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AN APPLICATION OF QUALITY CONTROL TOOLS TO MINIMIZING REJECTION OF RUBBER DEFECTS IN INJECTION MOULDING PROCESS: AN INDUSTRIAL CASE STUDY

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ABSTRACT

Damper and Vibration Isolators are the most imperativeparts of an automobile to decrease vibration or noise. Today's competitive environment every manufacturing organisation has focused on high quality product with defect free operation to increase productivity and reduce manufacturing cost.In this work a manufacturing unit located in northern region in India have been taken which dedicated to manufacturedNoise, Vibration and Harshness (NVH) parts. To manufacture NVH parts various processeswere studied through process flow diagram of manufacturing plant and it include degreasing, grit blasting and rubber to metal bonding through injection moulding. In order to manufacturethese parts, a major process which is required is injection moulding of rubber. In this process of injection moulding, various defects were analysed and identified with the help of Pareto analysis. These defects directly influence on efficiency, profitability and quality level of organization. With the application of Pareto diagram defects were prioritized by arranging them in order of their occurrences.Cause and effect diagram is being applied to investigateconceivable reasons of defects through brain storming session and identify the root causes of defects.This paper also suggests the possible solutions of major defects to improve quality level and productivity of plant.

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Keywords: Quality Control Tools,Pareto Analysis, Cause & Effect diagram, Injection Moulding Defects, NVH parts.

I. Introduction

In the competitiveworld of manufacturing because of exceedingly focused on business sector, organizations have look to search for different strategies and practices to enhance quality.Quality is a thought whose definition has changed overtime. Previously, quality signified "conformance of customer requirements". As indicated by Montgomery (2005), quality is the most crucial factor in the choice of products and services.Quality tools can be utilized as a part of all production process, from the starting point of product development to product marketing and customer support. Right now there are a significant number of quality control and quality management tools on disposal to quality experts and managers, so the choice of most appropriated one is not always a simple task. Selections of an appropriate quality tools for a particular process play a very important role in order to reduce rejection of defects in manufacturingindustries. Rejection of material/productimpact on the cost ofproduct and decreases the profitability of an organisation. Therefore organisations are consistently tryingto reduce rejection to maintain level of quality of products.

Quality control tools are used to improve quality of an organisation. Pareto chartused toidentify various defects and sequence them according totheir significance. Cause and- Effect Diagram used to identify root causes of defects. It helps to display reasons of a particular problem or quality characteristic. It represents the correlation between a specific defect and all the variables that influence this problem and hence to identify the root causes i.e. main reasons for a specific defect or problem. The reduction of defect in manufacturing processes will improve the efficiency of an organisation. Manufacturing industries need tohandle the idea of rising the concept of "Zero-waste" and "zero-defect" to ensure quality of products and hence improve productivity of an organisation. In this paper, a use of Pareto analysis and Cause-and-Effect Diagram has been considered to identify and classify the causes that are responsible thedefects ininjection moulding of rubber to metal bonding.

II.Literature Review

Juran (1940) applied Pareto charts for dividedthe "vital few" from the "trivial many". It shows the mostaffecting reason for rejection of raw materials. In this casestudy10 distinct categories of raw material rejects which accounts for 50% of all rejection.In another case study Wilson et al. (1993) has focused the Root CauseAnalysis to perform a complete review of critical defects. To identify the root cause and contributory factors toreduce defectsand generate an action plan along with measurement strategies through brainstorming to improve quality.Khamis (2003) presented a case study of an air conditioning manufacturing and assembly company in a department of plastic injection moulding process. It found that cross flow fan is a critical component in the manufacturing of air refrigerator. Rejection of cross flow fan is the main concern which appear from the injection moulding process. Themanagement team manage a brainstorming session to find out the root cause of the particular short-shot defectsthrough the Ishikawa diagram.

According to Perzyk (2007) has presented a study of foundry industry and identifythrough Pareto analysis that sand inclusion and gas holes are the major defects in foundry which contribute 72% of all defects. Pareto analysis can utilizeto define the targets. Most frequently occurring factors are determined with the help of Paretoanalysis and indicates the most imperative problem to analyze.

Mahto and Kumar (2008) applied cause and effect diagram to identification of dimensional defects in cutting operation in CNC oxy flame cutting machine and concludedthe result after implementation by reducing rejection rate from 11.87% to 1.92% on an average.Chandna and Chandra (2009) focused on forging operation in an organisationthat produce six cylinder crankshaftwhich used in automobiles. An application of Pareto analysis are used to identify critical areas of forging defects of crankshaft and defects have been prioritized by arranging them in order of their occurance. Then Cause and- Effect Diagram is applied to explore possible causes of defects through brain storming session and to determine the causes, which have the greatest effect. The corrective measures reduce the rejection rate from 2.43% to 0.21%.

Khekalei et.al (2010) has presented a case on reduction of waste in a belt manufacturing industry by using DMAIC methodology. In analyse stage, it used Ishikawa diagram in belt manufacturingto reduce cord wastages which have the maximum impact on the operational

wastages. After analysing, it is identified that tension setting and left over cord were the main root causes for high cord wastage. Possible solutions were suggested to reduce cord wastage and it achieved the reduction of wastage from 549531 to 17240.

Ahmed et.al (2011) has focusedon reduction of defects in lamp manufacturinglineby using Pareto analysis and Cause and Effect Diagram. They worked on the concept of zero waste and zero defects. They studied the historical rejection data of lamp manufacturing process. They utilized Pareto analysis to identify all defects and find major and minor contributors and apply cause & effect diagrams to found root causes of each major defect. They concluded that the application of Pareto and cause & effect diagram in manufacturing sector is highly useful to indicating the presence of variationin the process in form of excessive variations of process parameters.

From the literature review it is concluded that successful implementation of Pareto analysis and Cause & Effect diagram can significantly reduce the rejection rate and improve quality of product. In this study quality tools are used to enhance the quality of NVH parts manufacturing plant.

III. Company Background

NVH product manufacturing unit was selected to implement QC tools in order to improve the level of product quality by reducing rejection or rework. Company is located in North region of India. The company was dedicated to producedifferent mass dampers and isolator partsthrough rubber to metal bonding for commercial vehicles and passenger cars to fulfill the needs toreduce vibration or noise.Rubber to metal bonding has three essential elements: the rubber, the bonding agents and the substrate.

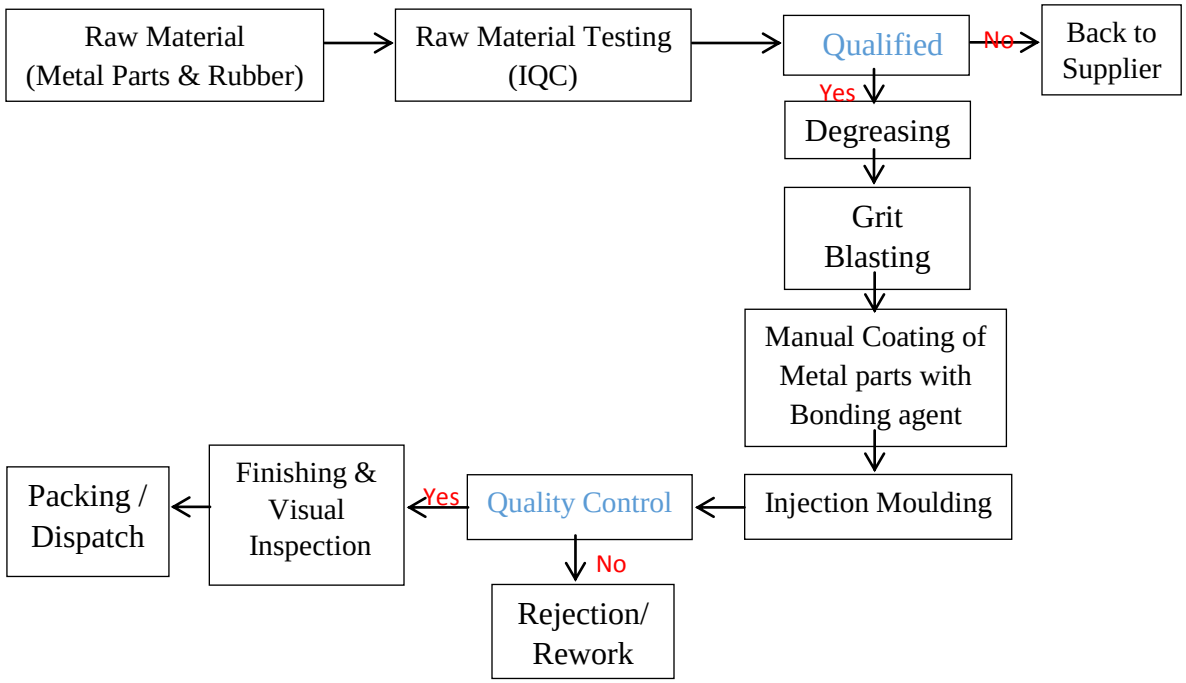

Fig. 1: Process Flow diagram of Rubber to metal bonding process to manufacture NVH parts

3.1 Injection Moulding

In rubber moulding process, Injection moulding is the most critical process in which the rubber material or compound is heated in extruder, and while the material or compound is in a flowable state in the injection barrel, the material or compound is forced or injected into the mould cavity under the pressure available. They should not cure before filling the mould, but cure quickly once it reach in the mould.

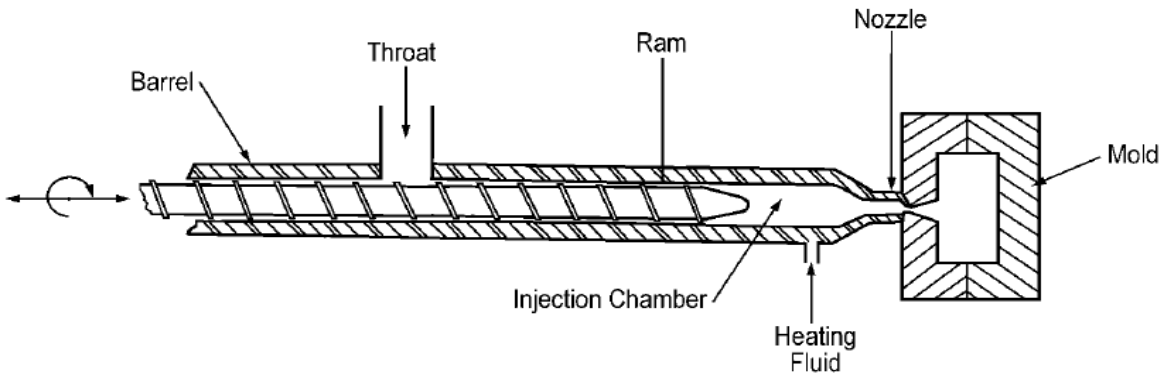

Fig. 2: Inline reciprocating screw machine for injection moulding
(Courtesy of J.Sommer, 1985)

IV. Description of Defects

4.1 Pareto Analysis

Pareto analysis is a unique type of bar chart where the plotted data are arranged from largest to smallest. An application of Pareto analysis is helpful to highlight the most frequently occurring defects or the most common causes of defects. To recognize the problem which causes frequent defects of rubber injection moulding process, a two months data had been collected. The actual rejection data is shown in table 1.

S NO.	Name of Defect	Frequency of defects	Cumulative frequency	Percentage of defects	Cumulative Percentage
1	Blister	1546	1546	21.4	21.4
2	Burn Marks	1424	2970	19.6	41.0
3	Rubber Crack	1380	4350	19.1	60.1
4	Loose Bond	964	5314	13.3	73.4
5	Short Rubber	857	6171	11.8	85.2
6	Old Rubber	463	6634	6.4	91.6
7	Deep Injection point	369	7003	5.1	96.7
8	Inter leaf missing	137	7140	1.9	98.6
9	Primer Failure	101	7241	1.4	100

Table 1: Defect data of rubber injection moulding process

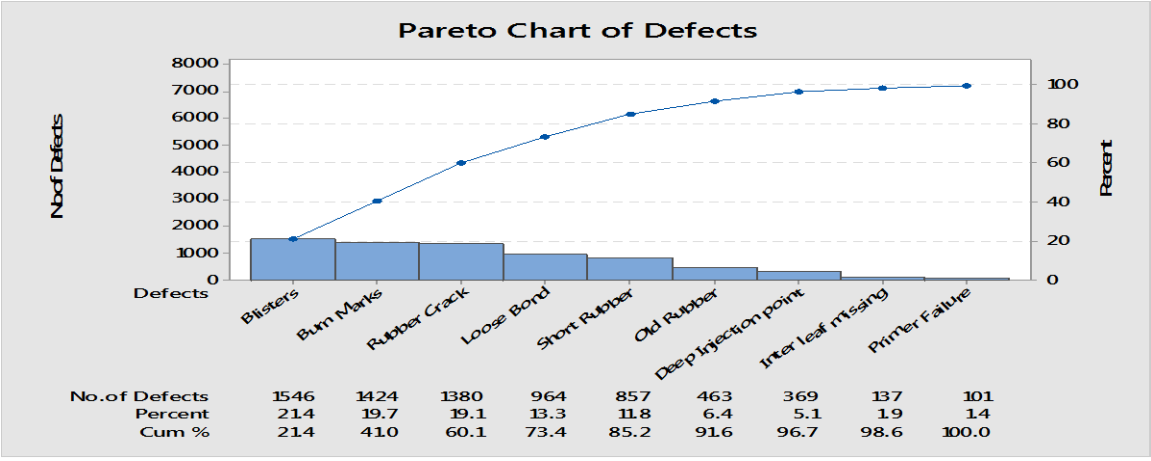

Fig. 3: Pareto chart shows type of defects in graphical form

Through vital few analyses (80/20) major contributed defects were taken for actions which highly contribute on rejection or rework. To control the rejection first found root causes of these defects through cause & effect analysis and then possible solutions were recommended through brainstorming.

Fig. 4: Blister and Burn marks defects

Fig. 5: Rubber crack and Loose bond defects

4.2 Cause & Effect Diagram

The cause-and-effect diagrams were constructed through brainstorming sessionswith the help of quality improvement team involving all employees those are the part in the related production and quality test activities.The main aim of the cause and effect diagramis to illustrate in a way of relationship between a given outcome and all the factors that influence this outcome. The main objectives of this quality tool are:

- Determining the root causes of a problem.
- A specific issue were focused without resorting to complaints and irrelevant discussion.
- Identifying regions where any lack of data.

To construct the cause & effect diagram following rules are follows:

- Do not criticize anyone's thoughts, by expression of motion.
- Do not talk about any ideas during the session, except for clarification.
- Do not hesitate to suggest a thought because it sounds "senseless".
- Do not permit any group member to present more than one thought at a time.
- Do not allow any group to be dominated by one or two people.
- Do not let brainstorming because anissue session.

4.2.1 Blisters

Blisters are hollow made on or in the shaped part. Rather than a void (vacuum) this ensnared gas canlikewise show up close to the dividers.

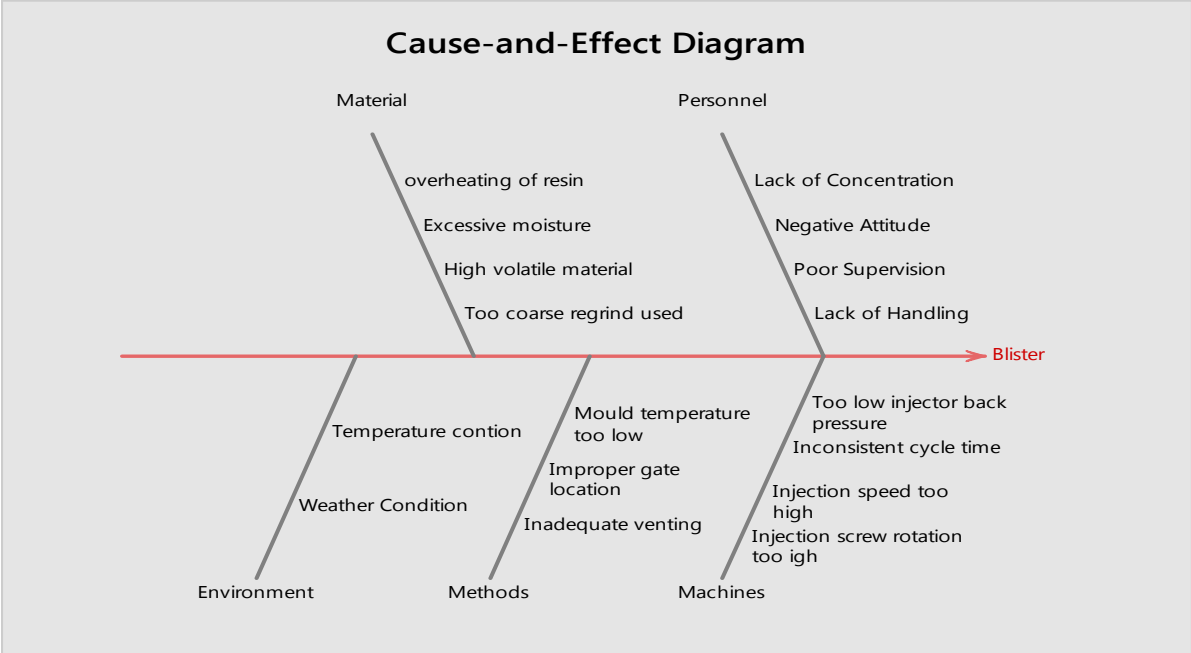

Fig. 6: Cause & effect diagram of blister defects

Root Cause: Tool or material is excessively hot, regularly brought by an absence of cooling around the tool or a radiator heater.

Possible Solutions

- Decrease temperature of melts.
- Decrease screw speed.
- Dry material.
- Increase back pressure.
- Increase mould temperature.
- Provide additional mould vents.
- Relocate gate.

4.2.2 Burn Marks

Dark or Black streaks appear in the moulded part and are usually caused due to thermal damage of the melt.

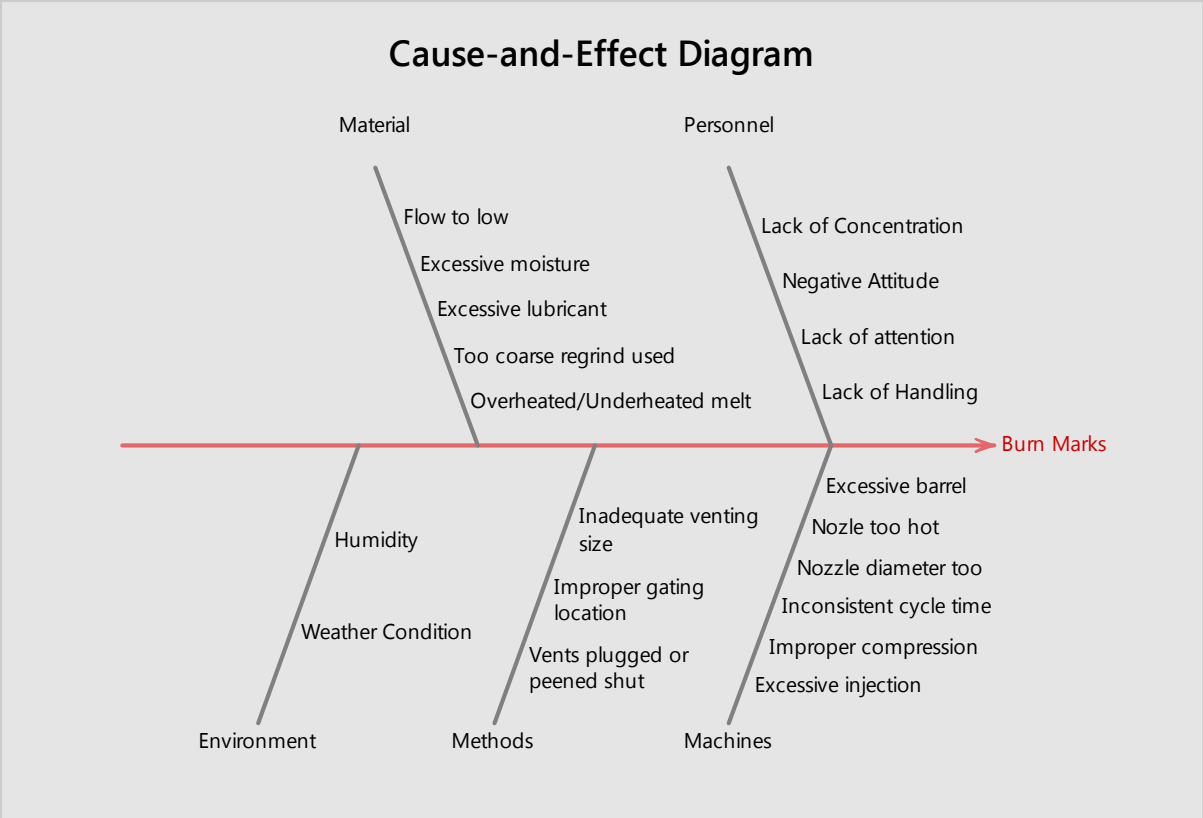

Fig. 7: Cause & effect diagram of burn marks defects

Root Cause: Too high injection speed, residence time or melt temperature.

Possible Solutions

- MaterialCheck for any contamination or air trap.
- Decrease the melt temperature.
- Decrease the overall cycle time of injection.
- Purge and/or clean the screw and barrel.
- Decrease the screw speed because high screw speeds may cause the material to degrade.
- Decrease drying time/temperature as per the drying instructions provided by thematerial supplier.
- Use more thermally stable material.
- Alignment between the nozzle and mould sprue is correct.
- The shot size might be too small for the machine. It might be necessary to move the mould to a machine with less injection capacity.
-

4.2.3 Rubber Crack

Cracking can be appeared as fracture or surface breakage in the material of a moulded part.

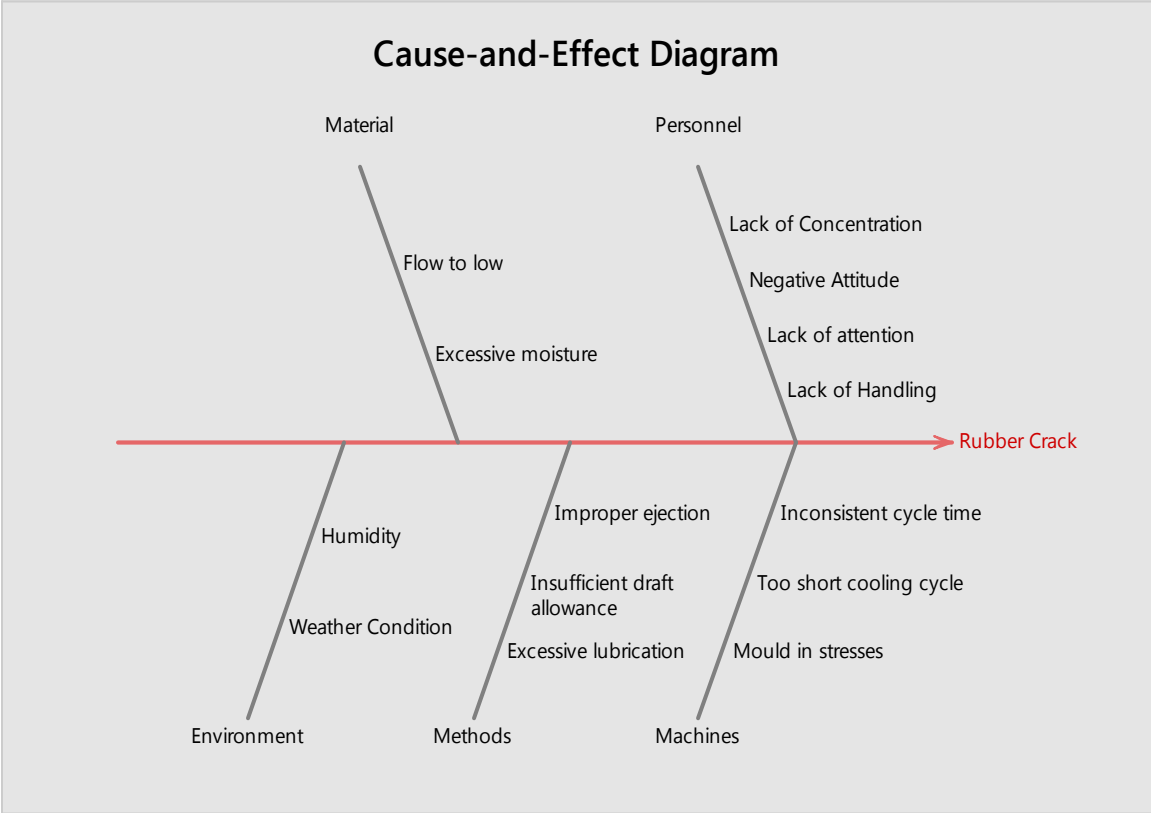

Fig. 8: Cause & effect diagram of Rubber crack defects

Root Cause: Cracking is caused due to high internal moulded in stress. They can be brought by a contrary external substance being applied to the finished parts.

Possible Solutions

- Decrease injection pressure.
- Used dry material.
- Increase cylinder temperature.
- Increase mould temperature.
- Increase nozzle temperature.
- Injection speeds modify.
- Material might be partially crystalline to reduce the mould and/or melt temperature.
- Material might be amorphous to increase the mould and/or melt temperature.
- Minimize differential shrinkage.

4.2.4 Loose Bond

Rubber is not proper bonding with metal part and improper sticking of the surface.

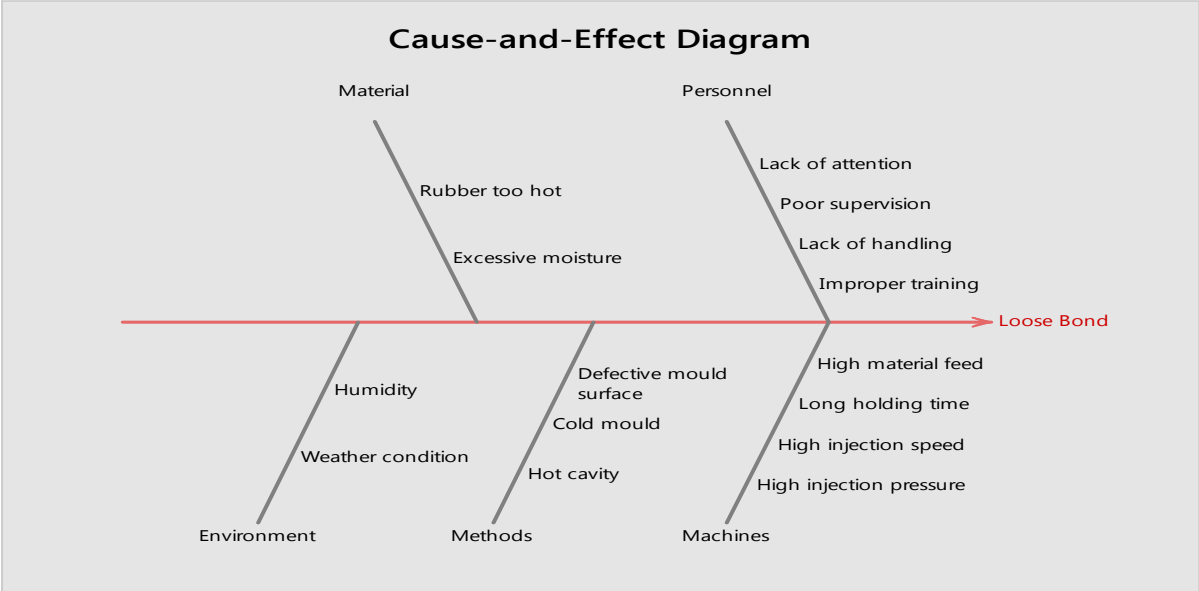

Fig. 9: Cause & effect diagram of loose bond defects

Root Cause: Screw of injection pressure too high.

Possible Solutions

- Confirm cycle time for cooling
- Reduce injection pressure
- Reduce injection hold time
- Reduce injection speed
- Reduce injection time
- Adjust feed
- Inspect mould finish
- Increase mould opening cycle
- Lower mould temperature
- Adjust differential temperatures
- Inspect for appropriate mould release

V. Results &Conclusions

Quality control tools are used to identify and evaluate different defects and their causes ofoccurrences which are responsible for rejection of components at different stages of rubber injection moulding process.This paper presents the utilization of QC tools in rubber moulding industry to enhancethe quality of vibration isolator parts. According to the Pareto analysis, the injection moulding process of rubber vital few defects are: Blister, Burn marks, Rubber crack and loose bond responsible for 73.4% of the total defects. According to the cause & effect diagram, root cause was identified for these defects and possible solutions are suggested in order to decrease the defects to minimize the rejection of the parts. After implementation of QC tools in selected manufacturing unit rejection of rubber to metal defects are highly reduced. Cause & effect diagram is useful to distinguishthe irregularitiespresentin the process as unnecessary variations of process, yet they can't demonstrate the reasons for the inconsistencies. Pareto analysis is used as important quality control tool for identification of the most significant defects by giving priority of their occurrences. It is worth noting that this method totally eliminate the less significant defects and does not clarify the sudden conduct of thesedefects.

It is essential to further analysis on various other defects which are less frequent but it will impact on the improvement of quality and of parts in this specific manufacturing area.This study proves that withan effective implementation of quality control tools, it is possible to control the rejection of rubber injection moulding process defects.

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