IJAET International Journal of Application of Engineering and Technology ISSN: 2395-3594

Vol-2 No.-1

MINIMIZATION OF DEFECTS RATE IN A RAIL SPRING MANUFACTURING UNIT BY USING TRIZ METHOD

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ABSTRACT

The Theory of Inventive Problem Solving (TRIZ) is a tool, method, and a process for systematic innovation. This innovation technology provides ways to overcome psychological barriers in product inventions and suggests generic ways for finding innovative ways to improve a production process. This paper discusses the various approaches and efforts made in the way of defect minimization in a Rail Spring manufacturing unit. Minimization of defects may leads to the saving in time, cost, and power of the industry directly or indirectly. Actually defects rate causes a direct effect on the profit margin of the product and decrease the quality during the manufacturing of product. The main thing in this thesis is to give the understanding of different problems in different departments in quality point of view and how to reduce the problems by taking preventive action against any defects produce during process. A study was conducted to identify the causes of defect in different sections of the factory. Several TRIZ tools, such as contradiction matrix, 40 inventive principles, S- Field analysis were applied to solve the problems. These were used to generate conceptual solutions to address the identified problems in the operation.

Keywords: *- TRIZ, 40- Inventive principles, 39- features, Contradiction Matrix, S- Field Analysis.*

I. INTRODUCTION

Railway Spring Karkhana (RSK) is a unique Factory designed for the manufacture of hot coiled springs for various types of rolling stock of Indian Railways. RSK was set up by the central govt. under the ministry of railway to make available uninterrupted supply of quality hot rolled coil springs for coaches and locomotives manufacturing units and railway repair workshops. This is the youngest and most modern of all workshops on Indian Railways. The Rail Spring Karkhana basically deals with the manufacturing of heavy coiled spring, which is used in bogies of trains. The guiding principle behind this factory is to achieve "Quality through Excellence", and produce springs with "Zero" defects. But this looks nearly impossible as it's some of the work-stations process the work with high rate of defect nearly about 6 to 8%.

To minimize the defects, traditional problem solving methods do not seem to be helpful for this case; in order to survive in today's cutting edge market. Being a Govt. sector unit, the problem also occurs due to human error by unfocussed operators or workers. So, being creative and innovative is the only possible way for such industries to keep up with shifting benchmarks.

The psychological inertia in the form of mental bocks resulted due to repeatedly using traditional techniques is the big hurdle in thinking innovative. Many psychological techniques have been suggested and practiced to overcome the psychological inertia, "TRIZ is one of them which is a technology based systematic methodology providing a large range of solution concepts.

II. TRIZ

TRIZ is a Russian acronym meaning, "Theory of Inventive Problem Solving". It is a unique Knowledge based technology for generating new concepts. TRIZ is a powerful methodology, based on innovation patterns and principles that can provide solution concepts for wide range of problems which were developed by Genrich Altshuller in 1946. Altshuller defined an inventive problem as one containing a contradiction. He defined the contradiction as a situation where an attempt to improve one feature of the system detracts from another feature. It provides ways to overcome psychological barriers in product inventions and suggests a generic process for finding innovative ways to improve a product design. TRIZ involves a systematic analysis of a problem to be solved and the application of a series of guidelines for the generation of solution alternatives. It has been used in many successful patents, proving that it improves creativity to come up with better ideas. However, as of today, TRIZ is only known by few, in fact most students are not aware of it.

III. NEED FOR INNOVATION

In recent times, it has become apparent that corporations who seek innovative solutions to engineering problems are able to maintain a competitive edge in the world market. The techniques of optimizing and perfecting existing products have now been applied widely and thus are neither able to help in keeping the leading position nor launch new products to create and capture new markets. Innovations in existing products and inventions for new products, that too quickly and with fewer resources, will help in maintaining a competitive edge in an era of downsizing. Companies like Sony (Japan), Motorola, Hewlett-Packard, 3M (USA) have all benefited by innovative strategies in the sense that more than 30% of their revenue has been due to products that were introduced in the last 2 years. The psychological inertia in the form of mental bocks resulted due to repeatedly using traditional techniques is the big hurdle in thinking innovative. This psychological inertia has to be overcome to obtain innovative solution concepts for the chronic technical problems. Many psychological techniques have been suggested and practiced to overcome the psychological inertia, "TRIZ is one of them which is a technology based systematic methodology providing a large range of solution concepts. The stress is on finding innovative solutions concepts, from other engineering fields, that utilize available resources. This directly results in improved product at reduced cost.

IV. PROBLEM SOLVING BY TRIZ

TRIZ offers a systematic creativity process built primarily on the concept of abstraction – in which a problem owner maps from a specific problem to a generic framework, out of which comes a generic solution requiring translation back to the specific as illustrated in Figure 1.

This systemization process effectively ends at the delivery of the Generic Solutions. These 'Generic Solutions' include the 40 Inventive Principles, the 78 Inventive Standards, the 39 parameters, Trends of Evolution, and the databases containing several thousand scientific effects. Although highly valuable, many problem solvers still find there is a considerable gap between these generic solution triggers and the desired specific solution, as depicted in red arrow in Figure 1. Again, the group problem-solving tool, Team Spirit, can be used to minimize the gap between "Inventive Principle" and "Specific Solution."

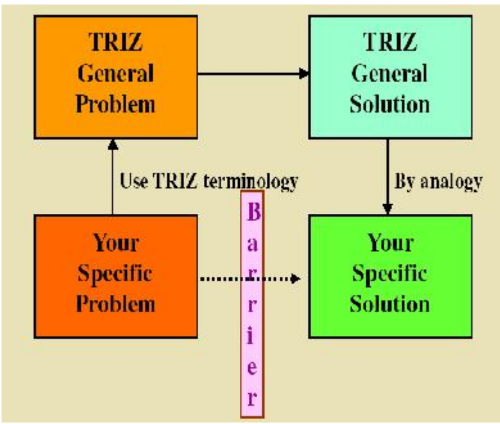

Figure 1 Problem solving by TRIZ

ISSN 2395-3594

V. SIGNIFICANCE

Indian industries have been primarily borrowing technologies from West and Japan. However, there are three main difficulties, TRIZ can help, in all the three cases with quick results using fewer resources, to maintain a competitive edge and hold the market share which is shown under following points:

1. Next generation product and/or New customer requirements
→TRIZ tool – Trends of Technical Evolution

2. Some products need to be modified to suit

a) Availability of new raw materials
→TRIZ tool – Ideal Final Result and Resources

b) New processing equipment
→TRIZ tool – Functional Analysis/Trimming

3. Chronic Engineering problems need to be solved
(Chronic implies that all known methods have been tried)
→TRIZ tool – Technical or Physical Contradictions elimination.
→TRIZ tool – Substance-Field Analysis and system transformations.

VI. CASE STUDY

Case study is undertaken at Railway Spring factory which is a Govt. sector unit under the ministry of Railway, involves in manufacturing of rail spring. The main concern of the company is the defect rate which is about 6 - 8% which reduces profitability of the company. The application of the methodology requires interviewing industries members, to get information based on their infield experience, observing each and every process closely to identify the problem and their root causes. During the industrial visit we observe each and every process closely to identify the problem and find the appropriate solutions to them.

SAMPLE AND DATA COLLECTION:

An appropriate questionnaire was developed to identify the problem using 5W's and 1H as discussed in previous chapter. The problem is identified workstation wise instead of concentrating at an individual process. Data are collected first from December 2013 to February 2014, by taking samples at each workstation to identify the defect. The data are again taken after implementation of the methodology from May 2014 to July 2014. Problem mainly found in End Tapering and Coiling sections of the factory. The data collected upto Feb. 2014 is shown in the form of graph in fig.-2, in which the percent defect rate shown workstation wise in a sample of 2000.

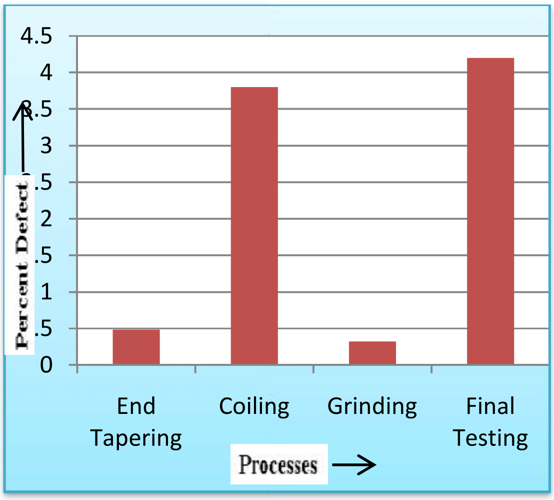

Figure-2: Graph showing percent defect in deferent processes

The problem and their respective solutions are mentioned under the upcoming headings workstation wise.

END TAPERING:

PROBLEMS, CAUSES AND PREVENTIVE ACTION/SOLUTION

The problems and their causes during End Tapering process are identified as:

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I. Temperature is not properly set in End Tapering furnace which may result in crack generation during End Tapering process.
II. Semi finished work due to sudden power off.
III. Tip thickness is not maintained within specified limit due to problems in die blocks.

END TAPERING FURNACE**:**

Technical contradiction found here is:

We should not increase the temperature of the bar above 930^0C in the furnace because heating the steel at higher temperature to a considerable time may cause deterioration, which includes:

- Surface decarburization
- Oxidation/Scaling
- Coarse Grain.

Decarburization means carbon diffusion out of surface layers of the steel bars. The harden ability of the surface diminished. The result is less strength of materials. Decarburization has to be prevented by maintaining low temperature in the furnace minimum soaking time. Oxidation results in scaling.

Following precautions should be observed during heat treatment of steel bars:

1. Minimum time should be taken while heating steel above 900^0C.
2. The bar should be charged and discharged from the furnace at uniform rates without unduly long soaking period at high temperature zone.
3. Coarse grains result from heating over 900^0C for more than half hour. It is urgently recommended to lower the temperature of the furnace to about 700 to 750^0C when interruption occurs.

From above it is clear that we should avoid heating the steel bars above 900^0C. But we found that there is temperature drop when these heated bars are transferred to the tapering machine through the conveyors which are open to air. And we know that the temperature should not be drop down to 850^0C while tapering because it may generate cracks during plastic deformation at such a low temperature. So, a contradiction occurs as it is not recommended to increase the temperature of the furnace above 940^0C, but on the other hand we should increase the temperature of the furnace above 940^0C to maintain it above 850^0C during tapering process to avoid cracks. The parameters used to solve such problem are shown in table 1 in the adopted contradiction matrix.

Table- 1: Adopted contradiction matrix

Worsening feature / Improving feature	14. Strength	13. Stability of the object composition	22. Loss of Energy	31.Object generated harmful factors
17. Temperature	10,30,22,40	1, 35, 32	17, 21, 35, 38	22, 35, 24, 2

While increasing the temperature we found that the strength decreases due to decarburization and oxidation and also the stability of the material's composition affected. From the above matrix we found that the inventive principle to sort out the problem would be:

35- Transformation of physical and chemical states of the object

- Change the temperature

Using this principle we increase the temperature of the furnace upto 980^0C so that the temperature of the heated bar could not be drop down to 850^0C during tapering or coiling processes. By this we can minimize the defect rate due to cracks during plastic deformation of steel bars. While observing the process we come in conclusion that increasing the temperature upto 980^0C will not do any harm as at the end of the coiling, Quenching and

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Tempering processes are also done on spring which increases its strength and hardness.

24- Mediator

- Use an intermediary object to transfer or carry out an action.

We can do one more thing to eliminate such problem. We observe that there is loss of heat when the heated bars are transferred to the tapering or coiling sections

after heated in the furnace which causes the heat loss to the environment as the conveyors are open to air. It is recommended to use isolation by covering the conveyor so as to reduce heat loss to the atmosphere. By doing so we can keep the temperature of the furnace upto 920^0C and as the transferring of bars are undergone through covered conveyors, the tapering process may be carried above 850^0C which result in reduction of crack defects while tapering.

Semi finished work due to sudden power off.

Another problem in the tapering section seen in the form of uncompleted work due to sudden power off. It is clear from the S-Field analysis as shown in the fig.-. The heated bars from the furnace are conveyed to the tapering machine, where both of its ends are tapered as per required specifications. The tapering machine is electrically operated. Now, when the power supply interrupted or failed during the operation, it may cause incomplete process of tapering in heated bar which can disrupt the required shape of the bar and result in permanently defective part that cannot be reworked.

Here the useful function performed by tapering machine is to taper the heated bar from its both ends as per specifications. The whole process is shown in fig.-3(a), using S-Field analysis. Here, F_1 represents the electrical field used to drive the tapering machine which in turn use to taper the heated bar on both of its ends.

Problem arises when there is interruption in power supply or complete power off. In such cases the tapering machine leaves the work in unfinished or semi finished condition which results in a permanently defective part.

Useful Action = End tapering of heated bars

S_1 = Heated Steel Bar

S_2 = Tapering Machine

F_1 = Mechanical Field

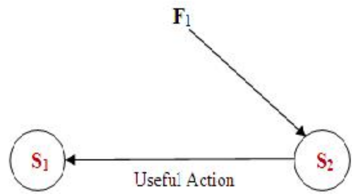

Figure- 3(a): S- Field model of the useful action in end tapering process

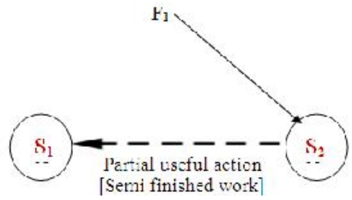

Figure- 3(b): S- Field model of the problem

The problem may be solved by introducing an uninterrupted power supply using a battery system.

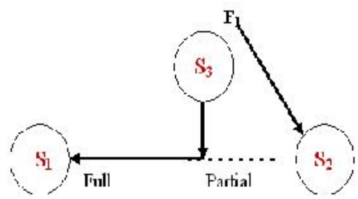

Figure- 3(c): S- Field model showing possible solution to the problem

S_3 = Uninterrupted power supply using a battery system

Tip thickness is not maintained within specified limit

The problem also seen on maintaining the tip thickness under specified limits while tapering of heated bars. The tapered bars having thickness out of range are treated as defective. So to minimize such defects, it is recommended to use the principle prior action to polish or repair the die-blocks which are employed in tapering of heated bars. It is also recommended to employ CNC Tapering Machine for tapering process which will help in more precise and defect free operation.

COILING:

PROBLEMS, CAUSES AND PREVENTIVE ACTION

I. Defects in input material may cause defects during coiling.
II. Temperature is not properly set in walking beam furnace (bar heating furnace) which may result in crack generation during coiling process.
III. Semi finished work due to sudden power off.

Defects in input material
Following types of defects in input materials may cause problem in coiling process:

- Tip thickness out of specified limits.
- Tapered length out of range.
- Defect in the form of crack in input material.

Most of the processes of the company are dependent processes. Here, output materials of the end tapering section are the input materials for coiling section. So, the material (Tapered bar) after tapering section should be defect free and for this it should be properly checked before coiling to reduce wastage of time and resources. Following problems arises due to material defects:

- Tip thickness out of range may cause clamping and adjusting problem during coiling.
- Tapered length out of range may result in pitch variation, pitch size out of range, shorter height of the spring, protruding ends or end biting.
- Defect in the form of crack is mainly found in spring due to material defect.

So, to avoid above mentioned defects or problems, proper care should be taken during end tapering of bars and it should be properly checked before coiling.

Bar Heating Furnace**:**

Some of the problems in coiling section are found similar to end tapering section, like maintaining the temperature during coiling, interruption in power supply etc. Hence, such similar problems should be solved in similar way as in tapering section. The temperature of the bar heating furnace is specified between 900 to 940^{0}C. But, as mentioned in previous section of end tapering furnace, it is recommended to set the temperature of the furnace at 960^{0}C, so as to coil the bars at 900^{0}C, to avoid crack generation of heated bars during plastic deformation (coiling), as temperature drop takes place during transferring of heated bars to the coiling section.

Semi finished work due to sudden power off

This problem is similarly rectified as mentioned in end tapering process in previous section by using uninterrupted power supply.

END GRINDING PROBLEM, CAUSES AND PREVENTIVE ACTION/SOLUTION:

The end of the coils are ground to secure a flat circumference about 270 degrees. The problem seen during this operation is the burn marks which makes the spring weak in strength. Here, the useful action is the grinding operation performed in the ends of the coils to secure a flat circumference as clear from the S- Field analysis in the figure below.

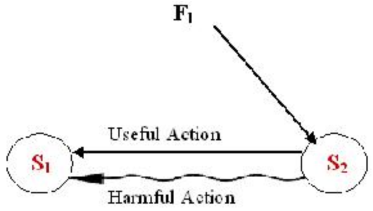

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Figure- 4(a): S- Field model showing problem during end grinding process

But the harmful effect is seen in the form of burn marks as a defect which makes the spring weak. To eliminate such harm, it is recommended to flood the grinding zone with coolant delivered at low pressure by a well positioned nozzle at velocity that matches the grinding wheel velocity. It is cleared from the of S-Field analysis shown in the fig.-4(b), where harmful effect of grinding is eliminated with the help of nozzle supplying the jet of coolant.

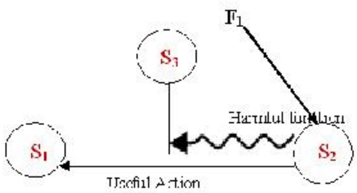

Figure- 4(b): S- Field model showing possible solution to the problem in end grinding

Other factors like wheel type, abrasive type, dressing, speed, feed etc. should be also taken into consideration while eliminating the harmful effect of burn marks on end surface of the spring.

Also, it is seen while our industrial visit that some of the coiled springs are grounded out of the specified limit of tip thickness. So, it is recommended to maintain the tip thickness as per drawing strictly during end grinding operation. For this a highly skilled operator and supervisor to instruct him should be deployed.

VII. RESULTS AND DISCUSSION

IDEAL FINAL RESULT:

The final phase implementation is largely dependent on the context in which the user is in. The first step is to identify the potential obstacles and ways to overcome them and this is done by developing both preventive actions and contingency plans. In the following three different approaches are present; attention which is used if the implementation depends on the acceptance of other people. Plan covers some suggestion to different that can be developed to organize the implementation, and the complex part presents a tool for implementation of complex project.

As we know that the case study is undergoing in a govt. sector unit where it is not easy to implement new tool or machineries. For this we have taken an ideal final result which shows implementation free ideal result.

By the Ideal Final Result we tries to give the implementation free description after the problem has been solved by the various TRIZ tools as mentioned in the previous sections.

In tapering section, our main objective is to taper the ends of the bar precisely according to specified dimensions without generating cracks along the bar. It is possible only when the plastic deformation (tapering process) is undergone upto specified temperature. On solving this problem by using the contradiction matrix as mentioned in earlier section, the defect in the form of crack and the tip thickness out of specified limits may be reduced or totally eliminated. In coiling process, by following all the suggestive measures proposed by us, the coiling defects may be reduce to minimum level.

Similarly, in End Grinding process, the problem of burn marks may be totally rectified by the solution proposed by us with the help of Su-Field analysis shown in previous section.

RESULT:

It is not possible to implement all the proposed methods and suggestions in a short period of time, as some of the solutions proposed by us take long time to remove hurdles like financial problem, acceptance of higher authorities etc. Solutions to the various problems sort out by using TRIZ methodology are mentioned in the table-- , out of which covering the conveyors, employing uninterrupted power supply, and use of CNC tapering machine cannot be implemented with immediate effect. It will take 5 to 6 years for actual implementation. However, the management of the company is convinced by our suggestions and solutions given to them and assured us for implementing above methods in near future. Apart from above solutions, rest of all are implemented and final result is determined in the form of reduction in defect rates.

Table- 2: Common problems with their solutions

Problems	Applied/Proposed Solutions
Crack generation during plastic deformation of heated bar	- Increasing the temperature of the furnace by 20^0C. - Covering the conveyors, so as to reduce the heat loss - Minimum time should be taken while heating steel above 900^0C to avoid decarburization and oxidation.
Semi finished work due to sudden power off	- Use of uninterrupted power supply.
Burn marks during Grinding	- Fixing a nozzle at right position which supplies the sufficient cutting fluid at low pressure and velocity that matches the velocity of grinding wheel.
Tip thickness out of specification during end tapering of the heated bar	- Polish or repair the die-blocks before use. - Employ CNC Tapering Machine for tapering process to have more precise and defect free operation.
Tip thickness out of range during end grinding operation	- The grinding operation should be performed by a skilled operator under the observation of supervisor.
Raw material defect	- Crack detection test should also be performed on raw material (i.e., peeled bar).

After implementing some of solutions proposed by TRIZ methodology, we collected the data again from May 2014 to July 2014 to find the improvement.

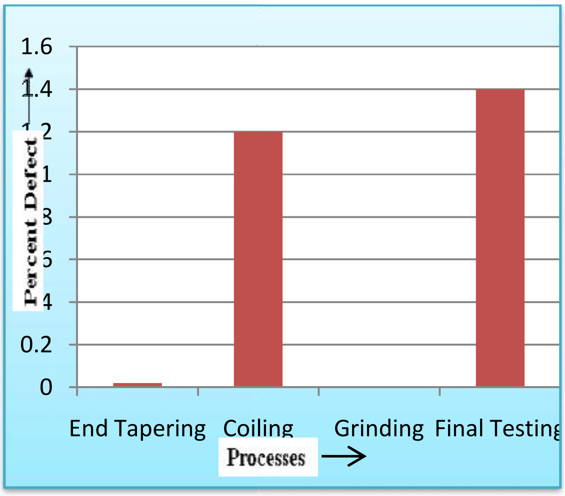

Figure- 5: Graph showing percent defect in different processes after implementation

During the final inspection I found that after implementation of some of the proposed solutions through TRIZ, the defect rate reduces upto 70%, as shown in above graph.

VIII. CONCLUSION AND RECOMMENDATIONS

In this thesis we presented some popular innovative problem solving techniques which can be feasibly used to solve the problem in a case study undertaken at Rail Spring Manufacturing unit. A number of TRIZ tools are used to solve different problems and to minimize the process defects of rail springs. After executing such a large number of measures, the defect rates of the products were reduced much, but not zero yet. The proposed solutions to the problem help to minimize the process defect rate of the spring likely up to 70%, since the factory has executed only few measures which are:

- Increasing the temperature of the furnaces by 20^0C,
- Grinding operation by a skilled and alert operator under the observation of supervisor,
- Polishing the die blocks periodically before use, and
- Supply of cutting fluid in sufficient amount with suitable pressure and velocity during end grinding operations with the help of well directed nozzle.

ISSN 2395-3594

During the analysis of case study, and our practical experience in Rail Spring Manufacturing plant, we came to know that, it is very necessary to minimize or eliminate defects in every work-station to achieve the required specifications of the customer (Indian Railway) in the finally finished product. To gain quality in service, the product should have good quality defect free operation.

Finally, it is recommended to implement rest of the suggestive measures as soon as possible to reduce the defect rate to the minimum level. Other suggestive measures recommended for implementation are:

- Covering the conveyors, so as to reduce the heat loss,
- Use of uninterrupted power supply,
- Employ CNC Tapering Machine for tapering operations to have more precise and defect free operation,
- Crack detection test should also be performed on raw materials (i.e., peeled bar).

To accomplish the Ideal final result, the company should adopt all the suggestive measures provided by us. This case study is most impressive in many points: achieving to solve a big problem in a short time by generating many solution ideas, deriving effective measures, executing many measures at once, etc.

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ISSN 2395-3594