To Analyze the Induction Hardening on Tulip and Cracks Reduction

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Abstract — In this Paper, defects encountered during Induction Hardening of Tulip have been done in detail. Major rejections occur during induction hardening due to cracking of the Tulip after Induction Hardening. Hence, in order to find the root cause of failure & to study the different defects during induction hardening process study was carried out, aim of the Paper was to find out reasons behind the cracks, to study the process of induction hardening and the defects encountered during the induction hardening process. A complete failure analyze was done on rejected Tulip which had developed defects during induction hardening. Different parameters were taken into consideration and various tests were performed to find the reason behind the failure. In the end some corrective actions and suggestions will be provided in order to improve the process and to counter the reasons that cause cracking of Tulip during induction hardening.

Keywords-

Induction Hardening, Tulip, Defects, Cracks.

1. INTRODUCTION

Hardening is a process that is used to improve wears resistance of parts without affecting core of the part. This combination of hard surface and resistance to wear is a very important property of a component. Most surface treatments result in compressive residual stresses at the surface that reduce the probability of crack initiation and help arrest crack propagation at the case-core interface. Induction heating is an extremely versatile heating method that can perform uniform surface hardening, localized surface hardening, through hardening, and tempering of hardened pieces. Heating is accomplished by placing a steel ferrous part in the magnetic field generated by high-frequency alternating current passing through an inductor, usually a water-cooled copper coil. The depth of heating produced by induction is related to the frequency of the alternating current, power input, time, part coupling and quench delay. Induction hardening of steel components offers a fast heating rate, high efficiency, and the ability to heat locally. Induction hardening is a highly nonlinear multi-physical process with electro-magnetic, temperature, phase transformation, stress, and shape changes all occurring in the component. Compressive residual stress in the hardened case is beneficial to the high-cycle fatigue performance.

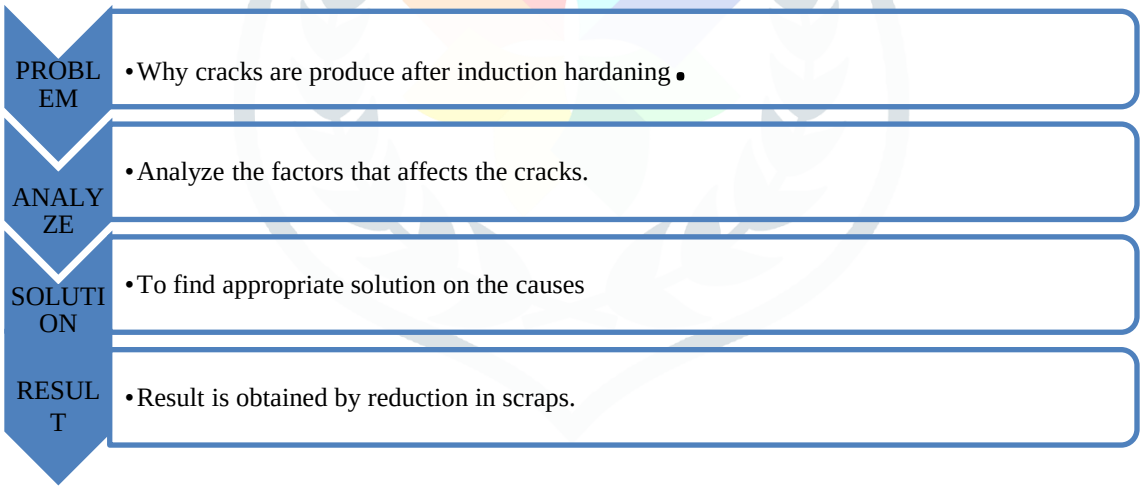
After the process there are several problems that should affect for the crack generation. Such has causes are:-

- Lack of skills of workers
- Improper machine handling, Experience of worker
- Alignment of machine
- Improper Quenching Power Failure
- Machine Vibrations
- Axial Rotation of work piece.
- Air Gap Setting
- Parameter Setting
- Material Properties
- Tool Not properly Design
- Quenchent Properties

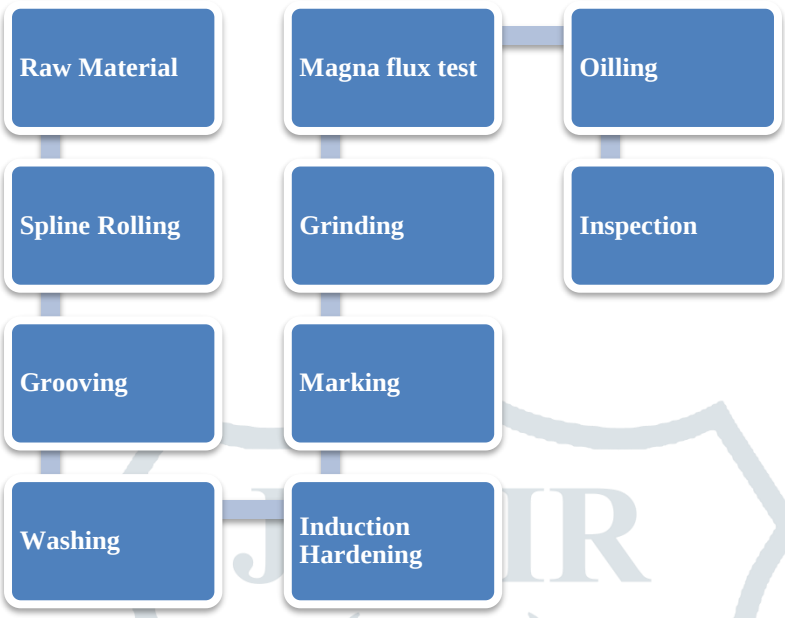
Problem

After Induction Hardening there are lots of problems which are responsible for producing the cracks on Tulip. Challenge in front of all the industries which producing tulips or shafts to reduce scraps due to cracks. The percentage of scrap parts is around 2 to 2.5%.

2.METHODOLOGY

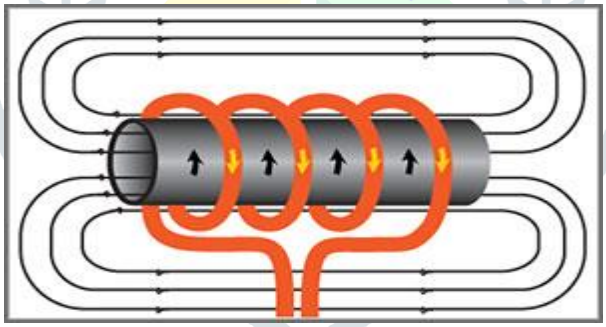


3. MANUFACTURING OF MALE TULIP



4. INDUCTION HARDENING-

Induction hardening is a form of heat treatment in which a metal part is heated by induction heating and then quenched. The quenched metal undergoes a martensitic transformation, increasing the hardness and brittleness of the part.

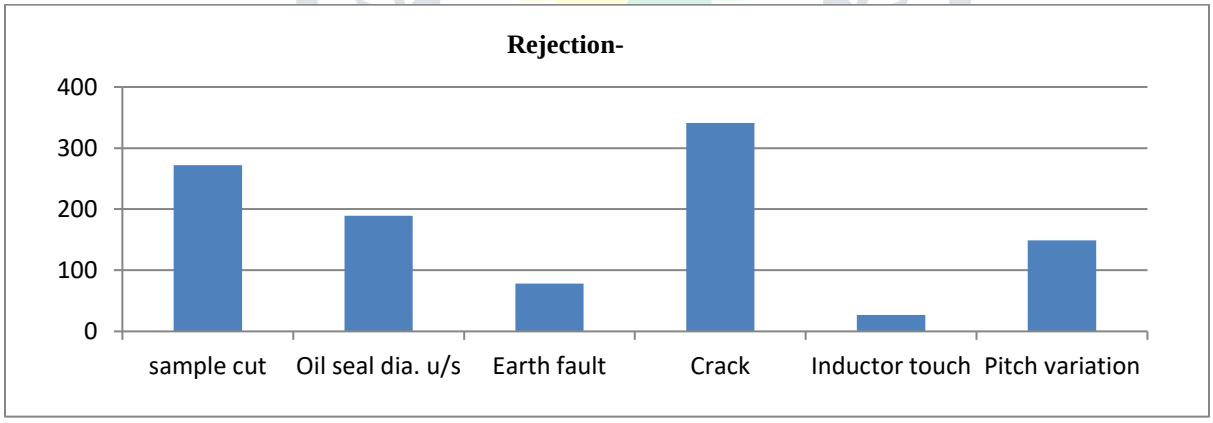


5. Analyzed Company Data-

Reason for rejection	Oct. rejection nos.	Nov rejection nos.
Sample cut	96	176
Bearing dia. u/s	0	0
Oil seal dia. u/s	24	165
Double hard	1	0

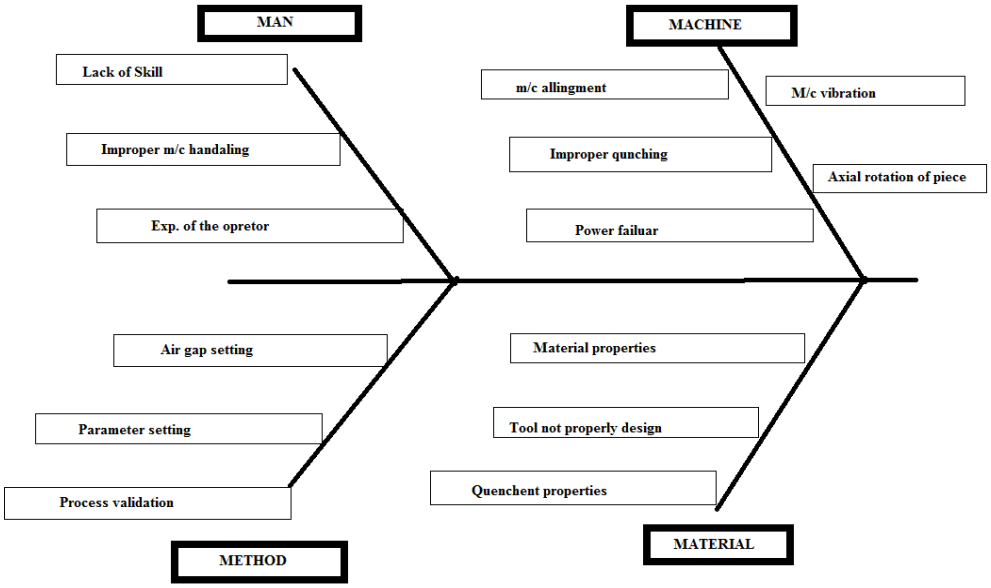
Spline gun not enter	1	0
Groove dia. u/s	0	2
Earth fault	27	51
Pitch variation	0	0
Spline damage	1	6
Rotation fault	4	13
Crack	214	127
Power fail	1	0
Thread damage	13	0
Face damage	0	0
Generator not ready	0	0
Spline OPD u/s	0	2
Groove damage	0	0
Other	1	0
Inductor touch	27	0
Pitch variation	56	93
Melt	19	7
Total	485	642

Table no. 1 Reasons for rejection in tulip cell.



From above graph it has been seen that amount of rejection due to cracks is very high as compare to other causes so it is very important to concentrate on such a factor. So we are selecting crack for analyze to improve the productivity.

6. FISH BONE DIAGRAM-



7 -Standardizes Solution

Man

Causes	Analyze parameter	Solution
Lack of skills	**1 – Verbal communication**-The top most sought after skill was good verbal communication. Almost every job will involve talking to colleagues or customers at some point and employees should be able to express themselves clearly, confidently and concisely, tailoring their style to their audience. Communication is not all about talking, the best employees will be able to listen to what people are saying, process it and act on it. **2 – Teamwork**-Many companies ask people to work in groups on projects, or in less hierarchical organizations, in self-managed teams. To succeed in these environments, employees should be able to cooperate with their colleagues, taking their share of the responsibility and putting forward their ideas in a confident, rather than passive or aggressive manner. **3 – Analyzing and investigating**-Problems crop up all the time and you need employees who are able to deal	1. Arrange training programs for workers 2.Proper discussion with workers 3.Problem discussions during working 4. Arrange time to time meetings for workers. 5. Provide proper motivations to workers 6. Provide proper wages and salaries. 7. Maintain healthy relationship between authority and workers. 8. Analyze way of working and provide proper suggestion's

	with them in a logical and analytical manner rather than getting into a panic or simply ignoring them. **4 – Self-motivation**-Managers can't spend every minute of the day monitoring their staff, so it's important that employees are self-motivated and able to use their initiative to priorities their tasks, come up with better ways of working and take responsibility for their own projects. **5 – Written communication**-Data from Skills for Life shows that 15% of adults don't have basic literacy skills. It's normally something which employers are made aware of straight away, as data from the Recruitment and Employment Commission highlights that around half of all CVs received by recruitment consultants contain spelling or grammatical errors. Being able to write emails, letters and reports with a clear structure and appropriate style and content is a valuable skill. **6 – Planning and organizing**-For workers to be at their most productive, they need to be able to organize their workload and plan their daily tasks effectively. Being able to work to deadlines and set themselves achievable targets is a beneficial skill.	
Improper machine handling	**1.Improper Maintenance**-When FED machines aren't cleaned and lubricated properly, a variety of problems may occur. If the material is sliding around during the cut, there may be debris preventing proper location and part fixturing. Over time, material and particulate can build up creating challenges for holding and locating parts creating issues with accuracy and redundancy. Simply put, FED machines should be kept as clean as possible. **2.Improper Programming**-Improper programming causes most other FED part Heating issues. Programming issues can be hard to remedy with newer employees, as they may not be aware of the part cutting	1.Provide proper lubrications to slide ways , bearings, pallets, conveyor belts and other moving parts. 2.Weekly change filters of quenchent system. Should be enter during programming 1.Proper coolant flow timing

	errors introduced by their program. In rare cases, simply powering the machine down and rebooting the system can resolve programming errors. This may cause operators to overlook their mistakes and blame the machine for the interrupted performance.	2.Proper axial movement of inductor 3.Proper rotary movement of pallet 4.Proper Heating Duration 5.Proper time for Loading and Unloading tulip.
Experience of workers	**1.Poor Performance-**Stress also can affect your ability to perform your job well. Stress can make it difficult to concentrate on complex problems or issues, and it might affect memory. You might neglect to complete certain important tasks or forget to perform a key part of a procedure. When you experience these feelings, you might no longer care about doing a good job. Health Effects Stress causes a variety of health problems, including high blood pressure, upset stomach, ulcers, headaches, palpitations, fatigue, sweating, weight changes, diarrhea, nausea, dizziness, dry mouth, appetite changes, sexual problems, stiff neck, muscle aches and back pain. **2.Unmet Expectations and Deadlines-**If you feel overwhelmed and exhausted, then meeting expectations or deadlines can be difficult. The effects of stress on your cognitive abilities can affect your ability to prioritize, and it can be difficult to decide which project should take priority.	1.Proper work distribution between workers. 2.Provide personal allowance to workers 3.Provide proper working conditions and proper lighting system 4.Proide safety to workers. 1. Give proper deadlines to workers. 2. Dont Over expect from the workers about doing the work.

Machine

Causes	Analyze parameter	Solution
Machine alignment	1.Movement of s1ideways 2.Bus Bars setting 3.Work head (L bracket alignment)	1.Smooth movement of slide ways should be done so provide proper lubrication 2. Bus bars setting should be done properly. 3. Daily alignment of work head should be done.

Machine vibrations	1. If the vibration are present in FED machine quenchent will not spread properly over the hot tulip. So that will cause of crack. 2. Due to Transverse vibration of machine air gap between the coil and tulip gets varied due to cyclic waves of machine so it effects on heating of tulip. 3. Feed rate of pallet 4. Upward and Downward movement of inductor	1. Provide rubber pad 2. Definite level of feed rate 3. For the time consideration the movement of inductor is too high for high production rate so it should be in desired level movement.
Powerfailure	Power is very important factor in induction heating. If supply of power cuts down desirable case depth can't obtain.	Continuous power supply should be provided. Power supply range is between 35 kw to 65 kw.
Axial rotation of piece	Tulips are mounted on rotary types of pallet. It programmed such that after several time it rotates in 45 degree. If rotary pallet is not aligned properly rotation obtained is not in proper manner because of this reason coil does not place properly in tulips mouth.	Axial Rotation of pallet should be take place in proper manner so daily checking of pallet should be done.

Method

Causes	Analyze parameter	Solution
Air gap setting	1.Proper air gap between coil and tulip is necessary for desirable amount of case depth. Due to improper gap between coil and tulip uniform heating does not take place. It was more than 2.5. 2. Inductor alignment	1. Air gap between the inductor and tulip is to be maintain properly its range is between 1.5 mm to 2 mm. 2. Inductor alignment should be done by passing proper offline gauges.
Process Parameters	1.Voltage range was 475 dc volts to 550 dc volts which was fluctuating. 2.Current range was 0.3 to 0.5.	1.Frequency range should be 40 to 45 kHz 2.Voltage range should be 500 dc volts to 600 dc volt. 3.Current range should be 0.3 to 0.5 amp.

Material

Causes	Analyze parameter	Solution
Material properties	1.Hardness- Range was between 52 to 60 2.Strength	1.Hardness of the material should be in between 58 to 62 BHN. 2.Strenght should be as maximum as possible.

Tool Not Properly Design	In the EFD induction tube is use as tool. 1. Tube thickness Range between 1.2 to 1.4 because of wearing. 2. Copper purity 3. Inductor cooling flow rate 4. Life of inductor was 70000 no. of components.	1.Induction tube thickness should be 1.5 mm 2.Copper purity should be maintain. 3.Proper Inductor cooling flow rate 4.The life of inductor coil is over 60000 numbers of components.
Quenchent Properties	1.PH value range was between 6.6 to 7.5. It was acidic. 2.Conductivity 3.Concentration- range was between 8 to 10%. 4.Quility of water- Impurities were contained by the water like dust, dirt, burr.	1.PH Value of water should be maintain between 7 to 7.5 PH 2.Conductivity of quenchent should be maintain between 20 to 50 micro ohm/cm. 3.Concentration of aqua quenchent water should be 8 to 12 % 4.Never use de ionized water 5.Glycol should mix with water for proper concentration. 6.Should use of clean distilled water

Table no. 2 Standardize Solution

8.Conclusion-

Reason for rejection	Oct. rejection nos.	Nov. rejection nos.	March rejection nos.
Sample cut	96	176	130
Bearing dia. u/s	0	0	0
Oil seal dia. u/s	24	165	91
Double hard	1	0	0
Spline gun not enter	1	0	0
Groove dia. u/s	0	2	2
Earth fault	27	61	41
Pitch variation	0	0	0
Spline damage	1	6	7
Rotation fault	4	13	0
Crack	214	127	87
Power fail	1	0	2
Thread damage	13	0	3
Face damage	0	0	0

Generator not ready	0	0	0
Spline OPD u/s	0	2	5
Groove damage	0	0	0
Other	1	0	0
Inductor touch	27	0	0
Pitch variation	56	93	59
Melt	19	7	3
Total	485	642	430

Form above table we conclude that numbers of rejections of tulips are reduced by applying all the solutions. The percentage reduction in scraps is 32 % due to cracks.

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