Implementation of TRIZ Principle for Improving the Acceptance Level of Assembled Engines

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Abstract: *The Theory of Inventive Problem Solving, sometimes known as TRIZ, is a strategy that encourages innovative and inventive problem solving. Altshuller is the one who develops TRIZ for use in product design. In this research, an attempt is made to integrate TRIZ with quality measurements of the reducing engine rejection in the assembly line. Every built engine is put through a series of tests that focus on quality control and the identification of problems. The performance test must be passed with flying colors by each and every engine. The costs incurred by the corporation due to rejected engines on the test bed are increased, and the quality of the assembly is decreased. Therefore, in order to have a decent DRR (daily run rate), it is necessary to decrease engine rejection. An oil leakage testing setup is put on the assembly line so that every engine may undergo a leak detection test before it is transported to the testing bed for an evaluation of the engine's performance. The air ways pressure decay technique is the one that is used. The pressure measuring sensor indicates a decrease in pressure in order to identify the amount of leakage. The primary goals of this project are to investigate the issues that lead to the rejection of engines by the testing department and to conduct time and cost savings evaluations on a per-rejected-engine and annual basis. As a consequence of this configuration, customer satisfaction has increased, which has led to an improvement in PQCDSM and a reduction in the cost of poor quality (COPQ).*

Keywords: TRIZ, Leakage, DRR, PQCDSM, Rejection, COPQ

1. Introduction

Every engine must be checked for quality. Engine runs through various tests before it is mounted in the vehicle or to outside accessories (radiator) and before it is filled with fluids (oil, coolant). Leak is major problem even small leak can be very dangerous. Each component in an automotive internal combustion engine is tested for leaks at multiple levels in the manufacturing process. Though engine is passed a leakage test on assembly line it was rejected during performance test for leakage. The frequency of problem found increasing. After an analysis it is found that most of the components where leakage is found were assembled after leak test. Hence to detect these leakages at earlier stage fully assembled engine must be checked. For this modifications are required in the existing setup. Among various problems solving techniques TRIZ is used to solve this problem and further analysis is carried out.

Rejected engine on test bed enhance the cost of company and lowers quality of assembly. So rejection of engine during performance test must be reduced by a possible ways to maintain good DRR (Daily Run Rate). This work deals with the improvement in leak test of oil ways passage of an engine by utilizing TRIZ. The goal of this experimental setup study is to detect every leak in the engine on assembly line before it goes for performance test. Productivity, quality, delivery, safety, and operator morale have all improved as a result of this work.

The Theory of Inventive Problem Solving, sometimes known as TRIZ, is a methodical approach to finding novel solutions that may be utilized by researchers, engineers, workers, and decision makers. Altshuller began his research in 1948 and found that many different inventions adhered to a relatively small number of fundamental solution patterns [1]. He came to this conclusion after observing that many different inventions. According to the findings of Altshuller, the great majority of new innovative issues are amenable to resolution through the use of TRIZ and prior experience.

Ideality, contradiction, and resourcefulness are the three fundamental ideas that underpin the TRIZ methodology. The idea behind TRIZ is best understood through the lens of the term "technical contradiction." Only after a technical contradiction has been identified and removed can a problem be considered solved. The most essential elements of the TRIZ contradiction matrix and the forty inventive principles, which are utilised in the Contradiction Table, provide assistance to designers in the elimination of contradictions by providing broad suggestions of engineering parameters [2]. This was initially developed for, and still primarily employed in, the resolution of contradictions in product design issues.

Movarrei,R.et.al.[3] investigates challenges surrounding the cataloguing and categorization of innovations, most of which have experimental roots. 40 innovative concepts (classes) of TRIZ, one of the less popular modernization tools, served as the foundation for the study for recording and categorizing innovations in the company's procurement and supply chain management. Expert judgment has been used to classify (assign inventions to 40 classes and construct parallels) based on analysis for replicibility.

Xie, J., & Li, F,[4] Numerous local and international academics have studied the merging of TRIZ and Six Sigma as a novel strategy.The paper focused on the integration of TRIZ and DMAIC after analysing the foundation and structure of TRIZ and DMAIC. The paper predicted management, organizational innovation, and applied research in many industries based on integrated TRIZ and DMAIC on the basis of domestic and international studies.

Thanabalu et.al.[5] This paper examine the value of workplace safety and provide creative TRIZ-based problem-solving techniques for engineers. It explains how TRIZ can be used to generate creative ideas, to minimize and reduce workplace safety hazards, especially in the construction and manufacturing industries, and how to use TRIZ solver 2.2, an innovative problem-solving software, in this process by studying 10 specific Inventive Principles. It is understood that TRIZ can be a potent instrument to address challenging issues over a wide range to improve workplace safety.

Dubois et.al. [6] Inventive difficulties from various fields are typically issues we cannot resolve. The inability to solve the problem is frequently caused by an inaccurate or mismatched representation model of the problem that does not fit the actual problem. The Constraint Satisfaction Problem (CSP) and dialectical based approaches and models are the two problem solving theories we establish in this research for the solution less challenges (TRIZ). It is a speculative examination of both theories in order to contrast their methods and resources for grounding. To improve issue solving strategies for creative challenges by combining the CSP and TRIZ solving concepts, their potential complementarities will be further identified.

N. Hilleret [7] according to the researcher, there are many leak detection techniques that are presented, along with information on the tools that are used for this purpose. Before installation, it is required to verify the tightness of the vacuum vessel using a guarantee of leak-proof construction. Different leak detection techniques are chosen depending on the amount of the leak.

K Zapfe et.al [8] introduces the topic of vacuum system leak detection. There is a description of the helium leak detector, its numerous applications, and leak detecting techniques. The method that is most frequently employed in industry is the helium leak detector. Each vacuum system needs to have a specific permissible leak rate. Leak detection is crucial in the manufacturing process.

This work deals with leak testing method and use of TRIZ which is explained in the method section. Method also elaborates utilization of contradiction and application of TRIZ principle and deployment of best solution. Time and cost analysis is discussed in the result section followed by the conclusions made from the analysis.

2. Methods

A leak test process is typically used as a quality control step to ensure device integrity, and it should ideally be a one-time non-destructive test that has no negative influence on the environment or operators. There are a variety of leak-testing methodologies available, ranging from extremely simple approaches to more complicated systems. The Semi-Automatic setup is used to test fully completed engines in such a way that any leakage is detected on the assembly line conveyor before the engine is sent to the testing department for testing. Delivering air at a pressure of 120 millibar and monitoring the pressurized engine for air leaks indicative of a leak at one or more engine oil seals, the testing station checks for leaks in the oil passages. The pressurizing apparatus consists of a set of pressure or pneumatic connectors that seal and engage connected engine parts and are used to inject pressurizing air into the engine.

2.1 Using The Contradiction Matrix To Find A Resolution For Contradictions

The TRIZ methodology provides forty Innovative Principles that may be used to the resolution of technical conflicts in order to solve inventive challenges. The selection of appropriate solution principles is made a great deal easier by the use of a table known as a Contradiction Matrix. This table consists of 39 rows and 39 columns. The 39 engineering input parameters reflect the most significant aspects of technical systems, such as mass, speed, temperature, the amount of material lost, the precision of measurement, and the quality of production, among other things. They assist in the formulation of technical conflicts in words that are standardized. The Matrix makes its recommendations for innovative concepts by doing a statistical analysis on more than one hundred thousand patents. This analysis determines which principles are the most likely to solve a particular standardized technical problem. In most cases, the solution principles do not already include fully formed answers or approaches to the issues. On the other hand, they direct the user's thinking in the appropriate manner. When numerous different ideas are combined, they can frequently provide more satisfying outcomes.

	Which properties of the system change for the worse? / Properties of the system to be modified or improved	1 Mass of the moving object	...	27 Reliability	28 Accuracy of measurement	...	39 Productivity
1	Mass of the moving object			3, 11 1, 27	28,27 35,26		35, 3 24,37
...	...						
9	Speed	2, 28 13,38		11,35 27,28	28,32 1, 24		
10	Force	8, 1 37,18		3, 35 13,21	35,10 23,24		3, 28 35,37
...	...						
39	Productivity	35,26 24,37		1, 35 10,38	1, 10 34,28		

Figure 1 Search for solution principle using contradiction matrix

2.2 Utilizing The Contradiction Matrix

1. Mass of the moving object
2. Mass of the non-moving object
3. Length of the moving object
4. Length of the non-moving object
5. Area of the moving object
6. Area of the non-moving object
7. Volume of the moving object
8. Volume of the non-moving object
9. Speed
10. Force
11. Tension, Pressure
12. Shape
13. Stability of the object
14. Strength
15. Action time of the moving object
16. Action time of the non-moving object
17. Temperature
18. Brightness, Visibility
19. Energy consumption of the moving object
20. Energy consumption of the non-moving object
21. Power
22. Energy loss
23. Material loss
24. Information loss
25. Time loss
26. Amount of substance
27. Reliability
28. Accuracy of measurement
29. Accuracy of manufacturing
30. Harmful external factors
31. Harmful internal factors
32. Convenience of manufacturing
33. Convenience of use
34. Convenience of repair
35. Adaptability
36. Complexity of the structure
37. Complexity of control and measurement
38. Level of automation
39. Productivity

Figure 2 39 Engineering Parameters of the contradiction matrix

By following the processes that are outlined below, appropriate solution principles can be found:

- Using the 39 engineering factors, formulate the technical contradiction for the problem that has to be solved. A technical contradiction consists of two properties of a technical system that are in direct opposition to one another.
- Determine which of the system's properties on the list of 39 engineering parameters is going to be altered or enhanced and write down your decision.
- Using the same list, determine which aspect of the system would suffer as a direct result of the change or enhancement that was discussed in step 2, and then explain why this will be the case.

- Once you have finished making your pick, up to four different solution principles will be shown in the corresponding cell of the matrix. It is advised that, in many situations, many contradictory solutions to the same problem be developed at the same time. In this scenario, you will need to carry out Steps 2–4 once more.
- It is feasible to infer a second contradiction, which is an inverted version of the first contradiction, rather often. In this particular instance, the sequence in which the parameters are to be entered (steps 2 and 3) has to be altered. For example, if you initially put "speed" in step 2 and "reliability" in step 3, the order now has to be inverted so that "reliability" is entered first in step 2 and then "speed" in step 3; this is because step 2 now comes before step 3 in the process.
- If, after inputting the engineering parameters (steps 2 and 3), there are no solution principles accessible for this contradiction (which results in an empty matrix box), then another technical contradiction has to be constructed. It is important that the new engineering parameters are distinct from those that were selected previously in phases 2 and 3.
- The strategies that are most likely to be successful are those that adhere to the principles that are mentioned in the programme the most frequently. The solution concepts that have been proposed and the ideas that have been obtained can also be merged, which frequently results in new innovative solutions to the problem.

2.3 Applying TRIZ principle

From the table 1, applying TRIZ Principle for Quality Check to increase productivity the factors affecting like measurement Accuracy, Ease of detecting and measuring. If the accuracy measurement is to be improved then if affects productivity as for better accuracy requires maximum time for testing. For maximizing productivity, parameter manufacturing precision gets affected. Table 2 explains the solution principles suggested by TRIZ and their possible solution approach.

Table1 Contradictions parameters

Formulation of the Technical Contradictions			Solution Principles
N	Which properties of the system are to be modified or improved?	Which properties of the system change for the worse as a result of this modification?	Suggested by TRIZ
1	28. Measurement Accuracy	39.Productivity	10,34,28,32
2	37.Ease of detecting and measuring	28. Measurement Accuracy	26,24,32,28
3	39.Productivity	29. Manufacturing precision	18,10,32,1

Table2 Solution Principles and Approaches

Solution Principles	Frequency	Description	Solution Approaches
32.Changing color or optical properties	3	-	-
10. Prior action	2	In measurement there is sequence maintained while quality check.	Sequence can be altered with considerable changes. After complete assembly whole engine can be analyzed
28.Replacement of a mechanical system with 'fields'	2	Different types of mechanical parts in combine responsible for overall rejection	Measurements of respective parts should replaced with fields or checking sequence should be changed for the mechanical parts
1.Segmentation	2	Divide an object into independent parts.	-
26. Copying	1	Instead of an unavailable, expensive, fragile object, use simpler and inexpensive copies	Use of simple measurement rather than adopting advanced technology
24.Mediator, intermediary	1	Merge one object temporarily with another (which can be easily removed)	Collecting the group of parts which are not responsible for rejection
18.Mechanical	1	--	--

Depending on the solution Approaches discussed in the table2 TRIZ solution principle 10 i.e. principle prior action gives best solution to the formulated problem. Solution approach for this principle is sequence of the station can be altered i.e. engine must be checked for leak detection after full assembly. Turbocharger, non return oil line dipstick flange oil mist separator are the crucial parts of the engine which are fitted after leakage test. Most of leakage occurred during performance test are in this parts only. Hence prior action suggests these parts must be checked for leak test on assembly line. For this modification in the existing setup is required. Other principles suggested by TRIZ like replacement of a mechanical system with 'fields' also helps but this seems to be costlier than the prior action. Segmentation is not feasible also changing colors wont helps in problem solving.

3. Results & Discussion

Applying TRIZ solution principle a prior action, solution approaches for changing the sequence of operation. As shown in the figure 3and figure 4 oil leak testing setup is modified and operation sequence is changed. Several trials are taken after modification for validating new setup. Figure 3 and 4 shows the leak testing setup before and after modification.

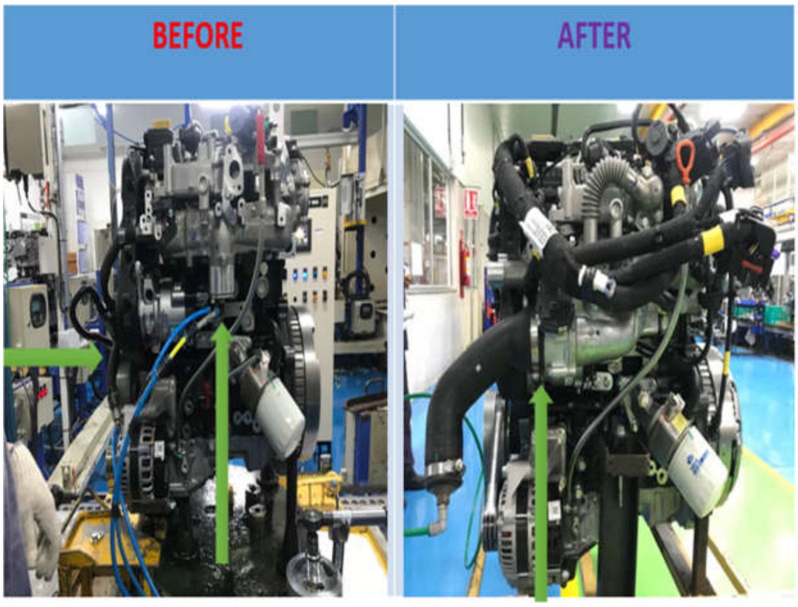

Figure 3Air supply plug

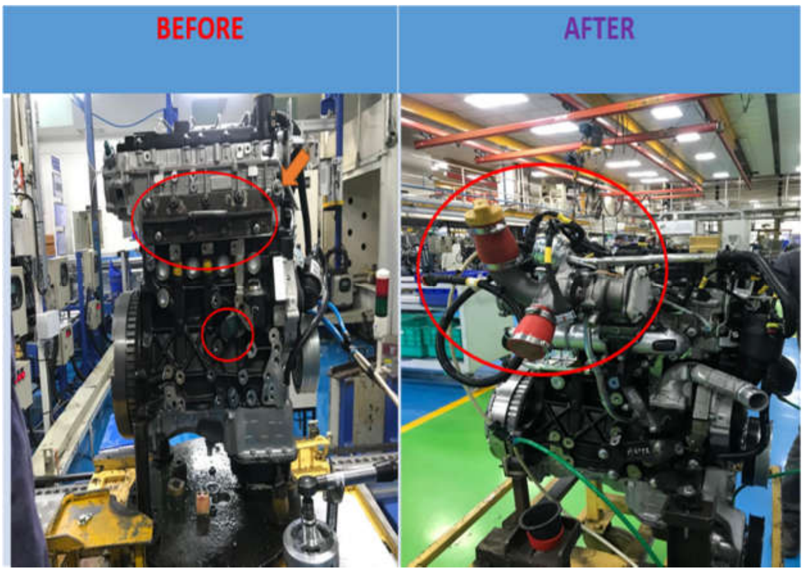

Figure 4 Sealing plugs

3.1 Time saving analysis

Table 3 Time saving analysis

Operation	Time (m)
Engine Loading	7.5
Test Run Time	7.5
Engine Unloading	5
Transport time from Testing to Rectification	40
Rework time	30
Again Transport time from Rectification to Testing	5
Engine Testing Time	45
Total	140 (m)

In 140 Minutes 3 engines get tested by operator but due to rejection of engine on test bed there is loss of time. Table 3 shows the total time required if engine gets rejected. Operator tests 8 engines per shift on each test bed. If engine is rejected due to leakage there is loss of one engine. Operator considers this engine on as tested though it gets rejected. After rectification we have to test this engine again but for test he will consider the engine as new one. Instead of testing 8 engines per shift he will test only 7 engines. Real cycle time for testing the engine is 45 minutes butdue to leakage it becomes 140 minutes. There loss of 95 minutes for per engines rejection. So with the help of new setup this can be avoidable and rework can be done on assembly line.

3.2 Cost saving analysis

Table 4 cost saving analysis

Material	Quantity	Cost (Rs)
Diesel (liter)	4	372
Oil (Liter)	1.75	532
Operator (Testing + Rework)		640
Electricity (kWh)	60	540
Total		2084

As we can see from the table 4 approximately 4 litre fuel (Diesel) is required to run the engine performance test on the test bed and if one oil sealing gets leaked during testing minimum 1.75 litre (depends on the awareness of the operator and engine speed) spills out from engine which cost 304 rupees per litre. Sometimes due to heavy leakage engine gets dry. So approximately 2084 rupees is loss per engine rejected due to leakage phenomenon.

This problem can be minimised with the implementation of improved oil leakage testing setup which add-on’s benefits to the company’s revenue.

Table 5 Engine Test data

Month	January	February	March	Total
Total Engines Tested	2854	3039	2977	8870
Engines Rejected	58	109	73	240
Rejection Percentage (%)	2.03	3.5	2.4	2.7

From the above tables 5 we can see from the month January to March total 240 engines are rejected out of which 41 engines rejection is due oil leakages from the fitment. This problem is due to existing oil leakage testing setup. This can be avoided with improved setup and rejection is minimized. Total rejection of engines for the month of January to March is 2.7 % out of which 0.5 % is due to partial assembled engine checked for oil ways leakage so this can be avoidable with improved set up and rejection cab be lowered up to 2.2 %

4. Conclusion

With the help of TRIZ we identified the possible approach for improving the productivity and reducing the rejection engines. Based on TRIZ principle prior action oil leakage testing setup is modified. Following conclusion we can make with help of this analysis

1. From the DRR of last three months reduction in rejections of engines is possible. It can be reduced from 2.7 to 2.2 % i.e. 0.5 %.
2. Leakages from Dipstick flange, Turbocharger banjo, TC Oil return line and exhaust side can be detected which was main drawback of existing setup gets eliminated.
3. Time saving analysis is done and testing time of 95 minutes can be saved if leakage gets detected earlier on the assembly line.
4. Engine rejection cost also reduced significantly.
5. Hence improved Oil leakage testing setup is more beneficial than existing testing setup and can implemented on the assembly line.

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