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Application of "8D Methodology" for the Root Cause Analysis and Reduction of Valve Spring Rejection in a Valve Spring Manufacturing Company: A Case Study

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Abstract

The Eight Disciplines (8D) is a problem solving technique intended to identify the root cause of a problem. 8D is a phenomenal first step to enhancing Quality and Reliability when the product is defective or not satisfying the customer. The study was conducted in a manufacturing company producing springs and stampings. The data was collected for a period of Six months from January 2014 to June 2014, to identify defective percentage of valve spring components and they were found to be high at the average rate of 17.07%. In this work the objective was set to reduce the rejection level to 5%. In order to achieve this, 8D problem solving technique was used to analyse and solve the problem. Then, Pareto analysis was done to identify vital causes contributing defectives. From the Pareto analysis, it was found that functioning length variation (L2) is the major cause for rejection. Further brainstorming sessions was held to identify the root causes. After the brainstorming session, cause and effect diagram was constructed and 5why analysis was carried out and it was found to be variation in the pitch distance at the begin-end side leading to negative helix in the functioning length of the valve spring. The suggestions to reduce the rejection percentage were to make pitch distance equal at begin-end side of the valve spring and to gradually increase the pitch up to 2 coils. After implementing the suggestion the pitch distance were equal at the begin-end side of the spring which reduces the negative helix in the functioning length reducing the percentage of rejection to 4.91% in July 2014, from average rejection of 17.07% (6 months data).

Keywords: 5why Analysis, 8D Method, Negative Helix, Pareto Analysis, Valve Spring

1. Introduction

The 8D sometimes also referred as Ford TOPS 8D, 8D, and Global 8D. Many industries especially in automotive sector consume the 8D methodology as a tool in the essence of standardizing process. The 8D consists of a group or teams working together in order to solve the problems by utilizing an organized 8 step approach to help focus on facts, rather than the opinions. It is a powerful method in creating appropriate activities in order to identify the root causes and give permanent solutions to eliminate the root causes. There are reports of effective utilization of this strategy to manage constant repeating issues, fundamentally imperfections or guarantee issues[1]. This method was first developed and adopted by Ford Motor Company, then in 1980's it was known as Team Oriented Problem Solving (TOPS). The early usage of 8D exhibited so powerful and essential

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strategies for archiving problem solving efforts, and the company keeps on utilizing 8D till today[2]. The 8D method is a special tool of ISO/TS 16949:2009 and has been broadly used in automotive industries for service, including the issues with supplier qualification confirmation, process deviations, maintenance, customer complaints, purchases, etc.[3]. Eight Disciplines (8D) Problem Solving is a method that uses a step-by-step approach for solving problems. This includes identifying, correcting, and eliminating recurring problems. The 8D approach has been adopted widely in the manufacturing world, but it is a management process. It needs other tools in order to complete the tasks in each step. In general, the 8D technique was never planned to replace a systemic quality system. The 8Ds' goal is to confront the problems and find the weakness in the system that allowed the problem to happen in any case[4]. The greatest misuse in the execution of the 8D includes utilizing the method exclusively as a one-page problem reporting exertion. This abuse is frequently further overstated by requiring the report to be composed inside 24 hours. A few steps can take a few hours, while others can take weeks[1]. In manufacturing, many problems can occur only just with a one of a kind condition. Sometimes they will be available, other times won't. Some studies and experiments must be conducted in order to understand the root causes. He additionally expresses that 8D reporting can be tedious and hard to create and keeping that in mind the end goal to effectively execute the 8D method, the people involved should get a suitable preparing.

Table 1. Eight disciplines in problem solving

Discipline number definition	Discipline number definition
D1	Establishing the team
D2	Problem Description
D3	Immediate action
D4	Identification of causes
D5	Corrective action
D6	Measuring of effectiveness
D7	Expansion
D8	Congratulate the Team members

Table resources: Bhote, 2002[4].

After receiving the complaint from the customer the response time rules associated step in 8D methodologies are as follows:

- Y1 (1 day) - A1;
- Y2 (2 days) - A2 and A3;
- Y14 (14 days) - A4 and A5; A6 and A7 defined;
- Y60 (60 days) - all steps completed.

For example, after receiving a complaint from the customer, steps A1 to AD3 should be finished inside 2 days and the customer should receive the second feedback on the complaint.

2. Literature Review

The research question for this investigation is: "How the chosen quality characteristics of speed and quality of the answers to customer complaints prevent them from repeating?" According to Yin[5], questions including "how" and "why" have to be addressed utilizing research techniques like case studies and histories. The case studies seemed appropriate for the present work, as they seek to explain how and why some events occurred. However, they are the most difficult and the most frequently challenged[6]. The decision between single-case and multiple-case studies relies on the research goals and the accessibility of resource. Due to resource and time constraints a single case study was performed.

Many authors describe the eight disciplines of systematic problem solving. Their practical experience and theoretical description on the utilization of the 8D method (eight steps) are gathered in the following sub-sections.[7-11]

Step I: Use Team Approach (Identification): Deviation from the requirements/rebelliousness, defect (referred as "Problem") can be connected with a product, service. To guarantee an ideal and much composed methodology, information support is normally utilized. The first main thing, the key information on the problem is entered, for example, 8D serial number, date, identification number, name, reference to plan, number of quantity, selecting a team to overcome from this problem. The teams have to incorporate people who are capable of performing 8D method. The team should be furnished with all the accessible documentation and important data.

Step II: Describe the Problem: To identify the problem, the 8D team tries to acquire more information as possible from the customer, which constitutes the first analysis performed in the problem-solving process. The location and nature of problem must be given along its effects. Another important information is whether the problem included is intermittent or whether it could happen on similar products or processes. While depicting the problem, the 5W (WHO, WHAT, WHERE, WHEN, WHY) and 2H (HOW, HOW MANY/MUCH) method should be used, where the accompanying inquiries must be addressed completely and efficiently and WHY for each question. The responses to these inquiries help us clarify the background and connections.

Tools to be used:

- Data collection for background information (is / is not analysis).
- Pareto charts.

Step III: Implement and Verify Short-Term Corrective Actions: In this step “stop” action should be done in the most limited time possible. In the car industry the typical time taken for this action is 24 hours. With regard to the stop action, the accompanying will be concurred with the customer: that our inward work force addresses the problem at the customer premises; that the client evacuates at our cost the parts found insufficient during processing Selection of any of above alternatives must be based on (1) client’s desire, (2) quality of service (3) expenses, and (4) time limits.

Step IV: Define and Verify Root Causes: In this step identification of genuine cause and determination of restorative measures aimed to solve the problem permanently. To obtain root cause, all the causes which are found wrong are wiped out. The problems are identified using tools such as 5-why analysis, Brainstorming and cause and effect diagram. To guarantee a suitable precise methodology, the utilization of one of the above devices is compulsory.

Step V: Verify Corrective Actions: Measurements are carried by two means, it is carried out by means of control devices in which digital data and outputs are associated to computers. And another means is carried out by using statistical method. Typical statistical methods are named Statistical Process Control, Process Capability (cp), Process Capability index (Cpk), histograms, and Pareto diagrams. A compulsory action to be enacted in the problem solving process is checking whether the customer complaint brings about any change to the contents in the FMEA (Failure Mode and Effects Analysis) to control documentation or other related records. If the change has been identified, it is compulsory to incorporate it in the above-noted reports.

Step VI: Measuring of effectiveness: In this step it comprises of measuring the long-term effectiveness of the previous step and to implement Permanent Corrective Actions. In the automotive industries, the default time period for this measurement has been set to 90 days, if it is necessary then the time period can be adjusted to meet customer requirements. At the point when the timeframe agreed for measuring the effectiveness of the corrective action has lapsed, the customer is informed about the result achieved. In the event that the process capability complies with the requirement, the customer confirms (validates) the corrective measure applied. If, however, the customer does not request a limit associated with the process capability, the team checks whether the capability complies with internal requirements.

Step VII: Prevent Recurrence: In this step the 8D team analyse whether the corrective action executed would avoid or enhance the quality of similar products and processes.

Step VIII: Conclusion: In this step, based on previously conducted and validated steps of the 8D procedure, the complaint-solving coordinator proposes its conclusion. Team recognition follows when the problem has been solved and the documents have been completed and archived. Congratulate the team for the work.

Table 2. Journals, Problems and their solution: Case studies by different researchers

Referred name	Journal	Problem	Solution
A[16]	An Effective Approach for Problem Solving in Automotive Assembly Line, Australian Journal of Basic and Applied Sciences, 8(22) Special 2014, Pages: 31-34	Sustaining a business by meeting customer expectations and satisfactions, an organization must promptly response and adapt to changing conditions in a competitive market. This great challenge due to mass production to mass customization required a flexible and faster solution of any problems occurred in production especially in automotive industry. In this respect, a method of Eight Disciplines Problem Solving (8D) was deployed to overcome a major defect encountered at one of major processes of assembly line.	This strategic tool had succeeded to meet the expectation of the quality team by overcoming the major defect of part at trimming assembly line. This situation elaborates that the method can be a significant option to be performed in others major processes of assembly line as well so that the major quality issue involved can be resolved. Particularly, the implementation of the method will alleviate the waste of defects that result to cost deduction. Therefore, the quality of the products can be improved and fulfill the customer satisfaction in the competitive market.
B[17]	Independent Journal Of Management & Production (Ijm&P), v. 4, n. 2, July – September 2013.	The article intends to create and execute a management tool utilizing the 8D quality for solving problems.	Root cause analysis is used to root cause of the problem which allows you to take all the necessary measures to counter that problem. If the employees trained properly this method works appropriately, guaranteeing a high speed for the pursuit and determination of problem.
C[18]	9th International DAAAM Baltic Conference "INDUSTRIAL ENGINEERING" 24-26 April 2014, Tallinn, Estonia.	Keeping in mind the end goal to be aggressive organizations attempt persistently enhance their production processes, product quality and increment the level of consumer loyalty by executing diverse quality improvement programs, approaches and methodologies.	In this paper were observed different continuous improvement methodologies, their capabilities, similarity and application to different situations. Every company can select and use a proper methodology and even combine some of them in continuous improvement of their processes. It is essential that the right methodology is accurately chosen by requirements and requests of the organization and further connected to the suitable process.
D[19]	With 8D method to excellent quality, Journal of Universal Excellence, Professional Article.	The article aims to set up the reasonableness of the 8D procedure for complaint settlement, and to recognize any subsequent change in quality.	In this research 8D method war used as a important tool for reducing the defects and preventing the defects from recurring. This perception is used for PPM results and cost analysis.
E[20]	Volvo Power train Assessment and improvement of Volvo Powertrain's "Quality Journal" problem solving process with respect to Six Sigma Larsson, Marcus and Norén, Martin	This thesis is made to investigate Volvo Power trains current procedure on solving problems, identify best practice and identify areas of improvement.	Volvo Power train has a problem solving process called the QJ-process, The 8D framework, which the QJ-process is built on, is more suitable for the problems that the QJs are intended for than the DMAIC framework. The current QJ-process could be improved by adopting some of the parts from the original 8D framework in a better way.
F[21]	Manufacturers of Controls for Land Based Turbines • Aircraft • Defense • and Oil Industries	The research was carried out at Young & Franklin and Tactair Fluid Controls, the main goal is to prevent problems and persistently enhance through the inclusion of all suppliers.	The genuine measurements of effective actions of corrective recurring problems and prevention of same problems. Corrective actions will be evaluated on their capacity to avoid further problems

3. Case Study

The case organization is a Valve spring manufacturing company. In this company there are many rejections in the “Valve spring” due to some defects which results in low productivity. Following are the defects that need to be addressed as soon as possible to reduce the rejections: free length variation (L1), functioning length variation (L2), setting scrap, burr, pitmark, tension mark.

Valve spring is a type of coil spring which is used in the fuel injection system. The valve springs hold the inlet and exhaust valves shut, so that compression can take place in the cylinder. Most valves are called ‘poppet’ valves.

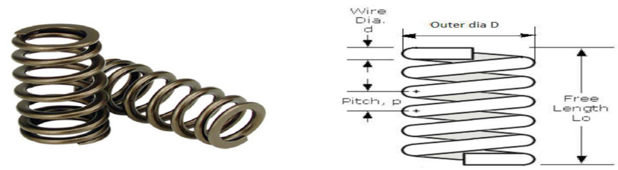
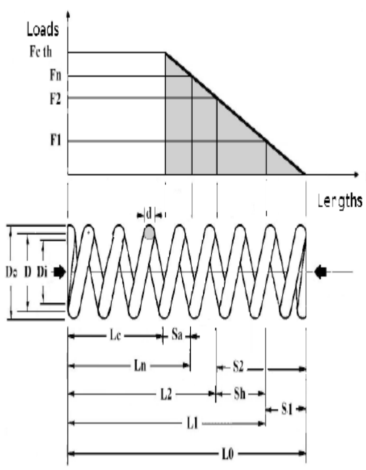


Figure 1. Valve spring

Pitch distance: The distance from center to center of the wire in adjacent active coils

Free length: The overall length of a spring in the unloaded position.

Functioning length: Functioning length is the length at which the springs would function as per the requirement when a load is applied.

	Were, D0 = Spring outside diameter D = Spring diameter Di = Spring inside diameter F = Spring force F1,F2 = Spring force associated with spring L1, L2 = Nominal length associated with the spring forces F1, F2 Reduction of percentage fallouts in functioning length of spring. Fcth = Theoretical spring force at solid length Lc, Lc = Block length Fn = Spring force associated with the smallest spring length Ln Ln = Smallest allowable spring length L = Spring length Lo = Nominal length of unloaded spring Sa = Sum of the minimum clearance distances between the individual spring length Ln S = Spring travel S1,S2 = Spring travels according to the spring forces F1,F2 Sc = Spring travel according to block length Lc Sh = Travel (Stroke) of the spring between two positions.	Specifications: Wire diameter (d)= 1.1mm Free length (Lo)= 17.560mm Functioning length(L1)= 15.8±0.05mm Functioning length(L2)= 15.1±0.05mm Spring force associated with spring length L1(F1)= 59.7N Spring force associated with spring length L2(F2)= 83.5N

3.1 Process Involved in Manufacturing of Valve Spring

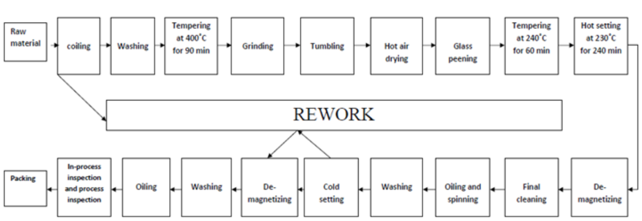


Figure 2. Process chart for valve spring

3.2 8D Report

3.2.1 1D Establishing the Team

The 8D team was formed consisting of 10 people including the four project associates, three employees from W-section and three members from planning section to collect and analyse the data and identify the particular stage where the problem was occurring.

3.2.2 2D Problem Description

The average percentage of scrap and rework rate was about 17.07% which was mainly due to functioning length L2 variation; where L2 is the length obtained with the application of load.

3.2.3 3D Containment Action

Containment action is that where we stop the products which are reaching the customers after detecting the problem. Since our products were not dispatched from the inventory this action was not done.

3.2.4 4D Root Cause

The team observed and identified the various causes that were possibly leading to valve spring fallouts. Once this was done, some of the 7QC tools were used to find the root cause of the problem. By collecting past six months data of valve spring inspected data Pareto chart was prepared. From this, we found that L2 variation contributed to the major amount of defect. A fish-bone diagram was prepared to find out the major causes that led to this defect. A 5-why analysis was further conducted to find the root cause of the problem. It was found that L2 variations were caused mainly due to pitch variations.

Pitch distance readings for 4 samples of valve spring were taken at each stage (after coiling, hot setting, grinding, cold setting) and it was found out that the readings were not equal at begin and end side.

3.2.5 5D Corrective Action

In this stage, changes were done in the program at the coiling stage which resulted in equal pitch distance readings at all the further stages.

3.2.6 6D Validate Corrective Action

Corrective action decided at the previous stage was implemented in the next batch of production and it was observed that this action was found to be effective.

3.2.7 7D Prevent Recurrence

In this stage, pitch distance variation which was seen in the previously collected data was avoided in further processes was made approximately made equal at the begin and end side of the spring.

3.2.8 8dVerify and Congratulate Team

By implementing the mentioned changes, an average percentage reduction of 4.91% was observed. Each team member's support and assistance was recognized and the team member's efforts were appreciated.

3.3 Data Collection and Analysis

Initially the data was collected for six months from January 2014 to June 2014, to identify defective percentage of valve spring components. Measured pitch distance of 4 samples at begin and end side. Then we measured free length and outer diameter at 5 stages in manufacturing process. The stages are coiling, tempering, grinding, hot setting, cold setting and final cleaning. And found average percentage defectives in January month 41.72%. February month defectives 30.53%, March month defectives 20.16%, April month defectives 18.60, May month defectives 24.57%, June month defectives 46.16%.

3.3.1 Root Cause Analysis (RCA)

It is a problem solving method utilized for identifying the root causes of problems.[23]. To prevents the problem from recurring a factor is considered from the sequence, though a causal factor is one that influences an occasion's result, yet is not a root cause. In spite of the way that ousting a causal factor can benefit a result, it doesn't keep its recurrence with conviction.

Table 3. Defects Wise Data

Defect List	Order Quantity	Inspected	Defect Quantity
L2<	252594	170258	29078
Pit Mark	42447	20797	218
Burr	20000	2000	1200
setting scrap	14000	14000	6940
tension mark	18047	210	205
e1>	19800	6	6
L1<			929

Table 4. Percentage of Defects

Defect List	Defect Quantity	Percentage Defects	Cumulative
L2<	29078	75.38	75.38
Setting Scrap	6940	17.99	93.37
Burr	1200	3.11	96.48
L1<	929	2.41	98.89
pit mark	218	0.57	99.45
tension mark	205	0.53	99.98
e1>	6	0.02	100

From the table observed that free length variation (L1), functioning length variation (L2), setting scrap, burr, pitmark, and tension mark are some of the defects that causing rejections and this defects need to be addressed as soon as possible to reduce the rejections. Then decided to identify the major defective causing reduction using Pareto chart.

3.3.2 *Pareto Chart to Identify the Major Defective*

This idea was initially noted by Vilfredo Pareto, a nineteenth century Italian business analyst. The Pareto analysis is based on the principle which states that most of the effects are the results of a few causes. Pareto principle states that 20% of defects cause 80% of rejections hence Pareto analysis was carried out to prioritize the defects. To arrive at 20% of defects we calculated the percentage rejection of each defect and cumulative percentage. Then Pareto chart was plotted by taking types of defects along x-axis and quantity of defects along y-axis. Draw bar chart and cumulative line. Draw the line parallel to x-axis at 80% of cumulative axis and again draw the line perpendicular to x-axis from the point of intersection of cumulative line and line drawn parallel to x-axis which will give us 20% of the causes. From the chart we can say that 1st significant defect is functioning length (L2). From this plot functioning length (L2) is identified as 20% defects causing 80% of rejections.

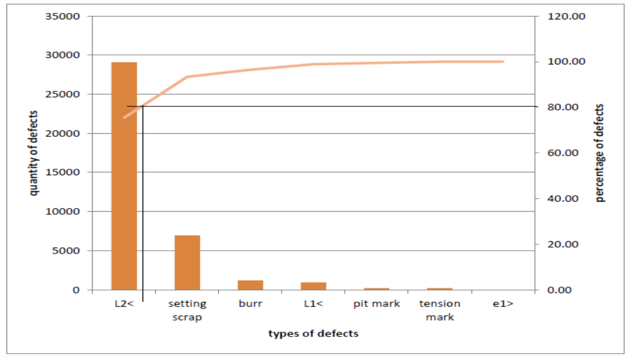


Figure 3. Pareto chart

3.3.3 *Cause and Effect Diagram*

Kaoru Ishikawa was the inventor of cause and effect diagram so it is also called as Ishikawa diagrams. By the appearance it is also called as fishbone charts. The function of cause and effect diagram is to identify the components or factors which causing an undesired impact (e.g., defects) for improvement activity, People involved in the process will identify the factors affecting. Main considerations could be assigned utilizing the "5 M's": Method, Manpower, Material, Measurement, and Machinery.

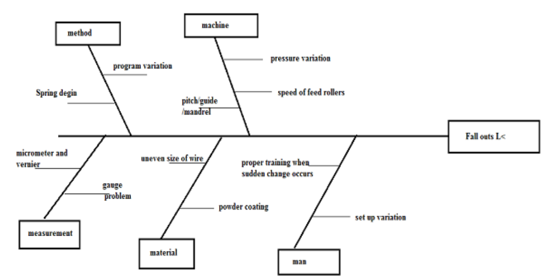


Figure 4. Cause and effect diagram.

In functioning length (L2) with respect to man we had identified the causes such as operator skill, inadequate training and setup variation. With respect to material some of the causes identified are raw material hardness, and uneven size of wire. With respect to method some of the causes identified are spring design, and program variation. With respect to machine we had identified the causes such as speed of feed rollers and pressure variation.

3.3.4 *5WHY Analysis*

5 Why's is a problem solving method that permits you to get a root cause of a problem decently, rapidly. It was

made prevalent as a feature of Toyota production system in 70's. Use of the methodology includes taking any problem and asking "why- what cause this problem?"

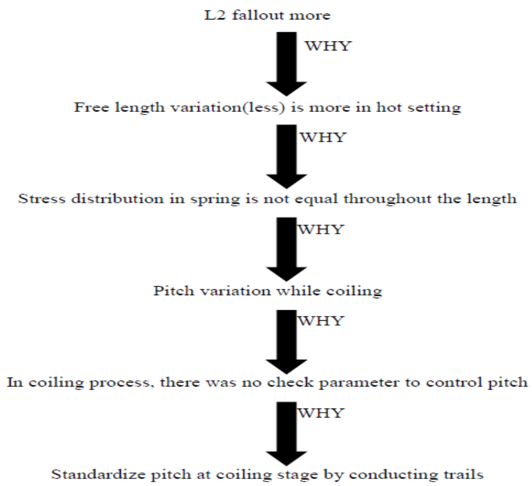


Figure 5. 5Why analysis.

After 5Why analysis we came to know L2 fall out is more in hot setting because of stress distribution in spring is not equal throughout the length. Pitch variation in the coiling process is more because of no check parameters to control the pitch. Then, Brainstorming session was conducted to overcome these problems and finally concluded to standardize pitch at coiling stage by conducting trails.

3.3.5 Before Implementation

Four samples were taken from a new lot with the same CNC program. Then, measured pitch distance of 4 samples at begin and end side. Then we measured free length and outer diameter at 5 stages in manufacturing process. The stages are coiling, tempering, grinding, hot setting, cold setting and final cleaning. We have considered free length and outer diameter because these parameters affect the functioning length (L2).

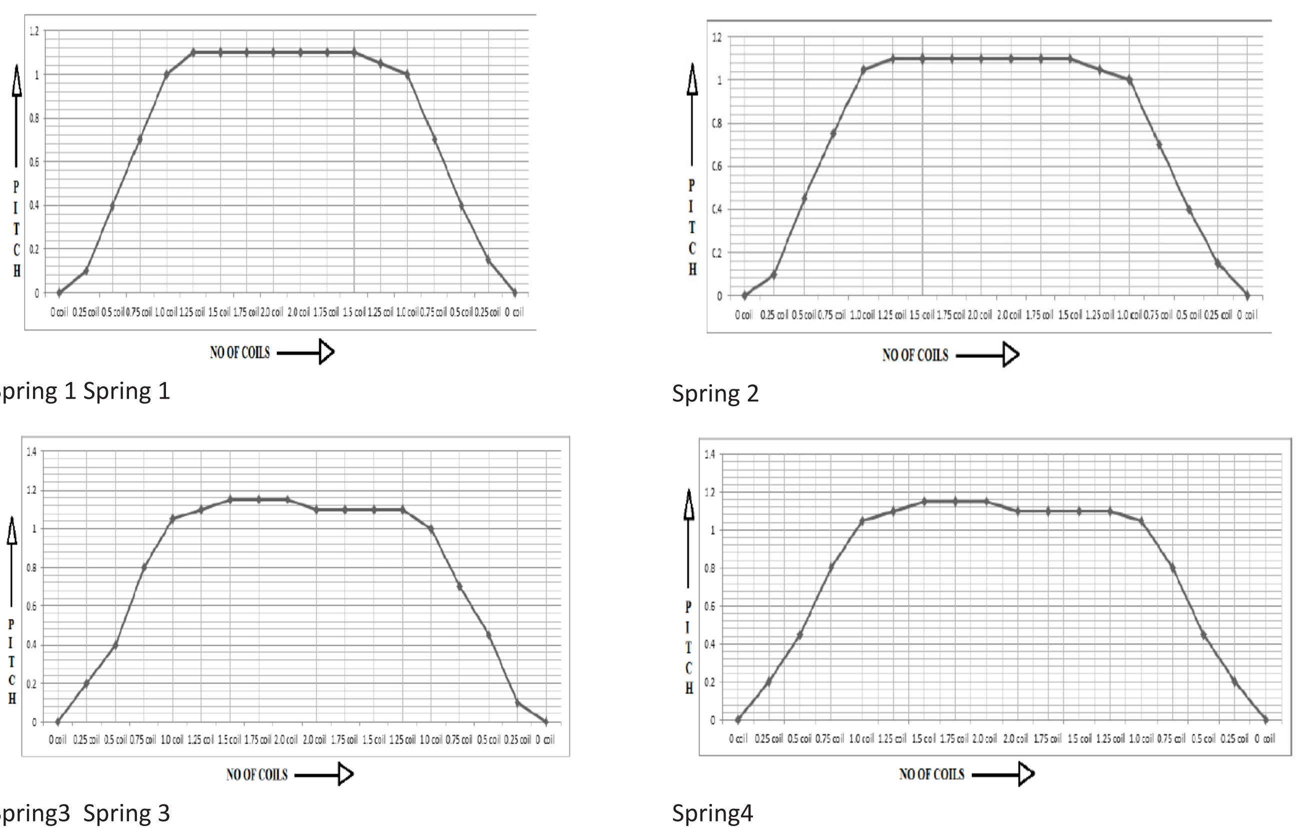


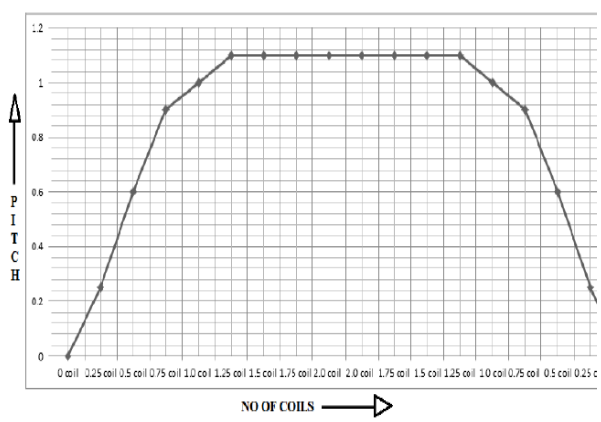
Figure 6 Graph shows the No. of coils in x-axis and Pitch in y-axis (Before implementing) for different springs.

Pitch distance readings for 4 samples of valve spring were taken at each stage (after coiling, hot setting, grinding, cold setting) and it was found out that the readings were not equal at begin and end side. From the collected data measured pitch distance and observed negative helix in different samples of the spring and observed that the range value is less in cold setting stage and pitch was not gradually increased because there was no check parameter to control the pitch in coiling stage.

3.3.6 After Implementation

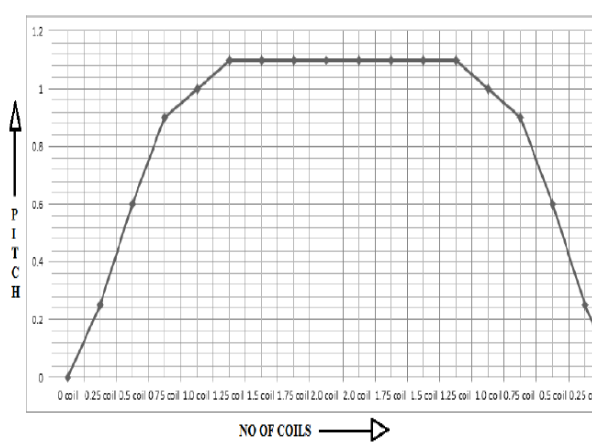
By giving and implementing suggestions in the month of July by making pitch distance almost equal at begin and end side and altering the pitch distance value at the coiling stage in CNC program by discussing with the operators. By gradually increasing the pitch distance up to 2 coils at the coiling stage, negative helix can be removed by implementing this changes, four samples were taken from July month new lot with the pitch distance were varied at the CNC program.

Pitch distance readings for 4 samples of valve spring were taken at begin and end side from the new lot of month July. Then we measured free length and outer diameter at 5 stages in manufacturing process. The stages are coiling, tempering, grinding, hot setting, cold setting and final cleaning and observed by making pitch distance equal at begin and end and by gradually increasing the pitch distance up to 2 coils at the coiling stage the rejection percentage was reduced.

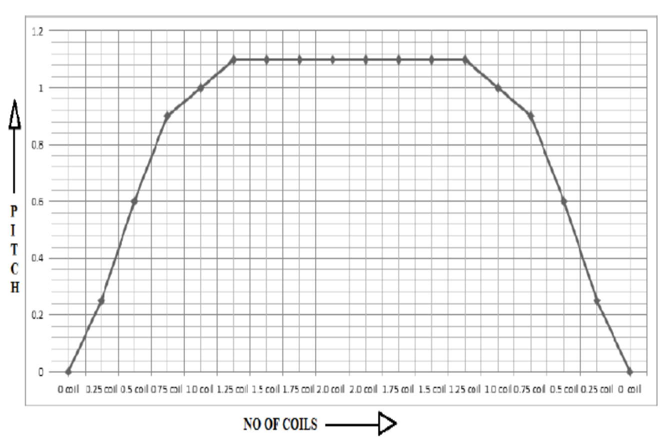


Spring 1

Spring 2



Spring 3



Spring4

Figure 7. Graph shows the No. of coils in x-axis and Pitch in y-axis (After implementing) for different springs.

Previous 6months data	After Implementing suggestion in July month
Total Inspected quantity = 170258	Total Inspected quantity = 15460
Total number of defects = 29078	Total number of defects = 760
% defects = 17.07%	% defects = 4.9%

4. Results and Discussions

The study reports the application of 8D approach in a in a manufacturing company producing springs and stampings. As a part of this work, the study was conducted on valve spring components. The data was collected for a period of Six months from January 2014 to June 2014, to identify defective percentage of valve spring components, we identified that there are 6 different types of defects such as free length variation (L1), functioning length variation (L2), setting scrap, burr, pitmark and tension mark which are causing high rejection. %. In order to achieve this, 8D problem solving technique was used to analyse and solve the problem. Then, Pareto analysis was done to identify vital causes contributing defectives. From the Pareto analysis, it was found that functioning length variation (L2) is the major cause for rejection. Further brainstorming sessions was held to identify the root causes. After the brainstorming session, cause and effect diagram was constructed and 5why analysis was carried out and it was found to be variation in the pitch distance at the begin-end side leading to negative helix in the functioning length of the valve spring. Initially the data was collected for six months from January 2014 to June 2014, to identify defective percentage of valve spring components. Measured pitch distance of 4 samples at begin and end side. Then we measured free length and outer diameter at 5 stages in manufacturing process. The stages are coiling, tempering, grinding, hot setting, cold setting and final cleaning. And found average percentage defectives in January month 41.72%. February month defectives 30.53%, March month defectives 20.16%, April month defectives 18.60%, May month defectives 24.57%, and June month defectives 46.16% .In this work the objective was set to reduce the rejection level to 5%. The suggestions to reduce the rejection percentage were to make pitch distance equal at begin-end side of the valve spring and to gradually increase the pitch up to 2 coils. After implementing the suggestion the pitch distance were equal at the begin-end side of the spring which reduces the negative helix in the functioning length reducing the percentage of rejection to 4.91% in July 2014, from average rejection of 17.07% (6 months data).

5. Conclusion

8D method was used in the case study and it proves to be an important tool to prevent defects from recurring. From the 8D reports suggestions were given to make pitch distance equal at begin-end side of the valve spring and to gradually increase the pitch up to 2 coils to reduce the rejection percentage. After implementing the suggestion the pitch distance were equal at the begin-end side of the spring which reduces the negative helix in the functioning length reducing the percentage of rejection to 4.91% in July 2014, from average rejection of 17.07% (6 months data).

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