Review of Analysis on Forging Defects for Quality Improvement in Forging Industries

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***Abstract*- The objective of this paper is to investigate the various forging defects that occur in the forging industries that causes high rejection rates in the components and this paper describes the remedial measures that can reduce these defects in the hot forging. This paper includes review of research paper on forging defects in forging industries.**

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 like underfilling, mismatch and scale pits through a brainstorming session and to determine the causes which have the greatest effect.

Finally, it is concluded that how several industries are able to control forging defects by improve manufacturing process, optimum selection of process parameter etc.

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

I. INTRODUCATION

Forging is defined as a metal working process in which the useful shape of work piece is obtained in solid state by compressive forces applied through the use of dies and tools. Forging process is accomplished by hammering or pressing the metal. It is one of the oldest known metalworking processes with its origin about some thousands of years back. Traditionally, forging was performed by a smith using hammer and anvil. Using hammer and anvil is a crude form of forging. The smithy or forge has evolved over centuries to become a facility with engineered processes, production equipment, tooling, raw materials and products to meet the demands of modern industry. In modern times, industrial forging is done either with presses or with hammers powered by compressed air, electricity, hydraulics or steam. Some examples of shapes obtained now-a-days by forging process are-Crane hook, connecting rod of an IC engine, spanner, gear blanks, crown wheel, pinion etc. Forging process produces parts of superior mechanical properties with minimum waste of material. In this process, the starting material has a relatively simple geometry; this material is plastically deformed in one or more operations into a product of relatively complex configuration. Forging usually requires relatively expensive tooling. Thus, the process is economically attractive when a large number of parts must be produced and/or when the mechanical properties required in the finished product can be obtained only by a forging process Though forging process gives superior quality product compared to other manufacturing processes, there are some defects that are lightly to come if a proper care is not taken in forging process design. Defects can be defined as the imperfections that exceed certain limits. There are many imperfections that can be considered as being defects, ranging from those traceable to the starting materials to those caused by one of the forging processes or by post forging operations.

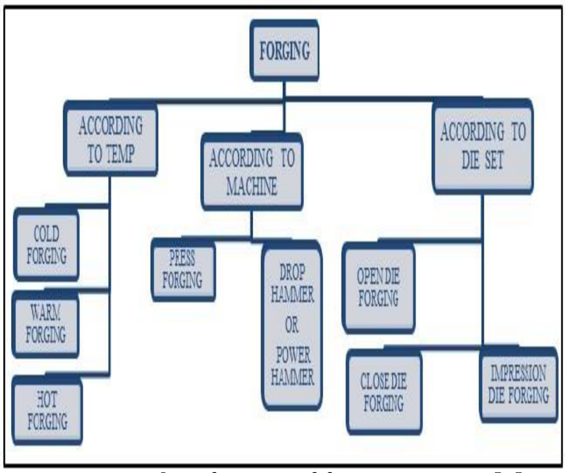

Fig.1 Classification of forging process [6]

Fig.2 Open Die forging

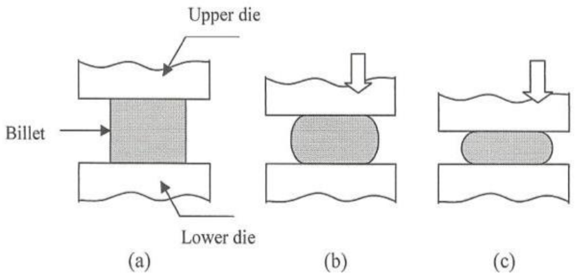

Fig.3 Open Die forging [4]

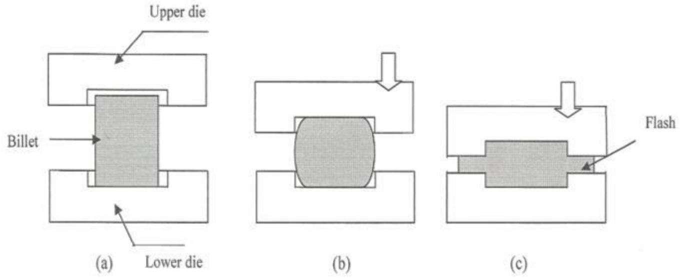

Fig.4 Impression Die forging [4]

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 place only 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 of underfilling 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 Pits defect.

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:
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]

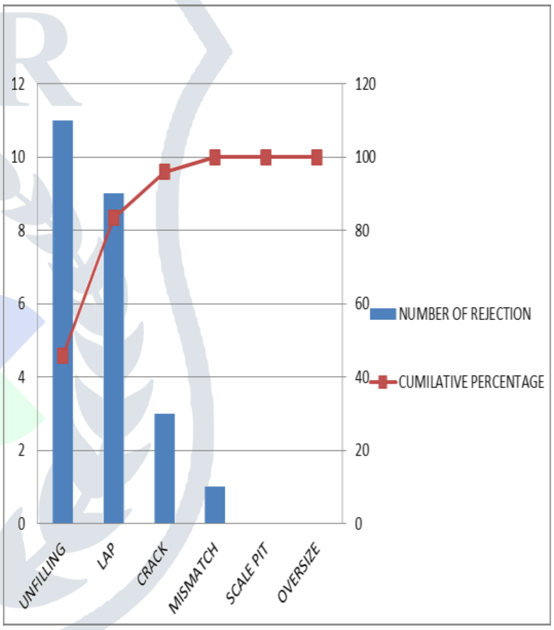

Fig.5: Defect Analysis Using a Pareto Diagram [1]

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 figure 6.

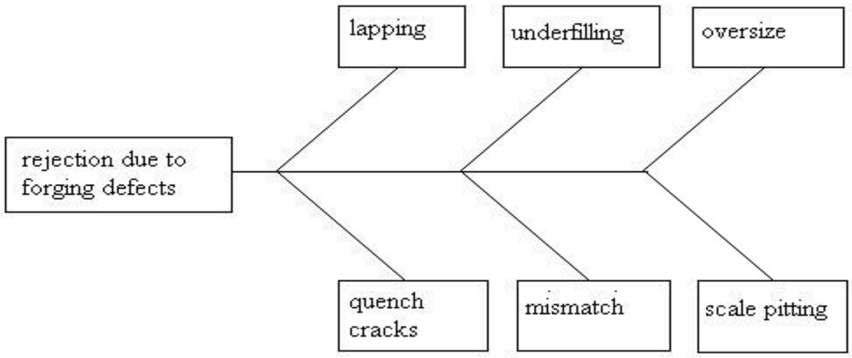

Fig.6: Cause and effect diagram for the rejection rate [2]

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.

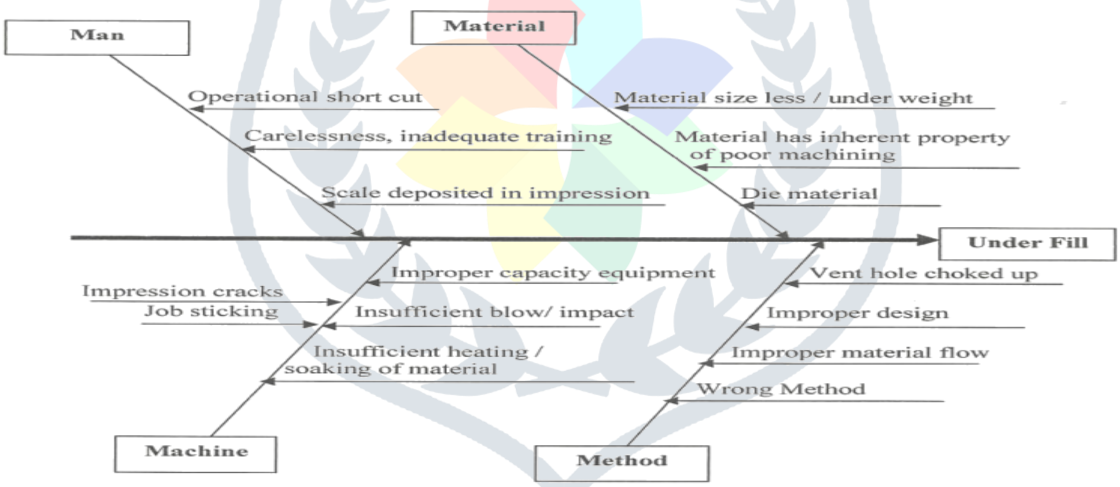

Fig.7: Cause and effect diagram for the under fill [4]

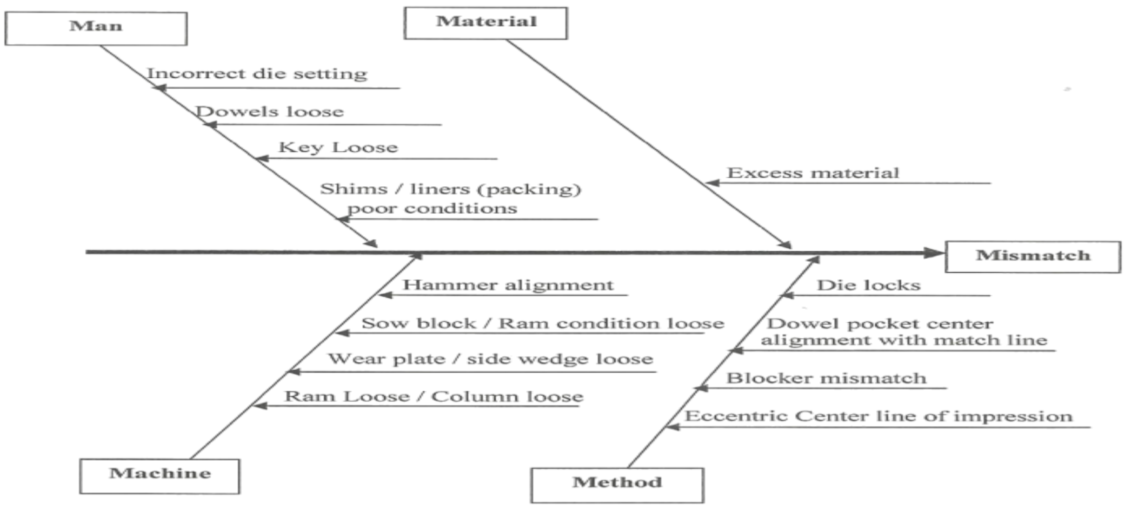

Fig.8: Cause and effect diagram for the Mismatch [4]

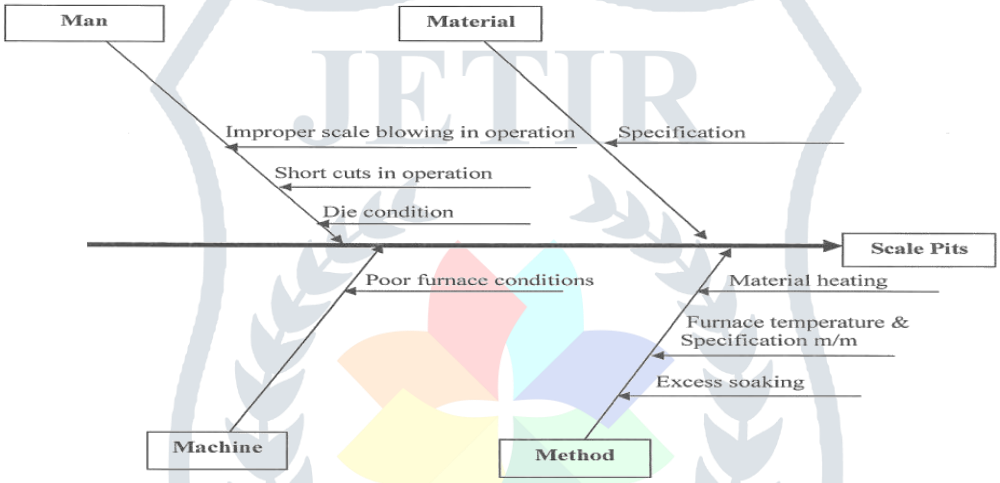

Fig.9: Cause and effect diagram for the Scale Pits. [4]

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 rate from 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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