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BEng (Hons) Engineering Portfolio

L4 – Quality and Business Improvements

Quality Tools and Root Cause Analysis

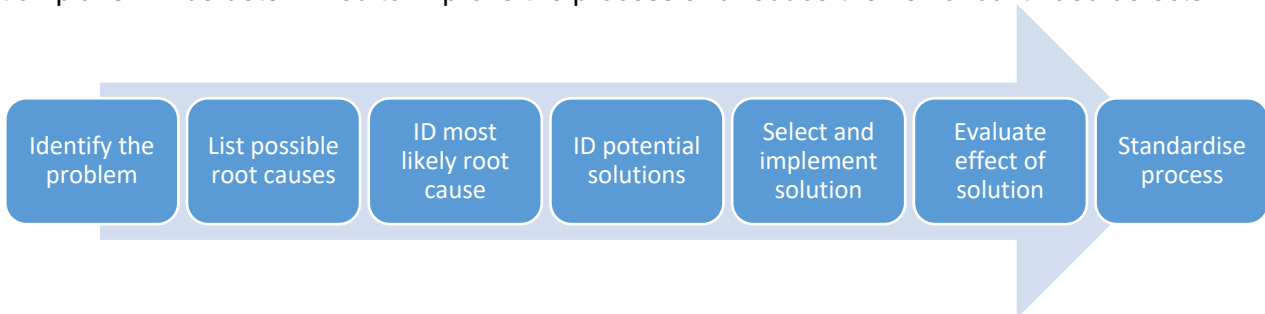
Assignment 1

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Introduction

The aim of this investigation is to understand why specific defects occur during the manufacture of a pillar drill base at a foundry. The two Operations consist of Sand-casting and Machine Milling/ Drilling. By collecting data on the types of defects and following the seven step problem solving model, corrective action plans will be determined to improve the process and reduce the risk of continued defects.

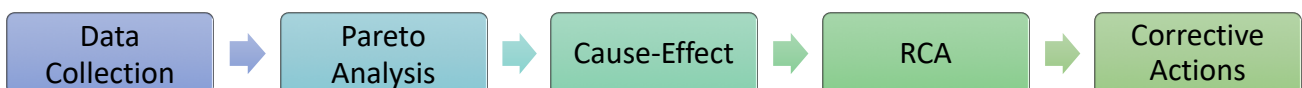


For the purpose of this investigation the following assumptions have been taken:

- All workers are on the same shift pattern which runs from 7am to 3pm Monday to Saturday.
- The workers are aged between 18 and 65.
- The pillar drill base has been manufactured from Cast Iron – This assumption was made through researching pillar drills on the market and the most common material used for the base.
- There is no skills matrix and no standard operating procedures in place.
- Quality inspections are undertaken at each Operation, 1 and 2.
- The company has a basic training system for new starters.
- The target number of units for the week is 1000 (167 per day).
- The type of casting at the foundry is Green-sand moulding.

Action Plan

As data has already been collected for the defects of the two operations, the next steps will be to analyse the data further, using the following quality tools; Pareto Analysis, Scatter diagram, Fishbone diagram and RCA functions. The resulting data will be evaluated to identify prioritised defects, cause and effects of these defects, potential solutions and corrective actions.



Equipment	Worker	Monday		Tuesday		Wednesday		Thursday		Friday		Saturday	
		am	pm	am	pm	am	pm	am	pm	am	pm	am	pm
Operation 1 (Sand Casting)	A	00X•	0X	000	0XX	000XX X•	0000XX X	0000XXX••	0XX	0000	00	0	XX•
	B	0XX•	000XX0	000000 XX	000XX	000000 XX••	000000 X•	00000X	000X••	00XX•	000000	00X	000•X00
Operation 2 (Machining Milling/ Drilling)	C	00X	0X	00	•	0000	000000 X	00	0•	00♦	00□	♦0	□0
	D	00X	0X	00	000•	000••	00000X	0•0	00♦	00♦♦□	0••	□00X	XX0
Legend: 0 Surface Finish		• Defective Finish		X Blow Hole		• Improper Shape		□ Others					

Table 1. Data collection of defects from two operations at casting foundry.

Pareto Analysis

The data collected has been set into numerical order by number of errors as seen in *Table 2* and then put into a cumulative frequency table (2.2). Using the Pareto diagram in Figure 1 and 80/20 rule, we can see that by prioritising our efforts into finding the causes of Surface Finish and Blow Holes, we can make an improvement on 80% of the defects.

Defects from sand-casting and Machining

Defect Type	Number of Errors
Surface Finish	124
Blow Hole	43
Improper Shape	20
Others	7
Defective Finishing	5

Table 2. Defective date in numerical order.

Defect Type	Number of Errors	Cumulative Frequency	Cumulative Percentage
Surface Finish	124	124	62.94%
Blow Hole	43	167	84.77%
Improper Shape	20	187	94.92%
Others	6	193	97.97%
Defective Finishing	4	197	100.00%
Total	197		

Table 2.1 Cumulative frequency table.

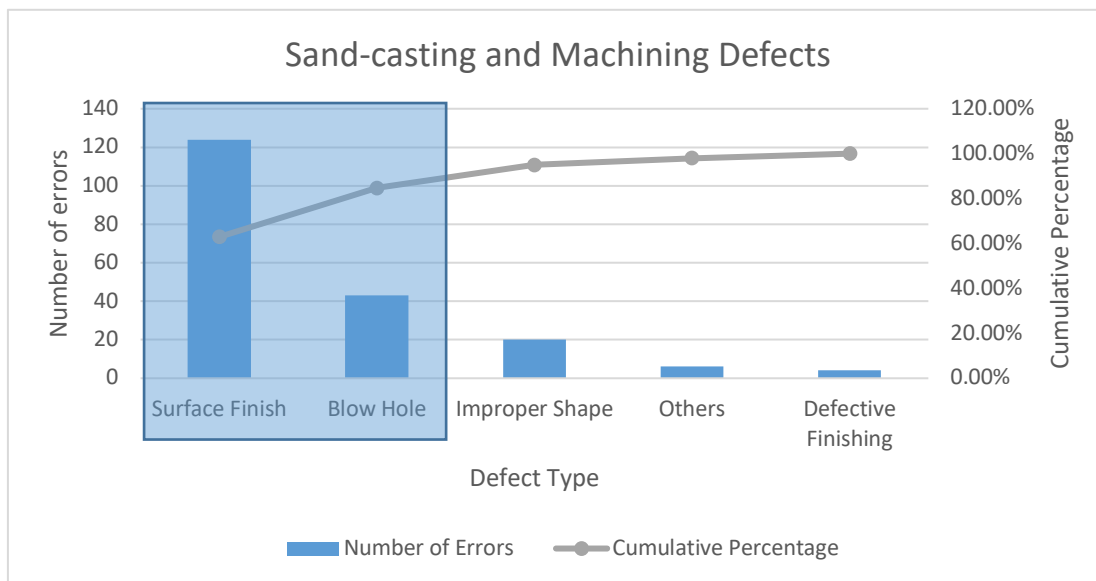


Figure 1. Pareto Diagram of sand-casting and machining defects.

Table 3 illustrates each worker and their number of defects through the week, broken down into mornings and afternoons. The reason for pursuing this information is to see if there is any correlation between workers and the time of day. What is clearly seen in Figure 2 and Table 4 is that there is no significant difference between mornings and afternoons, however, it is clear that worker B has a considerable amount of defects in relation to the other workers. In fact worker B has on average 12 defects per day equating to 7% of the daily target. This may be worth investigating later.

	A am	A pm	B am	B pm	C am	C pm	D am	D pm	Total	%
0 Surface Finish	17	9	22	26	13	11	13	13	124	62.9%
♦ Defective Finishing	0	0	0	0	2	0	3	1	6	3%
X Blow Hole	7	10	10	7	1	2	2	4	43	21.8%
● Improper Shape	4	1	4	4	0	2	2	3	20	10.2%
□ Others	0	0	0	0	0	2	2	0	4	2%
Total	28	20	36	37	16	17	22	21	197	100%

Table 3. Defect by worker and type broken down into AM and PM.

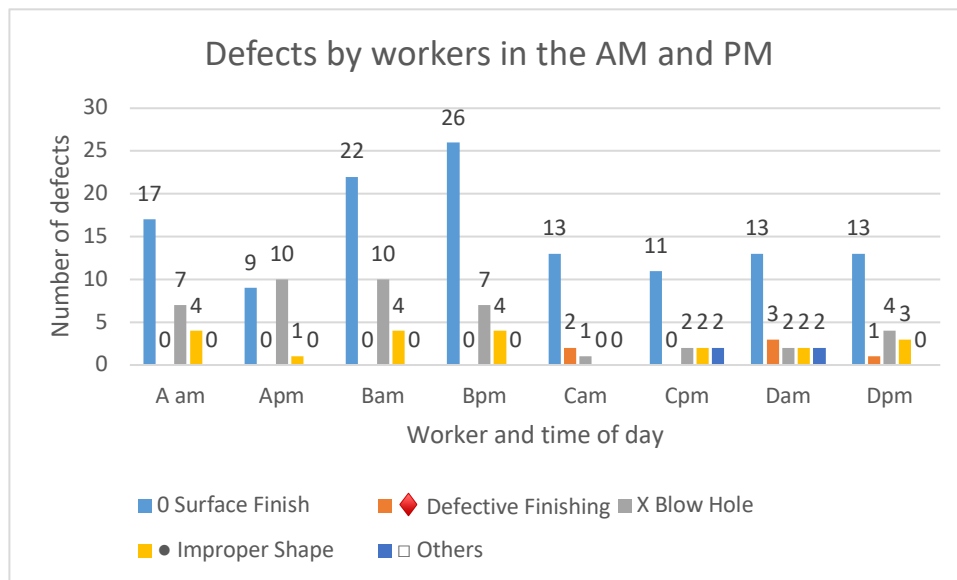


Figure 2. Bar chart shows type of defect by workers in the AM and PM.

	Total	% of Total defects	
AM	102	51.8%	No significant difference
PM	95	48.2%	
A	48	24.4%	High
B	73	37.1%	
C	33	16.8%	
D	43	21.8%	< 46 Defects higher
Casting	121	61.4%	
Machining	76	38.6%	

Table 4. Total defects by time of day, worker and area of operation.

Looking at Table 3, where workers A, B, C and D have been separated into defect types, we can see that workers C and D, who are machinists, have a total of 9 defects from Blow Holes. Research from Asia Quality Focus (AQF) reveals that blow holes appear below the surface of the material and only occur during the casting stage. This could indicate an inadequate inspection between the two operations. This may be worth investigating later. Table 4 also highlights that 61% of the defects occur during the casting stage, This number may increase after investigating the theory that some defects, such as Blow Holes, have passed onto the second operation.

The final analysis of this area has been completed by comparing the defect types by days of the week, we can see from Figure 3 that on a Wednesday the number of defects are considerably higher. This volume of defect totals to 32% of the Wednesdays total daily target.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
0 Surface Finish	14	20	37	20	20	13
♦ Defective Finishing	0	0	1	1	3	1
X Blow Hole	10	6	11	7	2	7
• Improper Shape	2	2	5	6	3	2
□ Others	0	0	0	0	2	2
Total	26	28	54	34	30	25

Table 5. Defect data by type and day of the week.

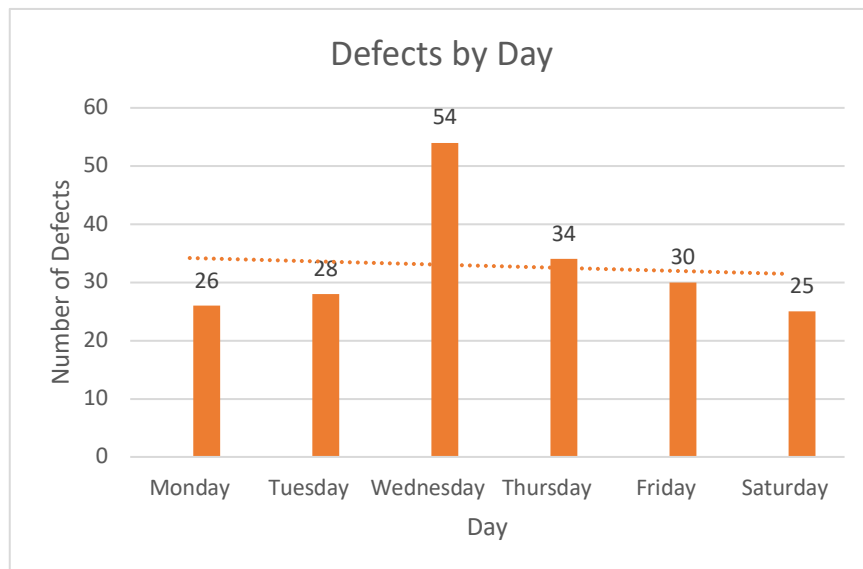


Figure 3. Number of defects by day of week.

This initial investigations have highlighted four things to investigate further at a later stage:

- 1) Prioritising the root causes of Surface Finish and Blow Hole defects will improve defects by 80%.
- 2) Worker B has a significantly higher defect rate.
- 3) Defects are much higher on Wednesdays and,
- 4) > 60% of the defects occur at the casting stage.

Table 6 along with Figures 4, 4.1, 4.2 and 4.3 all show no correlation between workers A, B, C and D and the days of their working week. Wednesday again highlights as a major defect day (5).

Equipment	Worker	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Total	Average Per Week
Operation 1 (Sand Casting)	A	6	6	14	12	6	4	48	8
	B	10	13	18	12	10	10	73	12
Operation 2 (Machining Milling/ Drilling)	C	5	3	11	4	6	4	33	6
	D	5	6	11	6	8	7	43	7

Table 6. Defects from workers and day of week.

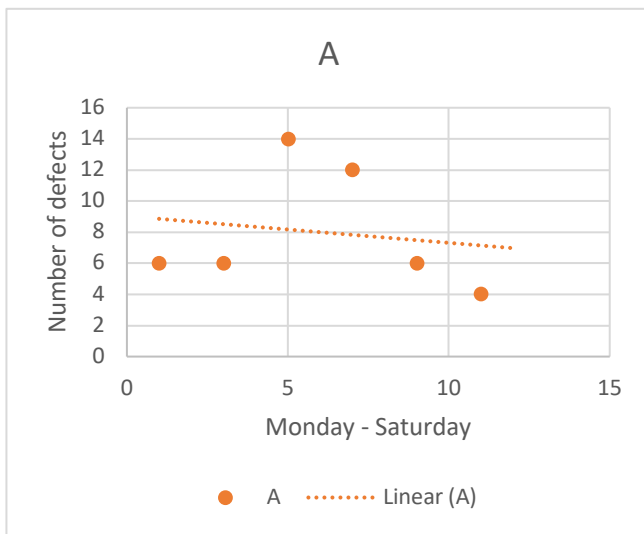


Figure 4. Scatter diagram of worker A.

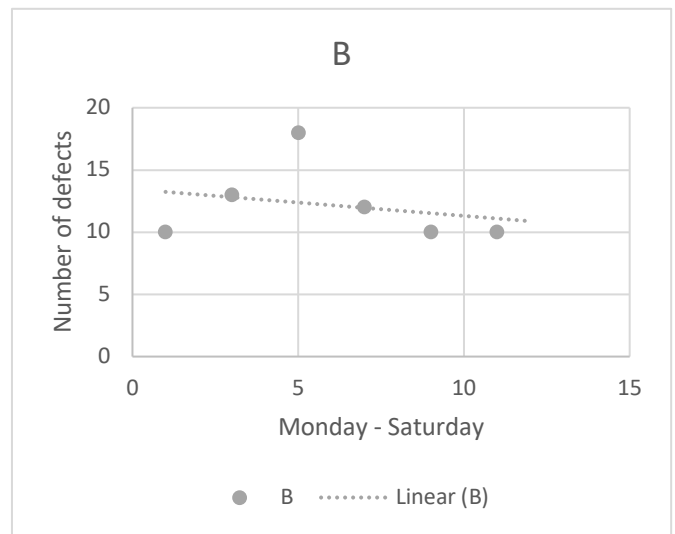


Figure 4.1. Scatter diagram of worker B.

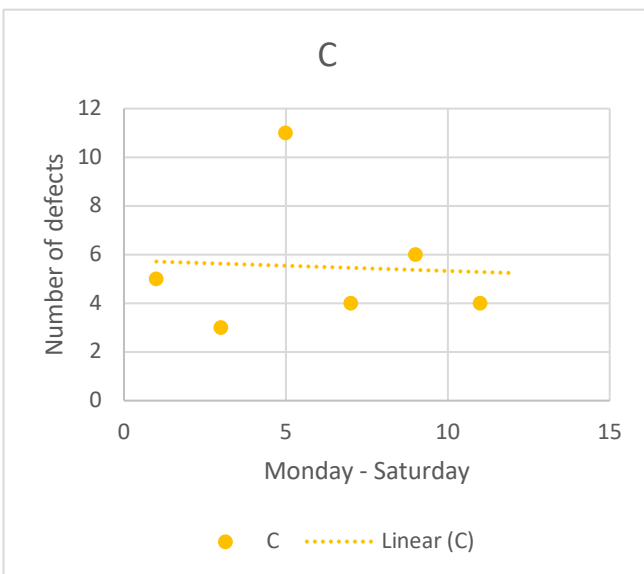


Figure 4.2. Scatter diagram of worker C.

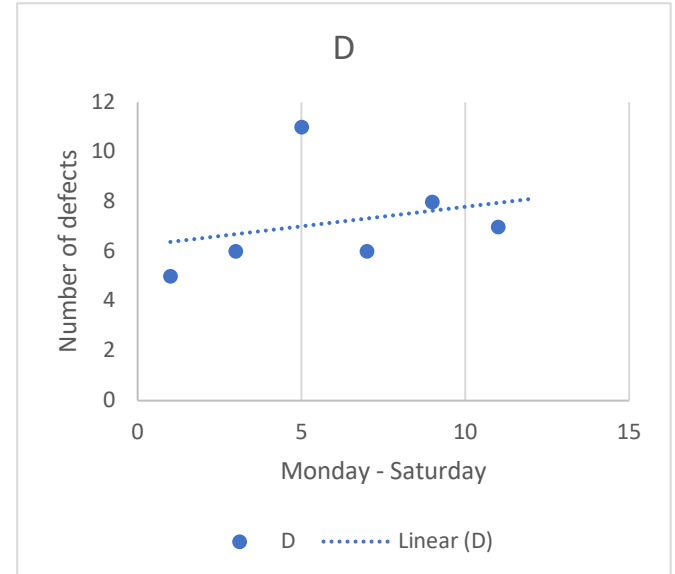


Figure 4.3. Scatter diagram of worker D.

Root Cause Analysis

Cause and Effects – Fishbone diagrams

Using a Fishbone diagram in Figures 4 and 5, we can gain an insight into some of the possible contributors of the prioritised defects, Surface Finish and Blow holes. A brainstorming exercise was held to determine possible causes and sub-causes for the two defects.

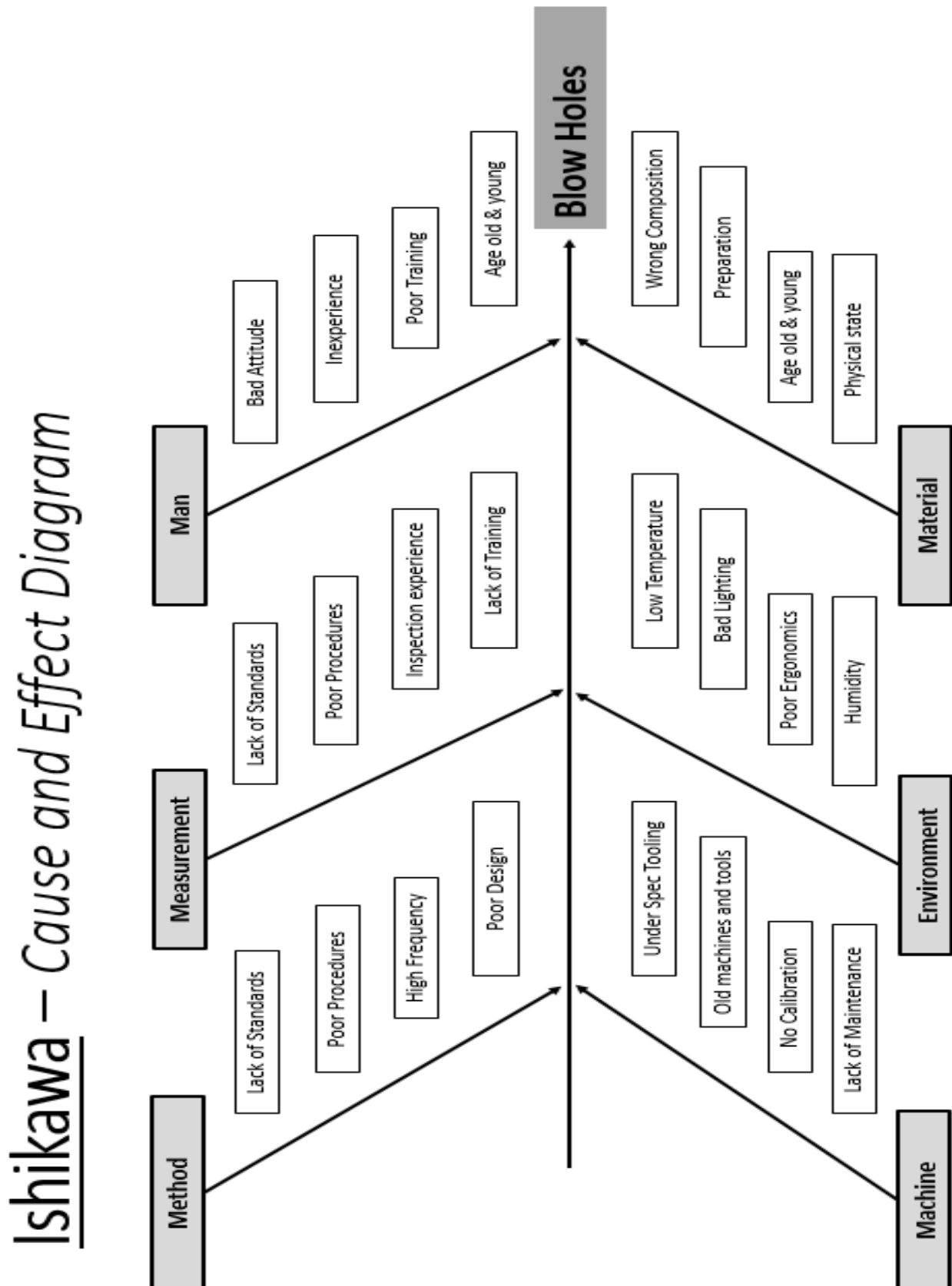


Figure 4. Fishbone diagram showing many causes of Blow Hole defects.

The Fishbone diagrams shown in *Figures 4 and 5* identifying possible causes for the 6 categories chosen. By prioritising these causes and using 5 whys the root causes should be made clear.

Ishikawa – Cause and Effect Diagram

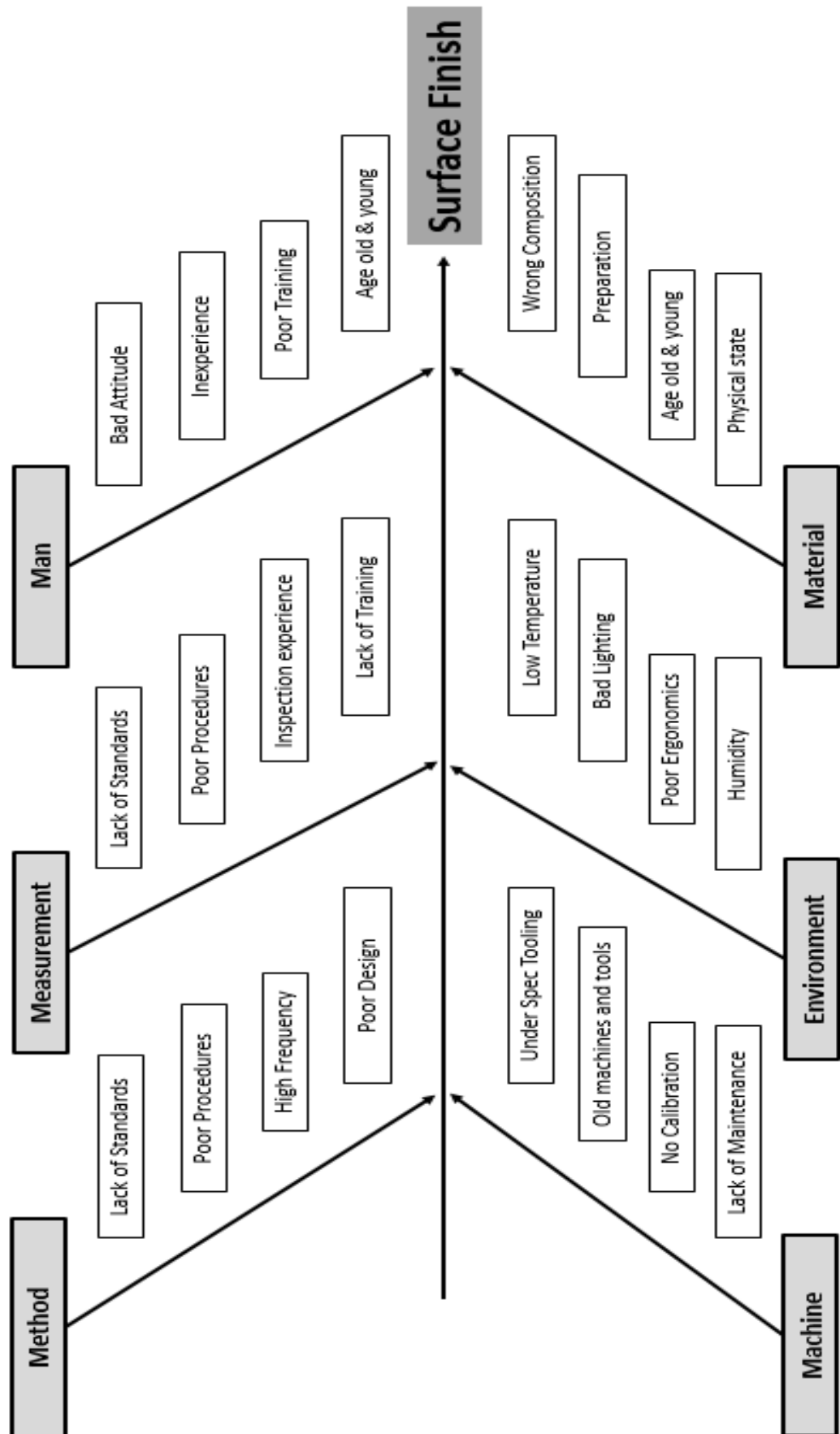


Figure 5. Fishbone diagram showing many causes of Surface Finish defects.

5 Whys

The following tables get to the root causes of the following questions:

- Why are Blow Holes occurring during sand-casting and machining?
- Why are Surface Finish defects occurring during sand-casting and machining?

Why are Blow Holes occurring during sand-casting? (1)

Why? (2)	Turbulent pouring of molten metal				Mould not adequately vented		Sand composition has low gas permeability		Bubbles forming in liquid metal	Temperature too low when pouring	
	Worker doesn't know how fast to pour	Worker cannot control the pouring			Vent too small to allow gasses and heat to escape	Mould has debris clogging vents	Incorrect materials used for purpose	Incorrect mix ratio	High gate speed	Temperature hasn't been reached before pouring	Cast is too far from furnace
Why? (3)	No Procedure in place	Worker fatigued			Design error	Poor maintenance	Poor design	The worker has mixed incorrectly	Gate deteriorated	Defective thermometer	Poor foundry layout
Why? (4)	No acknowledgement of procedure requirement	Age	Long working weeks	Physical ability/ medical condition	No DFMA took place	No maintenance schedule	First concept when foundry started	Basic training didn't cover sand composition	Lack of maintenance	No tool maintenance schedule	Layout not been considered

Figure 6. 5 Whys Blow holes occur during sand-casting.

Why are Blow Holes occurring during Machining? (1)

Why? (2)	Inspection are missing the defects below surface								
Why? (3)	They don't have the correct tools to check								
Why? (4)	Inspectors didn't know about different tools	Budget restraints							
Why? (5)	They have not received the proper training	Department targets							

Figure 6.1. 5Whys Blow Holes occur during Machining.

Why are Surface Finish defects occurring during Sand-Casting? (1)

Why? (2)	Poor expansion properties in sand		Course sand grain		Turbulent pouring of molten metal				Pouring temperature too high			
Why? (3)	Incorrect sand purchased	Sand untreated with combustible additives	Incorrect sand purchased	Incorrect sand requested	Worker doesn't know how fast to pour	Worker cannot control the pouring			Temperature has been exceeded before pouring	Worker error		
Why? (4)	Procurement error	Worker missed additives in mixing process	Procurement error	Design error	No Procedure in place	Worker fatigued			Defective thermometer	Lack of Experience	Bad Attitude	Lack of training
Why? (5)	Human error	Lack of training	Human error	No DFMA	No acknowledgement of procedure requirement	Age	Long working weeks	Physical ability/ medical condition	No tool maintenance schedule	New to role	Culture	No training schedule

Figure 6.2. 5 Whys Surface Finish defects occur during Sand-casting.

Why are Surface Finish defects occurring during Machining? (1)

Why? (2)	Blunt cutting tools		Lack of experience of worker	Poor lighting in foundry	Human error						
Why? (3)	No tool maintenance	Lack of consumables	New to role	Inadequate amount of lighting in area of work	Bad Attitude	Lack of Training	Worker fatigued			Lack of Experience	
Why? (4)	No maintenance schedule	Budget restraints	Position opened	No issues been raised before	Culture	No training schedule	Age	Long working weeks	Physical ability/ medical condition	New to role	
Why? (5)	No priority to create schedule	Department targets	Previous worker retired	Communication breakdown				Big targets to meet		Predecessor or retired	Expansion of employee in area

Figure 6.3. 5 Whys Surface Finish defects occur during Machining.

Figures 6 – 6.3 all reveal the potential root causes for each of the prioritised defects occurring from the two operations. From this analysis and that of the FMEA shown in Figure 7, it is of the authors opinion that *training*, *communication* and *standard processes* are the main factors for defects occurring.

This will be detailed in the final evaluation and recommendations for corrective and prioritised actions.

FAILURE MODE AND EFFECTS ANALYSIS												
Item:	Pillar Drill Base	Responsibility:	Production Manager	FMEA number:	1							
Model:	1	Prepared by:	Joshua Davies	Page:	1 of 1							
Core Team:	Process Improvement			FMEA Date (Orig)	01/04/2019	Rev:	1					
Process Function	Potential Failure Mode	Potential Effect(s) of Failure	Cause(s) Mechanism(s) of Failure	Current Process Controls	D e t e c t	R P N	Recommended Action(s)	Responsibility	Target Completion Date	Action Results		
										Actions Taken	S e v e r e	R P N
			No Standard Operating Procedure for task	None	10	1000	SOP to be created between production and quality for each operation.	Production and Quality manager	01/06/2019			0
Inspection of product prior to next operation	Product fails inspection	Part moves operation with un-identified defect	Lack of technical inspection equipment	Part is visually inspected by eye against an approved sample	9	378	Investment in non destructive testing equipment such as x-ray and ultrasonic.	Production manager and procurement	01/05/2019			
Machine surface and holes	Rough Finish defect	Surface Finish defect	Blunt cutting tool	Request new tooling through procurement when tools blunt	4	160	Procurement and production to discuss average tool life and create continuous purchase plan for consumable stock. Production to create Kanban in operational area for visual management and ease of access.	Procurement manager and production.	01/04/2019	Minimum order requirements set up each month for stock of cutting tools. Production have set up a cabinet with tooling along with tooling IDs near operational station.	10	30
			Employee fatigue	None	10	600	HR, management and production to discuss possibility of 5 day working week and/or hiring more staff to alleviate pressures.	HR, Production manager, Employees, Union (if applicable)	15/04/2019	Talks continuing with further meetings to follow.		0
			No Standard Operating Procedure for task	None	10	1000	SOP to be created between production and quality for each operation.	Production manager, Employees and quality manager	01/06/2019			0
Inspection of product prior to next operation	Product fails inspection	Part moves operation with un-identified defect	Lack of technical inspection equipment	Part is visually inspected by eye against an approved sample	9	378	Investment in non destructive testing equipment such as x-ray and ultrasonic.	Production manager and procurement	01/05/2019			0

Figure 7. FMEA of Pillar Drill Operations 1 and 2.

Evaluation of analysis:

1. There are 197 defects in total. This equates to 19.7% of the weeks' target output.
2. Surface Finish and Blow Hole defects together hold 84.77% of the total defects.
3. Worker B is responsible for >37% of total defects alone.
4. >61% of total defects occur during the sand-casting, Operation 1.
5. Most defects occur on a Wednesday at 32%. This is unexplained and will require further investigation.

Prioritised Action Plan

Worker B holds the highest amount of defect and is also part of operation 1, where the majority of defects occur. In Table 8, we can see that Worker B is responsible for 39% of defects relating to Surface Finish and Blow Holes. By prioritising on training and mentoring Worker B alone a difference of 39% improvement could be achieved.

	A am	Apm	Bam	Bpm
0 Surface Finish	17	9	22	26
♦ Defective Finishing	0	0	0	0
X Blow Hole	7	10	10	7
• Improper Shape	4	1	4	4
□ Others	0	0	0	0
	43	26%	65	39%
Total	28	20	36	37

Table 8. Worker B percentages of defects for Surface Finish and Blow Holes.

The following are recommended actions for immediate introduction:

Prioritised Actions				
Step	Actions	Comments	Target date	
1	Design Review of materials and mould.	The design is the initial influence on a finished product. If the design is clear and understandable, the manufacturing process becomes easier.	01/06/2019	
2	Worker B to receive full training within Operation 1. Competency assessments to be held at monthly intervals for the first six months and then 6 monthly.	Skills matrix, once produced to be reviewed every 6 months for initial year.	24/04/2019	
3	All tooling is to receive servicing followed by a weekly planned maintenance schedule for the casting moulds and milling/ drilling machines. This includes calibration of all tools on a quarterly basis, staggered as to not affect production and put a strain on workers time.	Shadow boards to be created for current and new tools.	01/05/2019	
4	Daily/ weekly 15 minute departmental meeting to communicate business needs, production restraints and daily/ weekly targets.	This is compulsory. All levels must attend and everyone has a voice.	24/04/2019	
5	Procurement of non-destructive testing equipment such as x-ray or ultrasonic. Inspection to receive training for use of new tools.	The sooner tooling is purchased the sooner quality can make better decisions.	01/05/2019	

Table 9 Shows prioritised actions to be introduced in the first 2 months.

Table 10 below outlines recommended organisational actions for consideration based on the failures highlighted in this report. “Data should drive the decisions of an organisation in improving quality” Jack B. Revelle. (2002) The FMEA and 5why analysis’ reveals an organisational failure to standardise processes required to ensure and maintain a quality product. If these recommendations were observed, the result would be a substantial improvement in product quality and less waste. All actions recommended should undergo periodic review to ensure they are still applicable.

Recommendations of corrective actions			
Step			Target date
1	Daily 15 minute department meeting with production manager, quality inspection and production to discuss daily targets, restraints and other communications relevant to business needs.		24/04/2019
2	Production manager to assign a competency assessor. Recommendation to use skilled, experienced and knowledgeable workers.		24/04/2019
3	Procurement of non-destructive testing equipment such as x-ray or ultrasonic. Inspection to receive training for use of new tools.		01/05/2019
4	Planned maintenance schedule for tooling to be set up and audited monthly for compliance. Calibration frequency to be confirmed by quality		01/05/2019
5	Production manager to create new training manual. Alongside basic starter training, specialised operational training manual for different		01/06/2019
6	All employees to receive new training, staggered over a couple of months as to not disrupt production.		01/06/2019
7	Design to hold DFMA to review current mould composition, gating and venting system. Drawing revisions to be updated with new material and released to shop floor.		01/06/2019
8	Production manager, production workers and quality to create new Standard operating procedures for each operation; mixing sand and bonding composition, packing mould, heating metal and checking temperature, pouring, timing cool, removing cast, transporting cast to inspection, inspection via NDT, transportation to machining, machining of part, inspection of finished product and transport to dispatch. All in conjunction with training manual.		01/07/2019

Table 10. Recommended corrective actions.

Bibliography

Jack B. Revelle. (2002) Manufacturing Handbook of Best Practices: An innovation, productivity, and Quality Focus. 9(2.1), 205.

Asia Quality Focus (AQF) <https://www.intouch-quality.com/blog/21-casting-defects-and-how-to-prevent-them-in-your-products>