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Review of Forging Fault Analysis for Forging Industry Quality Improvement

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***Abstract*- This paper's goal is to explore the numerous forging flaws that lead to high component rejection rates in the forging industry and outlines the corrective actions that can lessen these flaws in hot forging. This essay offers a critique of a study on forging flaws in the forging industry.**

To explain how faults arise and how to avoid them, forging analysis is performed. This is frequently done with the aid of a Pareto diagram to identify key areas. The cause and effect diagram is then used to discuss potential causes of flaws including underfilling, mismatch, and scale pits and to identify the factors that have the biggest impact.

Lastly, it is shown how various sectors can reduce forging faults by improved manufacturing processes, the best possible choice of process parameters, etc.

***Index terms*: Forging defects, Forging process parameters, Seven Quality Control tools, under filling, lapping**

I. INTRODUCATION

Forging is referred to as a metalworking process in which compressive forces are exerted through the use of dies and tools to solidify the work piece into a functional shape. The metal is hammered or pressed during the forging process. One of the earliest known methods of metallurgy, it dates back thousands of years. A smith would traditionally use an anvil and hammer to forge metal. Forging crudely involves the use metal a hammer and anvil. Over the course of many centuries, the smithy or forge has developed into a facility with engineered procedures, production tools, equipment, and products to satisfy the needs of contemporary industry. Industrial forging is currently carried out using either presses or hammers that are powered by compressed air, electricity, hydraulics, or steam. Nowadays, forging is used to create shapes like as the crane hook, the connecting rod of an IC engine, spanners, gear blanks, crown wheels, pinions, etc. With the least amount of material waste, the forging process creates products with exceptional mechanical qualities. The initial material in this process has a relatively simple geometry, and it goes through one or more processes where it is plastically deformed into a result with a highly complex configuration. Often, forging requires expensive tooling. As a result, the technique is economically advantageous when producing numerous pieces or when a forging process is the only way to achieve the mechanical qualities needed for the end product. Although though the forging process produces products of a higher calibre than those made using other manufacturing techniques, there are some faults that are easily possible if adequate care is not taken in the design of the forging process. The faults that go above specific thresholds are referred to as defects.

There are several flaws that can be categorised as faults, ranging from those that can be linked to the raw materials to those brought on by one of the forging processes or by operations performed after forging.

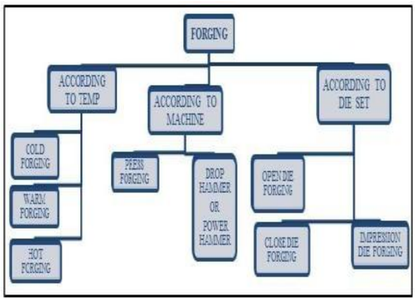

Fig.2 Open Die forging

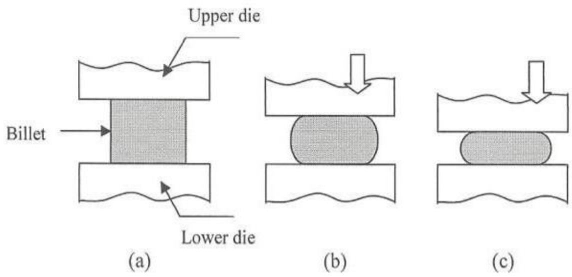

Fig.3 Open Die forging [4]

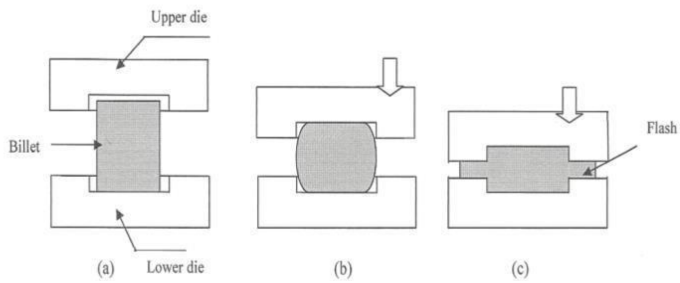

Fig.4 Impression Die forging [4]

II. CHARACTERISTICS OF FORGING

Usually involves discrete parts, May be done on hot or cold materials, Often requires additional finishing processes such as heat treating, machining, or cleaning, May be done at fast or slow deformation rates, May be used for very small or very large parts, Improves the physical properties of a part by controlling and refining the flow or grain of the material.

III. FORGING DEFECTS

When a forge shop begins to experience defects in their process, they should try to find the root cause of the problem, initiate corrective action and implement procedures to prevent its recurrence. A brief description of defects and their remedial methods is given below:

1) ***Incomplete forging penetration:*** Dendritic ingot structure at the interior of forging is not broken. Actual forging takes placeonly at the surface.

Cause-Use of light rapid hammer blows
Remedy-To use forging press for full penetration.

2) ***Surface cracking:***
Cause-Excessive working on the surface and too low temperature.Remedy-To increase the work temperature

3) ***Cracking at the flash:*** This crack penetrates into the interior after flash is trimmed off.Cause-Very thin flash
Remedy-Increasing flash thickness, relocating the flash to a less critical region of the forging, hot trimming and stress relieving.

4) ***Cold shut (Fold):*** Two surfaces of metal fold against each other without welding completely.Cause-Sharp corner (less fillet), excessive chilling, and high friction
Remedy-Increase fillet radius on the die.

5) ***Unfilled Section (Unfilling/Underfilling):*** Some section of die cavity not completely filled by the flowing metal.Cause-Improper design of the forging die or using forging techniques, less raw material, poor heating.
Remedy-Proper die design, Proper raw material and Proper heating.Fig.7-Shows the fish-bone diagram for root-cause analysis ofunderfilling defect.

6) ***Die shift (Mismatch):*** Misalignment of forging at flash line. Cause-Misalignment of the die halves.
Remedy-Proper alignment of die halves. Make mistake proofing for proper alignment for eg. Provide half notch on upper and lower die so that at the time of alignment notch will match each other.Fig. 8-Shows the fish-bone diagram for root-cause analysis of mismatch defect.

7) ***Scale Pits (Pit marks):*** Irregular depurations on the surface of forging.
Cause-Improper cleaning of the stock used for forging. The oxide and scalegets embedded into the finish forging surface.
Remedy-Proper cleaning of the stock prior to forging.Fig.9-Shows the fish-bone diagram for root-cause analysis of Scale Pitsdefect.

8) ***Flakes:***These are basically internal ruptures.
Cause-Improper cooling of forging. Rapid cooling causes the exterior to cool quickly causing internal fractures.Remedy-Follow proper cooling practices.

9) ***Improper grain flow:***

Cause-Improper die design, which makes the metal not flowing in final interred direction.Remedy-improper die design.

10) ***Residual stresses in forging:***

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Cause-Inhomogeneous deformation and improper cooling (quenching) of forging. Remedy-Slow cooling of the forging in a furnace or under ash cover over a period of time

IV. REVIEW OF RESEARCH ARTICLE

1) **Christry Mathew et.al (2013):** The study is focused on the forging analysis of an integral axle arm produced by hot forgings are made. Forging analysis is done to explain that how the defects occur and how to prevent them. With the help of Pareto diagram, this is mostly used to identify major areas. Then the cause and effect diagram is used to explore possible causes of defects through a brainstorming session and to determine the causes which have the greatest effect. Corrective measures are being suggested to overcome the forging defects of the integral axle arms. Finally, few remedial measures and suggestions have been provided for the existing integral axle arm production process in the forging shop. Pareto analysis is made according to data obtained and from the Pareto charts the major defects were clearly highlighted as shown in fig.5

Month	Rejection	Unfilling	Lap	Scalepit	Oversize	Crack	Mismatch
Aug-12	5	2	2	0	0	1	0
Jul-12	5	2	3	0	0	0	0
Feb-12	1	1	0	0	0	0	0
Jan-12	2	2	0	0	0	0	0
Dec-11	2	0	1	0	0	1	0
Oct-11	2	1	1	0	0	0	0
Jun-11	1	1	0	0	0	0	0
Mar-11	2	0	1	0	0	0	1
Jan-11	4	2	1	0	0	1	0
TOTAL	24	11	9	0	0	3	1
% contribution		45.83	37.5	0	0	12.5	4.17

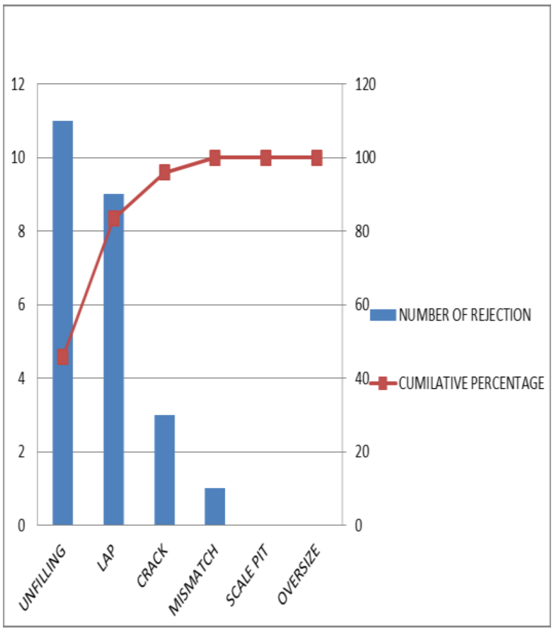

Table I Rejection Details of Integral Axle Arms [1]Fig.5: Defect Analysis Using a Pareto Diagram [1]

2) **Aju Pius, Sijo,et.al(2013):** The author studied and investigate the various forging defects that occur in a forging industry that causes high rejection rates in the components and remedial measures that can reduce these defects in the hot forging. The investigation was done with the help of quality assurance department within the industry. The result indicates that the rejection rate in the company was more than five percent of the total productions made each month. The defects

in the forged components includes the lapping, mismatch, scales, quench cracks, under filling etc. The remedial actions includes the proper use of anti-scale coating, venting process to prevent the under filling, the simulation software for determining the material flow, proper lubricant instead of furnace oil etc. The author used the cause and effect diagram of the forging defects and its causes as shown in the figure6.

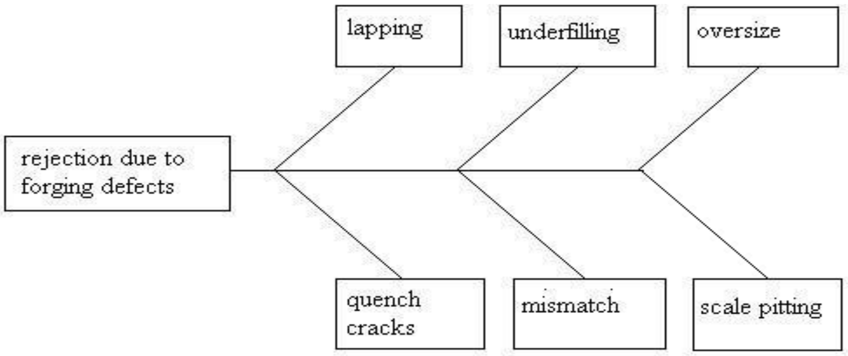

Fig.6: Cause and effect diagram for the rejection rate [2]

3) **Chandnaand Chandra,et.al(2009)**: Discussed the forging analysis of six cylinder crankshaft manufactured by TAT motors, Jamshedpur INDIA , produced by hot forging having engine bore of ninety-seven mm popularly known as 697 crankshaft. Forging analysis has been being made to explain that how the defects appear and how to prevent them. Analysis has been done with the help of various quality tools generally used for quality improvement process such as Pareto analysis, Brainstorming session of workers and Cause and Effect diagrams. Based on the analysis Corrective measures were suggested to overcome the forging defects in existing crankshaft production line in the forging shop and controlling forging defects will reduce the present rejection rate from 2.43% to 0.21% and rework from6.6 to 2.15%

4) **M.G.Rathi, N.A.Jakhade,et.al (2014)**: Discussed forging defects those repeatedly occurring along with their cause and remedies. Then the fish-bone diagram are used to explore the possible causes of defect like unfilling, mismatch and scale pit through a brainstorming session and to determine the cause, which may has the greatest effect shown in fig. 7, fig.8 and fig.9 respectively.

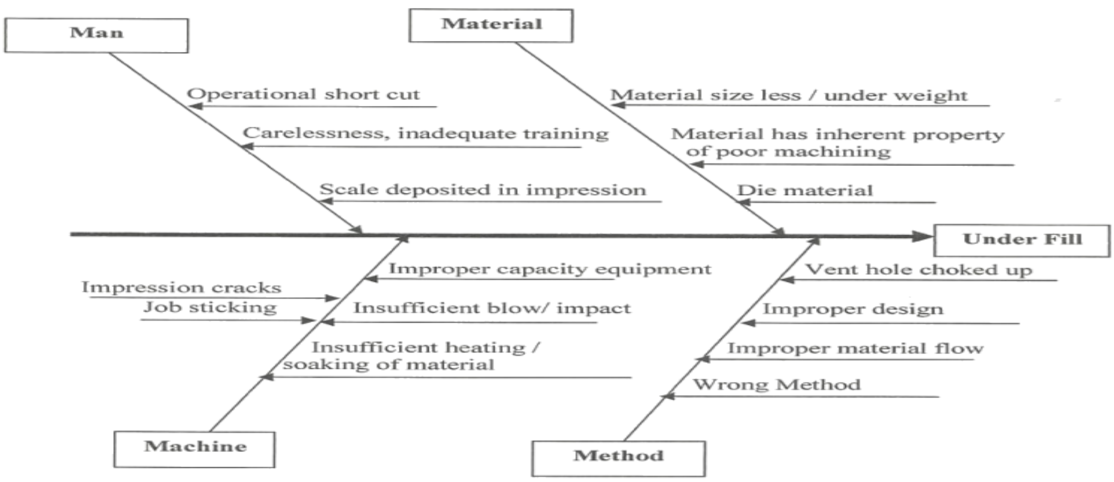

Fig.7: Cause and effect diagram for the under fill [4]

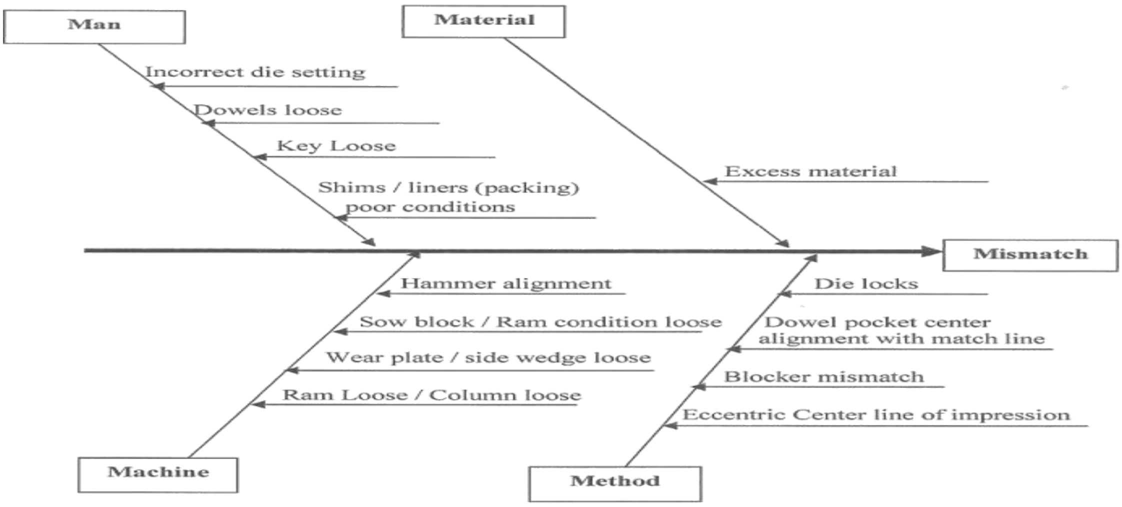

Fig.8: Cause and effect diagram for the Mismatch [4]

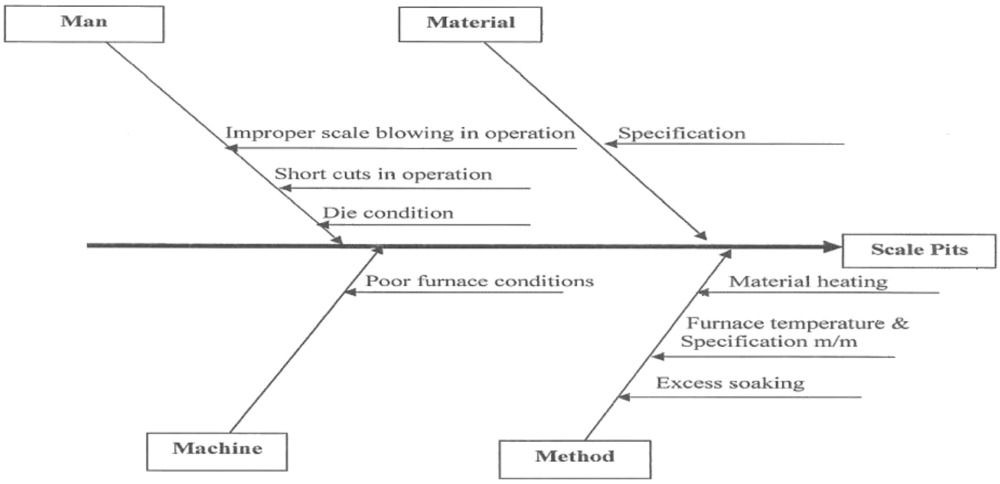

Fig.9: Cause and effect diagram for the Scale Pits. [4]

5) **M.Sekhon, Dr.G.Brar,et.al (2014)**: The author studied and investigate the various forging defects that occur in a forging industry. An analysis was done using six sigma technique and seven quality tools like Flow chart, Pareto diagram, Check sheet, Control chart, Histogram, Scatter plot, Cause and effect diagram. The major defects are cracks, scaling and low hardness. The remedial action includes the proper use of anti-scale coating, proper lubricant in the forging process.

V. CONCLUDING REMARKS:

1) Several investigators have identified that major forging defects are underfill, crack, lapping, scalepit, mismatch and oversize. Majority industries are experiencing unfilling and lapping are major defects in their processes.

2) Few investigators have used basic quality control tools to investigate the forging defects and they are able to identify major defects, their causes and remedies to control the forging defects. They have shown improvement in the rejection ratefrom up to 2 to 3%.
3) Scaling defect can be reduced by anti-scale coating and proper lubricants in the forging process.
4) Forging process can be optimized to minimize the defects by proper selection of parameters like forging temperature, heating time, and billet weight.

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