki, Toyota, Honda, etc using the Just-in-time (JIT), Kaizen, and quality controls as lean attributes.

Lean practices in the industrial and management literature are

_ JIT/continuous flow production
_ Pull system/Kanban
_ Quick-changeover techniques
_ Lot-size reductions
_ Continuous-improvement programs
_ Cross-functional work force
_ Preventative maintenance
_ Total quality management
_ Self-direct work teams
_ Cellular manufacturing
_ Focused-factory production
_ Cycle-time reduction
_ Process-capability measurements
_ New-process equipment
_ Safety-improvement programs
_ Bottleneck removal (production smoothing)
_ Quality-management programs
_ Re-engineered production process

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_ Competitive benchmarking

_ Maintenance optimization

_ Planning and scheduling strategies

In Six Sigma, the management of the improvement project follows the DMAIC (Define – Measure – Analyze– Improve – Control), DMADV (Define - Measure - Analyze - Design – Verify) and DFSS (Design for Sixsigma) cycles. Six Sigma tools like QFD (Quality Function Deployment) and VOC (Voice of the Customer) help in identifying the customer requirements which have the highest impact on success. For systems design the DFMEA (Design FMEA) helps to analyze potential malfunctions and causes. It defines counter measures in turn that help to increase the product reliability. A method like DOE (Design of Experiments) helps in system design to analyze the dependency of design parameters and decide about optimized design parameters which have an impact on e.g. reliability and quality.

There are a few other "flavors" of DFSS: IDOV, DCCDI and DMEDI.

- IDOV acronym is defined as Identify, Design, Optimize and Validate.
- DCCDI is defined as Define, Customer Concept, Design and Implement.
- DMEDI stands for Define, Measure, Explore, Develop and Implement.

Modern vehicles are having more fuel economy, safety and more stability. Best mileage car approved by ARAI, Pune in India like Maruti Ciaz SHVS 28.9 kmpl, Baleno 27.39 kmpl, Honda Jazz 27.3 kmpl, Tata Tiago 27.28 kmpl, Toyata Prius 26.27 kmpl etc are possible due to

i) Effective implementation of lean manufacturing in vehicle assembly line.

ii) Designing the new models of vehicle with more advance system in vehicle can be implemented through one of DFSS methodology like IDOV methodology.

IDOV is a well known design methodology, especially in the manufacturing world. The IDOV acronym is defined as Identify, Design, Optimize and Validate.

- Identify the customer and specifications (CTQs).

- Design translates the customer CTQs into functional requirements and into solution alternatives. A selection process whittles down the list of solutions to the "best" solution.

- Optimize uses advanced statistical tools and modeling to predict and optimize the design and performance.

- Validate makes sure that the design you've developed will meet the customer CTQs.

Some of technological changes or upgradation in vehicle that contributes to more mileage and these further helps to reduce exhaust emission to meet Bharat stage IV norms comfortably are as follows,

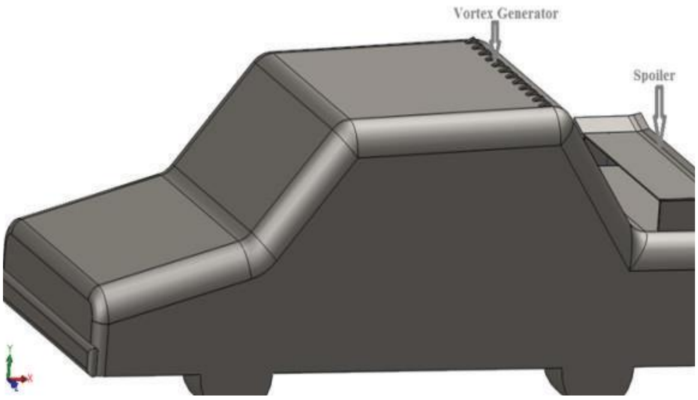
i) Engine management system: Engine Management System (EMS) comprises of Electronic Control Unit (ECU), sensors, actuators and control algorithms that determine the performance of the Engine as a whole and as part of the vehicle.

Engine Management System (EMS) comprises of Electronic Control Unit (ECU), sensors, actuators and control algorithms that determine the performance of the Engine as a whole and as part of the vehicle. High pressure pump work with ECU controlled metering unit. ECU controlled injectors with common rail system. Inline and rotary fuel pump is replace with Common rail direct injection system in modern vehicle to achieve better atomization of fuel leads to fuel economy and reduction of emission. CRD fuel pump is self lubricating with fuel only and conventional inline and rotary fuel pump required oil for lubricating fuel system. Modern Common Rail Direct Injection systems are working with very high pressure more than 1500 bar.

ii) Electronic throttle system: In recent years, many important functions of modern automobiles are shifting from a purely mechanical to an electromechanical implementation. These functions are implemented by using the so-called "x-by-wire" systems, including drive-by-wire and steer-by-wire systems [1, 2]. Electronic throttle system is one of the important drive-by-wire systems for modern automobiles. The electronic throttle is essentially a DC-motor-driven valve that regulates air inflow into the vehicle's combustion system. Its control system positions the throttle valve according to the reference opening angle which is provided by the engine control unit. In recent years, the electronic throttle is increasingly being used in modern automobiles in order to improve the vehicle drivability, fuel economy, and emissions.

iii) Start- Stop system: Global environmental protection requirements, which have increased worldwide in recent years, have accelerated efforts for improving the fuel economy of vehicles. A typical example involves adopting engine start-stop function to reduce energy consumption when the vehicle is stopped, thus improving the urban environment [3]. This function shuts off the engine when the engine power is not required and restarts the engine when necessary. In the New European Driving Cycle (NEDC), this function can achieve a fuel economy improvement of approximately 5% [4].

iv) Aerodynamic body of car (Vehicle dynamic): In the process of car design, the aerodynamics must be seriously considered. A car design can, generally, only be acceptable if its form drag is reduced to a set target. Many researchers have made use of CFD techniques [5–8] to perform numerical simulations related to automobile aerodynamics. The current study presents the development process of aerodynamic holography of the vehicle outer body. Several numerical simulations were performed to analyse the pressure field, velocity vector field, and aerodynamic force prediction related to a passenger car. Then, the stability of the aerodynamic forces caused by the airflow over the car was examined. Thereafter, the installation of add-on devices that leads to lower aerodynamic drag was carefully evaluated.



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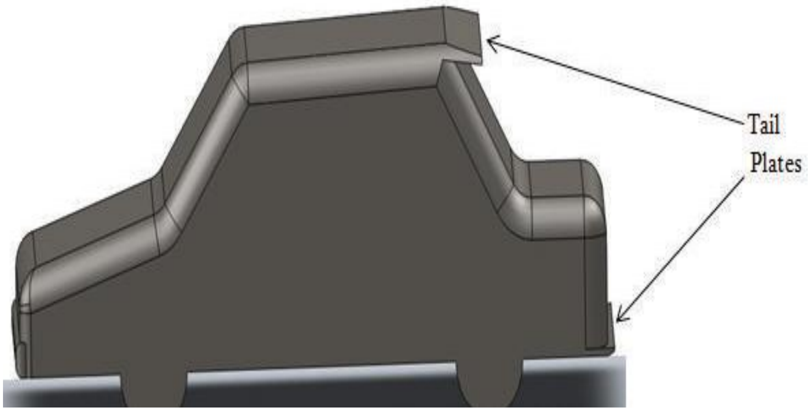

In order to decrease the drag of the passenger car the combination of the add-on devices is applied on the car surface to overcome the drag coefficient of the car. In the above analysis there are different types of aerodynamic add-on devices used on the baseline car to get the results for the coefficient of drag and coefficient of lift.

In the first case **the spoiler is applied on the boot of the passenger car** with the inclination angle 12◦.The coefficient of drag is 0.3441 and the coefficient of lift is 0.1985.The percentage reduction in drag coefficient in comparison with baseline car is 2.02% and in coefficient of lift is 6%. Hence, drag force and lift force on the passenger car are reduced as proportional to drag coefficient and lift coefficient, respectively.

In the second case **the vortex generators are applied on the rear side at roof of the baseline car** with inclination angle 12◦. The coefficient of drag is 0.3471 and the coefficient of lift is 0.2085. The percentage reduction in drag coefficient in comparison with baseline car is 1.17% and in coefficient of lift is 9.8%. Hence drag force and lift force on the passenger car are reduced as proportional to drag coefficient and lift coefficient, respectively.

In the third case **the tail plates are applied on the rear side**: one is at the rear side of the roof garnish and the **other is at the tail bumper of the passenger car**. The coefficient of drag is 0.3376 and the coefficient of lift is 0.1926. The percentage reduction in drag coefficient in comparison with base line car is 3.87% and in coefficient of lift is 16.62%. Hence drag force and lift force on the passenger car are reduced as proportional to drag coefficient and lift coefficient, respectively.

In the fourth case the **spoiler and VGs together are applied on the rear boot and rear side at the roof of the passenger car.** The coefficient of drag is 0.3359 and the coefficient of lift is 0.1875. The percentage reduction in drag coefficient in comparison with base line car is 4.35% and in coefficient of lift is 18.83%. Hence, drag force and lift force on the passenger car are reduced as proportional to drag coefficient and lift coefficient, respectively. From the above analysis, it is found that spoiler with VGs is more effective add-on device to reduce the drag coefficient and lift coefficient which are applied on the passenger car when the car is running on the road. The drag coefficients and drag forces are proportional to each other so when the drag forces are reduced, lift forces are also reduced because it is proportional to the lift coefficient.

The effects of different aerodynamic add-on devices on flow and its structure over a generic passenger car may be analysed using CFD (Computational fluid dynamics simulation) approach. The objective is to reduce aerodynamic drag acting on the vehicle and thus improve the fuel efficiency of passenger car. Hence, the drag force can be reduced by using add-on devices on vehicle and fuel economy, and stability of a passenger car can be improved.

v) Variable Value Timing(VVT): Internal combustion engines are a main power source for vehicles. Improving the engine power is important which involved optimizing combustion timing and quantity of fuel. Variable valve timing (VVT) can be used in this respect to increase peak torque and power.

Variable valve timing (VVT) is used in spark ignition automotive engines to improve fuel economy, reduce NOx gases, and increase peak torque and power [9]. Valve control is one of the most important parameters for optimizing efficiency and emissions, permitting combustion engines to conform to future emission targets and standards. Thermodynamic conditions during the closed cycle (compression, combustion, and expansion) can be directly controlled by adjusting the intake valve opening (IVO) and intake valve closing (IVC) angle, which defines the total intake mass flow rate and the effective compression ratio of the engine [10]. Control of the intake valve provides optimal filling of the cylinder at all engine speeds. This natural supercharging, and the improved engine torque and power that accompany it, makes it possible to downsize engine capacity and thus reduce fuel consumption at all operating conditions [11]. Variable valve timing (VVT) relates to both the opening time and the duration of the valve's open interval. Controlling valve timing can improve the torque curve, the brake power curve, or the indicator-power curve of a given engine. Variable valve timing can also be used to reduce the fuel consumption and, to a small extent, the engine emissions [12]. The adoption of a continuous variable valve timing (VVT) system is able to optimize engine torque and efficiency [13].

vi) EGR (Exhaust gas recirculation) system: EGR is technique used in the Diesel Engines to reduce Emission of Nitrogen Oxide (NOx). EGR works by recalculating a portion of an engine's exhaust gas back to the engine cylinders. In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. This means the heat of combustion is less, and the combustion generates the same pressure against the piston at a lower temperature. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture. Because NOx formation progresses much faster at high temperatures, EGR reduces the amount of NOx the combustion generates. NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature.

vii) Lubricants: Automotive industries made a paradigm shift in selection of viscometrics of engine lubricant, from higher to lower viscosity grade, for improving fuel economy of vehicles. Engine fuel consumption is influenced by friction between the various engine components. Engine friction power (FP) of a direct injection diesel engine is calculated from the measured value of in-cylinder pressure signals at various operating conditions. For predicting FP, as a function of speed, load, and lubricant viscosity, a full factorial design of experiments (DOE) was formulated and an empirical correlation was developed. Response surface methodology (RSM) was used for analyzing the dominant parameters and their interactions, which influence engine friction power significantly. Predicted results of engine FP are in good agreement with measured values at all operating points. ANOVA and RSM analysis revealed that the significant parameters influencing engine FP are speed, load, viscosity, speed-load, and speed-viscosity. The effect of engine lubricant viscosity on friction power of a diesel engine was insignificant at low speed, whereas, at high speed, it played a vital role. The empirical relation developed for predicting FP is very useful in estimating engine friction power for various combinations of engine speeds, loads, and lubricant viscosity without running the engine.

IV. CONCLUSIONS

Waste minimization and improving efficiency have been identified as key objectives of lean manufacturing system implementation. It helps to manufacture vehicle at low cost without affecting the quality. But further improvement in vehicle can be done through upgrading and developing new system in the vehicle through effective implementation through DFSS that can leads to fuel economy and reduction of emission.

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