An investigation into the synergy of the root cause analysis and Poka Yoke at suppliers of Toyota South Africa Manufacturing (TSAM) and a cable manufacturing company in South Africa.

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Abstract

The study revealed that the companies that supplies TSAM has well-established R&D department that work with the Individual Quality sections to improve productivity by eliminating defects. Both companies aim at preventing defects from passing to the customer if identified in the manufacturing plant. Customer identified defects are studied by the R&D team to improve productivity and corrected once and for all. The study looked at the 5Ms namely Method, Material, Manpower, Machine and Mother nature. The root causes of defects in material, process, operator, and equipment were mitigated using the 5WHY approach. The study revealed that the defects caused by materials is the highest in the sample taken and mother nature also played a significant role due to the covid 19 pandemic.

Key words

Lean, Poka yoke, 5WHY, 5S, mitigation.

1. Introduction

There are many factors that affect the success of implementing the Poka Yoke (PY) in Lean manufacturing (LM). These issues are ranging from executive through management, cultural, implementation to technical issues. The section is considering mainly the Technical issues in the implementation of PY and its dependency on other LM tools.
PY is widely described as an inadvertent error prevention tool that helps employees avoid mistakes. An error is a human nature, a defect is not and often happening undetected when workers shift attention. PY's goal is to give due respect to employee efforts by deciding on the repetitive tasks where errors can occur. Shigo Shingo was quoted as saying "We are trying to prevent the act of forgetting what we have forgotten." Parts that are in one group should be marked with features that distinguish them from the rest to prevent a mistake.

Two Poka Yoka systems are used in manufacturing and service industry. These are the Attention and the Preventive PYs. They can be used in isolation or combined depending on the company policy.

The Attention PY checks the process parameters and when they go outside the limits. In this case the machine gives a signal and stops the process from making defects. The machine will not run unless the parameter error is corrected hence it prevents any error to be taken to the next operation.

The Preventive PY have warning and control systems that are executed using three primary methods. The first is the contact method which uses fool proof pins or blocks that do not allow parts to be seated in the wrong position prior to processing. The second is the counting method that counts number of parts that are mounted on the main body, if there are left overs it means the job is incomplete. The third is the motion sequence that uses sensors which detect if all motions have occurred in the correct sequence, if the machine stops and gives a signal. This ensures you get it right the first time.

2. Literature Survey

The literature is used as a guideline of methodologies that has been used to compile the interview and questionnaire schedules sent to local supplies of TSAM. TSAM is based in the Port of Durban in Prospection in the South Coast industrial site. The supplies of TSAM are located from a few meters to hundreds of kilometres.

(Parhizkar et al., 2014) study used the sigma infallibility that ranged from 4 to 5 whilst the % improvement ranged between 300 to 689% in some sections. Unlike other traditional control methods, infallibility (Poka Yoke) is not an after production method, rather this technique is employed during the production process to prevent errors and failure from the beginning to prevent production of any defective product

(Zhang, 2014) showed how PY can be used for a quick adjustment and correction of the process when an error is about to occur using an attention tool. If no one attends to it, it will stop until it has been corrected (autonomation). The concept is based on the method of Engineering Design (ED) and Information Systems Management (ISM). The ED triggers a switch that passes information to the reader and the screen shows an attention (orange) light first. If no attention is taken within a set time a red light shows and the operation stops. These are widely used in manufacturing business operations and has contributed to the successful practices of Poka-Yoke.

The tool ensures that parts are produced with zero waste. The strategy eliminates defective parts and cost of establishing an inspection department. IMS provides imminent feedback on every part that is produced in the factory by inspection at each stage using the machine not humans. In the IMS system, the operator just waits to receive the signal which he will be checking from time to time thus simplifying implementation and attracting support from management.

(Niranjan and Sharma, 2015) the success of Poka Yoke depends on many factors, among them is the ability to detect an error. When the error is detectable then a preventive solution can be designed so that the error cannot be repeated. Normally an error pops up several times the solution is just temporal and the root cause is not yet established. The error should be traceable to the source to remove the root cause. When the root cause is established the team of engineers then develop and implement the safe procedure.

(Kurhade, 2015) analysed a case study on a punching machine in India and obtained improved productivity, achieved zero PPM defects, eliminated rework and avoided all mistakes. The Poka Yoke principle improves the defects by taking action before a defect is made. He concluded that its success does not only depend on the talent but also on the capital investment on intelligent equipment that detect a fault on the onset.

(Che-Ani et al., 2017)'s paper used the quality tools such as Pareto and Ishikawa diagram to obtain the possible root causes of the quality issue and solving the issue by PY concept. The study was carried on a vehicle assembly plant where they enumerated defects. The defects were classified as broken (35%), bend (30%), trip loose (10%), bolt broken (5%), scratch (5%), crack (5%), wrinkle (5%) and others (5%). They then plotted a Pareto curve using these values. For improvement they used the root cause analysis and successfully eliminated the defects. The root causes determined were mainly as a result of human error in the method used. The solution was to set up preventing and warning PYs counter loss of attention by the operator.

(Diego et al., 2018) initiated a case study that was enhanced by the fixation of the front stabilizer bar in the suspension, where the loose screws were caught by the quality inspectors. The task was to identify and eliminate the root cause of failure using the 5WHYs analysis. PY was applied to check if fixings have not been carried out. If the worker skips any of the fastening steps and simply releases the release button, the whole production would stop and signal the operator and person in charge of production that there is a problem. The PY system installed that it does not affect both the company's profit and image in the market place. The use of 5WHYs and installation of an anti-failure system that senses an error made PY successful.

(Sarai, Hosana and Sarai, 2018) evaluated the impact of using computerized Poka Yoke by Zimbabwe Petroleum industry from the point of loading, to transportation, to offloading, storage and selling of these products to customer. The trio used the Pareto curve and root cause analysis to successfully apply the PY.

(Lazarevic et al., 2019) in the reviews identified five PY devices that can be used in a manufacturing factory. The first is the passive devices (PPY) that is used to warn about possible error during the process but cannot stop the error because it does not have electro-mechanical reaction within it.

3. Methodology

A work study on the production line of two companies was conducted with a check list to determine the targeted production per shift and its outcomes. The outcome would reveal the correct products and defects produced. Statistics of these were obtained from the quality and the research and development which were analysing the defects to obtain the root cause. Defects were caused by 5pillars of manufacturing namely:

i. The process (Method)
ii. The operator (Manpower)
iii. The equipment (Machine)
iv. Consumables (Materials)
v. Environment (Mother nature)

The 5WHY mitigation was done on each pillar and defect to determine the root cause in each production work centre using the table 3. Each of the 5Ms was mitigated using the guidelines in the table. The 5th M is mother nature which is about the environment and natural happenings. During the period of study, the covid 19 pandemic became the most influential mother nature. It affected each pillar in one way or the other resulting in many defects being made in car parts.

Table chapter 3.0 The 5WHY mitigation process at TSAM suppliers

	Sheathing	Injection Moulding	Metal bending	Wire drawing
Materials (Tools & consumables)	Storage Packaging Transportation Feed stock Contamination Hopper level	Out of specification Blending & mixing Stiffeners additives Product & colour change Inaccurate inventories Late material from suppliers Contamination of raw materials	Mechanical properties (Malleability Ductility) Metallurgical Properties (Steel grade) Primary forming defects (gas holes, non-metallic inclusions	WHY? Mechanical properties (Malleability Ductility) Metallurgical Properties (Al grade) Primary forming defects (gas holes, non-metallic inclusions

Operator	Experience Supervision Consistence Between shifts Unnecessary movement Lack of communication from client and supplier.	Not trained Fatigue Operator distraction Cycle setting-time Fluctuating mental stress Unexpected absenteeism Lack of back up	Sick children Lack of communication from client Operator attitudes No SOP Management & QC not agree/ collaborating Carelessness Behaviour	Was the rod over-stretched Worker Fatigue Overlapping tasks Lever too hard Multiple tasks- lockdown Personality Conversancy
Equipment	Wrong diameter of nozzle. Emergency repairs Gauges not calibrated or zeroed	Screw design Extruder barrel Nozzle design Mould design Machine control Clamp design Instrument Environment Overheating Cooling power Heating power Injection & ejection	Worn out tools Wrong size fasteners Gauges not calibrated or zeroed. Wrong gauge used Jam Over current Return spring faulty Dirty equipment	Speed? Tool geometry? F_D = Drawing force? Maintenance (Lubrication/ cooled) Machine settings Worn out dies
Process	Instructions not clear? Instructions not followed?	Injection speed Boost pressure Hold pressure Hold time Cycle time Precision Accuracy Die closing	Lack of SOP Process speed Temperature Maintenance Inspection Flow rate too low Engineering	Die inserted properly Work inserted properly Drawing speed correct Correct temperature Feed rate correct
Mother nature Environment	Unplanned Power cuts Load shedding Dim lighting Constant alarms Covid 19 Pandemic	Dust Unwanted material stuck in the machine. Low quality raw materials Noisy co-workers Lighting dull	Dirty environment	

4. Findings

Most of the Jigs for automotive parts were designed and manufactured in China by a supplier. The equipment has to be modified to prevent defects. Some of these jigs would not fit properly to clamp or guide the tools in the plant and required some modifications to suit the design for manufacture process. When the jigs and fixtures are modified at the TSAM supplier this is communicated to TSAM and the assembly line may need to be modified. However, for tools that are fitted by the supplier such as the wheel jack, wheel spanner this may not be necessary. Redesigning the dies to suit the process parameters at the manufacturing plant. The 5th M played a role because no international travel was permitted during the study period and all collaboration was being done online.

The process if not organised according to each step may cause defects especially in plastic moulding. A cable manufacturing plant that sheaths the cables with plastic of different colours loses a lot of plastic material if the sheathing process is not controlled properly. Piles of defective plastic is placed in the Red tag area before disposed as waste. The process is not fully automated and does not have Jidoka sensors so when a defect starts it may be noticed after the plastic has been wasted.

Fig 1. Plastic coating/sheathing defects

Figure 1 is showing some defects which were a result of the process temperatures and sheathing speed that were higher and the plastic coating material did not set properly. The material is Red tagged in the local area before disposed to waste yard a recycling company sorts and collect for further processing.

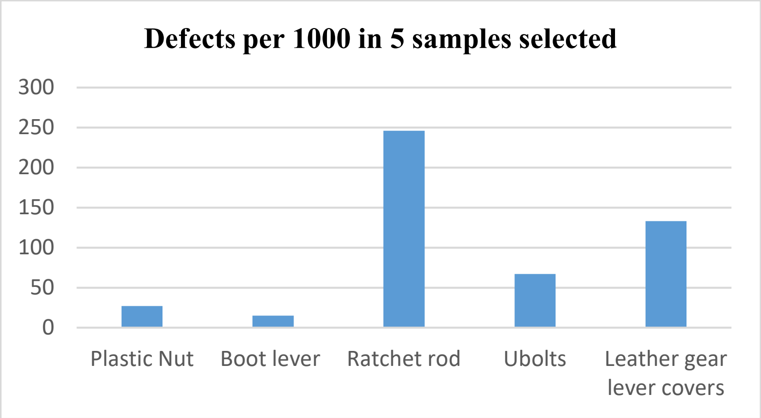
An injection moulding process is used the production of a plastic wheel nut. A common process defect experienced in this section are gas pockets in plastic nuts for the wheel spanner. The process engineers analysed the weak nuts and found gas pockets which makes the nut weak. Such nuts should not reach the customer but corrected before fitting. Injection moulding process has to analysed and cause of gas leaks into the material eliminated. The company also manufactures products for VW and ford in which the colour of the plastic diffentiates the wheel spanner nut. During the changeover of dies and materials purging of excess materials should be thorough so that the colours do not mix (TSAM-Grey, and VW -white). The injection process, dies, temperatures, injection rate, cycle times are modified to reduce air pockets in the nut.

Process bottlenecks requires cross-training of workers to reduce setup times and improve maintenance practice. The Manpower is allocated continuous improvement tasks in areas of specialization and interest where they are trained frequently to empower them with the ability to make changes. Operators are empowered to do some maintenance and adjustments that removes the bottleneck. Scheduled maintenance is done by specialised teams after consulting with operators and cross teams so that the correct maintenance is done according to plan.

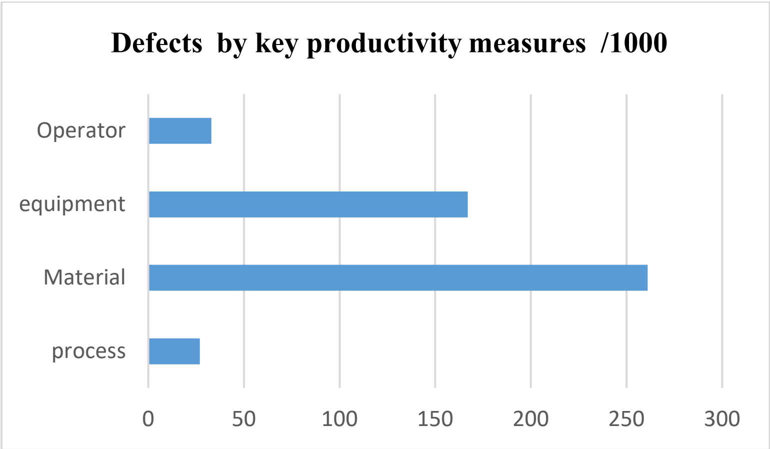
Materials can cause defects if not manufactured to customer specifications. The Ratchet spanner handle was found to crack in large numbers during bending operations and the findings were attributed to the material used to make the handle. The supplier was tasked to analyse both material and processes used to make the materials. The chemical and heat treatments required were also to be analysed. The Metallurgical Grain orientation of the materials is to be checked and possibly changed to allow bending across grain instead of a long grain. The car boot opening levers were fracturing during bending and were analysed in the same way as highlighted in the diagram.

Fig 2. Defects caused by materials in manufacturing in South Africa

At one company that manufactures steel, Cu and Al cables by wire drawing and coat the wires with plastic, Al rods supplied from India were not meeting the tensile strength required by breaking during drawing operations. The eleven (11) rolls received from a vender in India were fracturing during drawing. The tensile forces at breaking point was lower than the drawing force. Al rods breaking were returned to supplier in India after the tensile strength was found to be below required. Collaboration with supplier critical before supplier ships materials. Material (Mild steel) improvement to reduce cracking during metal forming. Stress relieving, annealing the materials before its delivered from China and ensure that the supplier adheres to required specifications.



More than 20 products are manufactured by the company and I sampled 5 products in the production line to analyse the defects per thousand pieces. These products are made from plastic, metals and leather.



More than 50% and 35 % of defects are caused by material properties and the equipment used**.** The materials are largely supplied by companies abroad that collaborate with the manufacturer.

The Al alloy used was breaking during wire drawing at drawing forces that are less than the tensile force applied when the cables are in service. Worse still some of the cables are not used as conductors but mine hoist cables.

The equipment namely the tools and dies are manufactured by the tool makers at the manufacturing company or subcontracted. Due the recession both companies have retrenched most of the tool makers and are subcontracting major jobs.

Fig 3. Tool defects in Pipe bending

The defects caused by the operator are 8 %. This is attributed again to the multiple tasks that the operators have at both companies.

The Process accounts for 7% of the defects in the plastic moulders. This is caused by poor setting of dies, punches, pressures, velocity with respect to the material dimensional parameters. For sheet bending and injection moulding the process pressure and temperature should correspond to the thickness and ductility of the material to reduce defects. The rate at which the process occurs is dependent on the process temperature ductility and speed.

Fig 4. Combined defects from Lean manufacturing companies in South Africa.

5. Discussions

It is unusual to have such a number of defects but mother nature by the covid 19 pandemic has changed the productivity. Many production units in the plant which are not essential have shut down and the employees have been retrenched to meet the fall in demand of new vehicles. The remaining workers are overlapping and do multiple tasks in the plant. The company had started manufacturing hand sanitising equipment for the community it serves.

The defects caused by materials is attributed to the materials ordered from oversea like China and India which were adversely affected by covid 19. Due travel restrictions collaborating face to face with supplier is limited. The materials used in plant then contribute to most defects. The R&D departments were not affected and the staff is even busier than before because of the defects that are accumulating. The material vendor who can collaborate with the user is often chosen so that the raw materials supplied have the correct physical, mechanical, metallurgical and chemical properties at the right time. The material handling and storage system should protect the material from chemical and mechanical damage by incorporating the 5S principle to enable a safe working and storage environment for the materials and tools. Some of the materials manufactured during the covid 19 pandemic period do not meet specifications due to change of staff, supplier and so on.

For manpower training is critical to improves and develop new skills in machine settings. Man-hours and task allocation is adjusted to avoid fatigue on staff. In the study manpower was overwhelmed by tasks due to staff shortage emanating from the effect of the pandemic. Skilled personnel are not present all the time because they are quarantined when they contract covid 19. SOPs are put in place so that the machine is safe to run without failure and ensure zero rejects. Parameters such as pressure, temperature, velocity, rate of doing work, cooling and heating rate, holding times and so on. When the SOP are followed less defects are caused by the process.

Machine problems call for a proper maintenance plan to service and bring the equipment up. The speeds, loading and feed rate are determined and maintained to keep the machine running. Sound alarms, Andon lights are used to detect if the machine is overloaded or speed is above normal. This also rapes in Jidoka sensors which stops the machine just before a defect is made. An active PY is ideal to prevent the manufacture of defects in the line. The study revealed that most suppliers of TSAM have the passive PY which allows a mistake to happen. These do not have Andon lights to sense and detect the error on the onset.

The companies need to invest in the active Poka Yoke electronic system that detects the defects before it occurs and prevent producing rejects. All the companies have devices that detect the errors but do not use the Andon lights system that stop the machine. The defects are passed to the local quality check where they are detected. This is a loss to the organization even though they dispose most materials to recycling companies. The root cause models designed will help develop error proofing systems that will be incorporated to the equipment to prevent defects from occurring at the source.

5.1 The Root cause analysis Framework

The failure to apply PY successfully does not need just an apology to the stake holders, but needs a corrective plan to be developed with the full participation of stake holders. TSAM involve stake holders in any lean tool development and also train staff from suppliers. TSAM listens to the customer and supplier, any defect identified by customer is analysed by team from supplier and manufacturer to find the root cause. The solution will involve establishing enough security on the machine to detect the problem on the onset so that the machine will send a proper signal.

Traditional manufacturers normally mark "As it is" and "No returns" tags on products which are forever under promotion. Manufacturers and suppliers of TSAM in SA do not have such banners and have empathy to the customer.

5.1.1 Injection moulding

For plastic parts such as bolts, bushings and caps for engine and door fitting the injection moulding process is used widely to produce similar products for different customers. They differentiate some products by size and colour. During changeover from one customer (say VW) to the next (say Toyota) purging of the injection moulding machine is done to change the material by colour. The Hiejunka levelling principle is applied on the same machine and work centre.

Many defects are made in this section due method, machine, material, and manpower. The model in figure 5.1.1 shows the causes of defects in the plastic moulding processes depicted by arrows pointing to the left and the possible solutions pointing to the right. A Poke Yoke system will detect the problem on the onset and prevent the defect from occurring. If purging is not done or not done properly the system should indicate and disallow the machine to proceed with process as an error proofing measureInjection moulding is used manufacturing plastic components for the car. Figure 5.1.1 was constructed using the defects on the plastic nut that is produced by injection moulding.

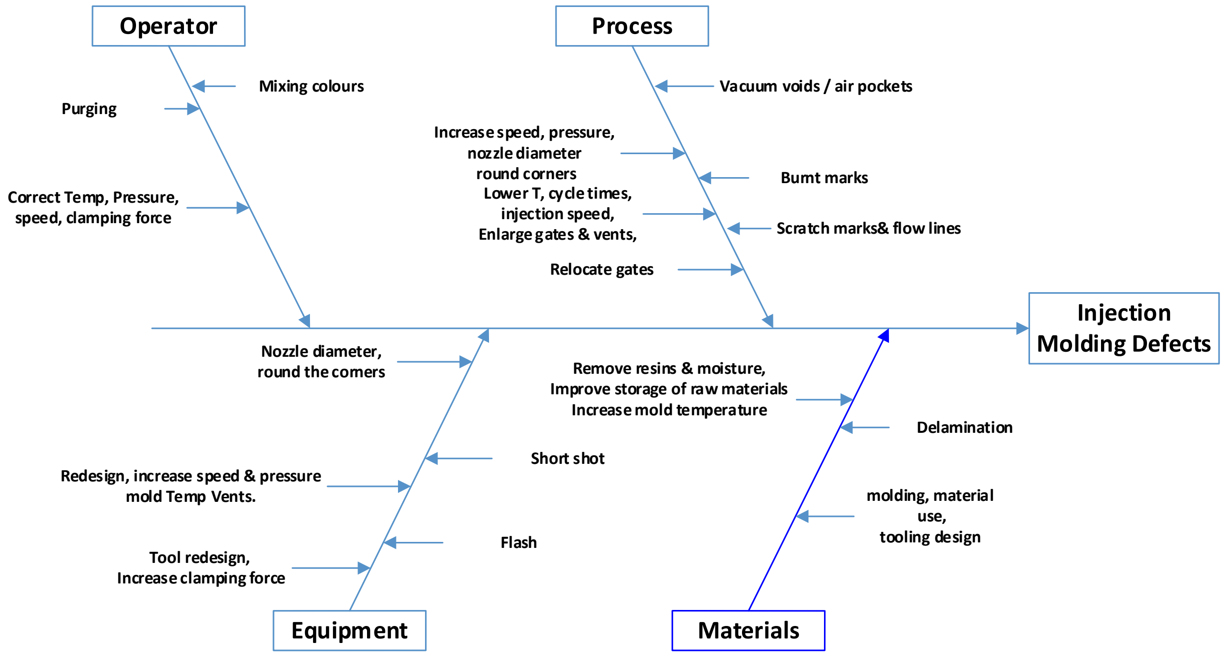


Fig 5.1.1. Root cause model for injection moulding

5.1.2 Pipe bending

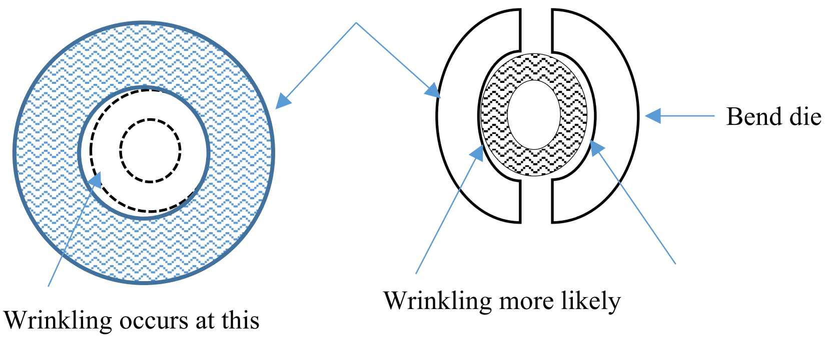


Fig.5.1.2 Pressure Dies in pipe bending

Fig.5.1.2 shows a wrinkling behaviour of a thin and thick walled tube. Thin tubes almost collapse and the wrinkle is for the whole thickness on the inside top and bottom. Thick walled tubes wrinkle only at the surface in the inside. If a sheet is likely to wrinkle due to a large gap between thin tube and mandrel the system should pick it up and signal the gap is greater than required.

Setting up of tools for thick walled tubes is less cumbersome to experienced operators, but for thin walled tubes it more challenging for setting up for small bending radius ratio $R/D \leq 2$ and large diameter $D/t \geq 2$. Thin walled tubes reveal an adverse wrinkling behaviour if these contact conditions are followed.

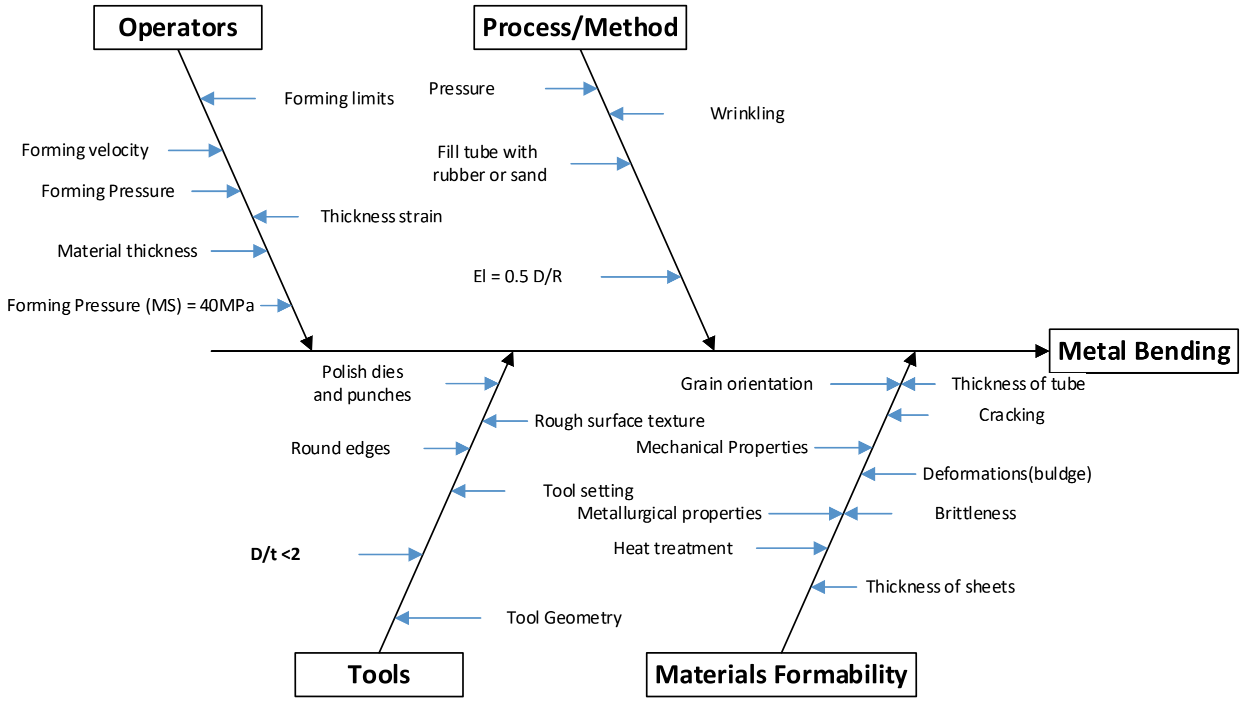


Fig 5.1.2 Root Cause model framework for square tube bending

The magnitude of wrinkling is high where the dies are not in contact with the metal. The tube wall is in contact with the mandrel or bending sand or rubber to minimise wrinkling. This framework applies to fig 5.12 where square tube bending is done.

6. Conclusions

In LM, management intervenes and acknowledge any defect in their products. The source of the defect is identified and analysed so that the team can start to develop the corrective measures. All staff in the section is given a chance to explain his ideas in brain storming until a proper solution has been obtained. Rather than blame the specific staff members whose work did not meet the expected outcomes they do the Poka Yoke process. A defect at TSAM is the starting point for improvement. Exceptional treatment is given to all sections where customers have issues and respect the customers' demands.

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