FAILURE CRITICALITY ANALYSIS USING FISHIKAWA DIAGRAM

(A CASE STUDY OF DUMPERS AT OCP, RAMAGUNDAM)

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Abstract: Open cast mines are one of the major sources for extracting coal to generate power. The machineries used in the open cast have prominence in producing coal. Any interruption may arise due to poor quality of assemblies or improper maintenance, which results in the production loss. In the interest of enhancing the productivity, the interruptions in the form of failures are to be avoided and the availability of the machinery in the field thence can be maximized. Some failures not only cause the interruption (production loss) but also cause damage assets and even may consume human lives. This necessitates the prediction offailures in advance. In this perspective, “fishbone” diagram, introduced by Ishikawa gained popularity in identifying the root causes of failures.This paper attempts to find criticality using C-I-N analysis and root causes of the various failures that occurred in dumpers used in mining industry. The causes and effects of failures canenlighten the maintenance managers to focus on the areas of causes of failures that considerably can minimize the failures.

Index Terms - Criticality, Fishbone diagram, dumpers.

I. INTRODUCTION

The cause and effect analysis is a preliminary tool for analysing the root causes and their effects for a problem. It was invented and incorporated by Mr. Kaoru Ishikawa, a Japanese quality control statistician.Ishikawa first proposed the seven tools for quality control, this special tool is exclusively propounded by him and is known as the most effective and powerful tool for defect analysis.The fishbone diagram and analysis typically evaluates the causes and sub-causes of one particular problem and therefore assists in predicting the problems by focusing on the root causes. In the present study, the failure categorization was done based on its criticality using C-I-N analysis. Further, root cause analysis was done for the failures occurred in the machineries used in the open cast mines.This study was carried out at the Singareni Collieries Company Limited (SCCL) which is undertaken by the Telangana govt. and union govt. of India.

Although there are various machineries were available like Drills, Dozers, Dumpers, Loaders, and Shovels etc. at the mine, for which dumpers has found giving more trouble. A failure can occur in many forms, each failure will have some cause to occur. Also there will be an effect either may be major or minor for each failure. If the causes which makes the failure to occur are known then the same failure may not be repeated. In this study, the failures of dumpers used in open cast mines were studied and root causes of each failure and their categorization were investigated using fishbone diagram and C-I-N analysis.

II. C–I–N ANALYSIS

All machines fail at one time or another.A machine will fail due to many reasons and in general situations all failures will not have the same importance due to their improper failure distribution pattern, time of repair, cost of the component, function, etc. Also, it is very difficult for maintenance department to focus on all kind of failure that occurs in equipment. Thus, care to be taken obviously differs based on the importance of failures. To have control and modeling of the failures which are of less occurring or importance, maintenance managers should establish a procedure to sort the failure based on their importance. C-I-N analysis is one such procedure that gives a clear picture on three classes of failures. This classification is also based on criticality. C–I–N classification is often used for machinery and equipment.

- C stands for critical machines/failures.
- I stands for important machines/failures.
- N stands for normal machines/failures.

III. ANALYSIS OF FAILURES

This study was carried out at the Singareni Collieries Company Limited (SCCL) which is undertaken by the Telangana govt. and union govt. of India. After a thorough study on the machineries used in open cast mines, it was found that load hauling dumpers are giving more trouble than any other machine. Concerning this, a critical study was done on the failures of dumpers and using fishbone diagram, root causes were found. Initially, data related to dumper failures for a period of two years was collected based as per the record available. Then after, all the failures are arranged in a chronological order. It has been found that, many failures were occurred in a span of two years, some of them are shown in the table no.1 as an example.

Table 1: Examples of Some of the failures occurred

Bucket exhaust adaptor broken.	Tappet setting metal in strain.	PTO problem, replaced.
Water leak in the exhaust pipe.	Horn not working.	Right side pulling.
Steering hard, turbo charger fixed.	Wheel alignment	Air leak
Engine oil leak.	Hydraulic oil leak seal fix.	transmission oil leak
Exhaust leak.	Clutch, gears problem.	tie rod broken
Seal broken in engine.	Breaks weak.	pin jammed
Clutch and Gears problem	Steering oil leak.	crank damage
Hoist cylinder leak, replaced.	Brakes weak.	suspension broken
Suspension seal leak.	Steering link broken.	
	Steering hard idle	

It was observed that more number of failures occurred in the stated period, all these failures were reduced to a small number for the convenience. Based on the element or the component which it belongs, these failures were categorised as seven major failures. Also a count has been taken for each failure mode about which it has been occurred in the stated period. These seven failures along with their occurrence of sub failure (in number of times) are listed in the table no.2. From the table, a total of seven failure components were listed along with their failure modes. Number of occurrences, time to repair (TTR) and average of TTR were recorded along with each failure mode. Component wise total failure occurrences, their average repair time also calculated and the product of these two gives the total production loss. Based on these value rank was assigned for each failure component C-I-N analysis were carried further.

Table 2: Seven Failure Components along with their failure modes and occurrences

F. No.		Failure Mode	TTR	Avg. of TTR	Occurrence	Avg repair time	Total No. of Failures	Production Loss	Rank
1	Brake Failures	Brake oil leak	85	17	5	38	21	798	IV
		Air leak from brake	140	70	2				
		Brake Jam	280	56	5				
		Brake wear & air loss	99	33	3				
		Brake Anchor Leak	78	13	6				
2	Suspension Failures	Suspension Bolt Broken	98	20	5	24	34	816	III
		Suspension Oil Leak	378	27	14				
		Suspension seal leak	322	36	9				
		Suspension preventive repair	74	12	6				
3	Engine Failures	Exhaust leak	67	35	2	75	17	1275	I
		Engine replaced	731	183	4				
		Engine head failed	759	126	6				
		Engine maintenance	21	11	2				
		Engine vibration	65	22	3				
4	Transmission Failures	Toe in toe out	59	12	5	15	19	258	VI
		Gear shifting problem	90	15	6				
		Transmission oil leaked	135	17	8				
5	Steering Failures	Steering oil cylinder leak	94	13	7	11	11	121	VII
		steering box bolts replaced	16	8	2				
		Steering ball bearing broken	24	12	2				
6	Hydraulic & Hoist Failures	Hydraulic oil leak	1100	61	18	24	53	1272	II
		Hoist cylinder leak	263	20	13				
		Hoist seal leak	152	22	7				
		oil leak from seals	75	25	3				
		ELC oil change	25	8	3				
		hoist not working	76	8	9				
7	Radiator Failures	water boil in radiator	106	26	4	27	15	405	V
		Water pump leak	99	33	3				
		Turbo charger oil leak	121	40	3				
		Radiator hose problem	18	9	2				
		Radiator fan damaged	78	26	3				

IV. FAILURE CRITICALITY THROUGH C-I-N

In failure criticalitythrough C-I-N analysis initially the average repair time and the number of failures for each failure component was calculated individually. Then the total production loss is calculated by multiplying the number of failures with its respective average time to repair. Then rankingwas done from the highest to the lowest production loss. Cumulative production loss was calculated and the graph between the number of failure and cumulative production loss has been plotted as shown in the figure1 which gives the Critical, Important and Normal failures.

Table 3: C-I-N analysis calculations

S. No.	F. No.	Failures	Total Prod. loss	Cumulative TPL	% Cumulative	% Failure	C-I-N
1	3	Engine Failures	1275	1275	4.96	14.28	Critical
2	6	Hydraulic & Hoist Failures	1272	2547	9.91	28.57	Critical
3	2	Suspension Failures	816	3363	13.09	42.85	Important
4	1	Brake Failures	798	4161	16.2	57.14	Important
5	7	Radiator Failures	405	4566	17.77	71.42	Important
6	4	Transmission Failures	258	4824	18.78	85.71	Normal
7	5	Steering Failures	121	4945	19.25	100	Normal

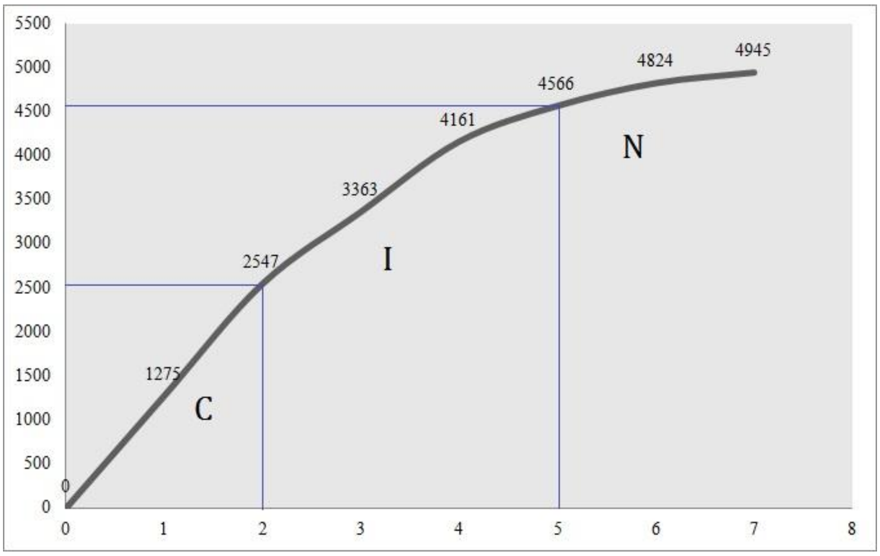

Figure 1: C-I-N analysis graph

V. KAORU ISHIKAWA

Kaoru Ishikawagraduated from the University of Tokyo. Ishikawa ideology focused that the quality improvement is a continuous process, and it can always be taken one step further. He was the first quality guru to stress the importance of total quality control of an organization, rather than just focusing on products and services. Ishikawa also enlightened the importance of the “internal customer,” the next person in the production process. He believed that the company’s vision and the goals should be shared by each and every worker in the organisation and the unity among them enhances the standard. He popularly knew for his implementation of quality circles, which are small teams of employees that volunteer to solve quality problems.

The first contribution of Ishikawa is transforming the Deming’s PDCA cycle into a six step plan. Ishikawa identified and showed the importance of seven tools of quality. His seven quality tool includes control chart, run chart, histogram, scatter diagram, Pareto chart, and flowchart. The most popularized and widely used seventh quality tool of Ishikawa is the Fishbone Diagram, Commonly known as the Cause and Effect diagram or Fishikawa diagram. This is the most notable of all of Ishikawa’s contributions to the field of total quality.

VI. CAUSE-AND-EFFECT DIAGRAM

Cause and effect diagram is used as a way of structuring the process of determining the root cause of a problem. Although Ishikawa first proposed the seven tools for quality control, this special tool is exclusively propounded by him and is known as the most effective and powerful tool for defect analysis. It can be applied to any situation and does not need any mathematical/statistical preliminaries.

This diagram evaluates the causes and sub-causes of a particular problem and therefore assists to resolve the same. In a common fishbone diagram major problem which is to be focused has been put oncentral bone as problem statement, the major categories of causes are put as side bones and sub-bones as detailed causes.With the aid of fishbone diagram, one can estimate and evaluate allpossible causes of a problem, and thence find the root cause of the fault, failure of a system. With the focus on the root problems, this diagram can provide considerable quality improvement from the "bottom up."

Some Noteworthy Points about Cause-and-Effect Diagrams

- Cause-and-effect diagrams (Ishikawa diagrams) are used for understanding organizational or business problem causes.
- Organizations face problems everyday and it is required to understand the causes of these problems in order to solve them effectively. Cause-and-effect diagrams exercise is usually a team work.
- A brainstorming session is required in order to come up with an effective cause-and-effect diagram.
- All the main components of a problem area are listed and possible causes from each area are enumerated.
- Root cause analysis (also included in this category) helps in finding the true root cause of a problem.
- The most likely causes of the problems are identified to carry out further analysis.

VII. Construction of Ishikawa (Cause-and-Effect) Diagram

The following steps will help in constructing a Fishikawa cause-and-effect diagram.

Step 1 (problem statement): A defect or an inconvenience or symptoms of such situations propel the problem. The detail of it or the definition of situation becomes the problem statement. In turn, this then becomes the label for the root effect arrow (also called spine) as shown by horizontal shaded lines in Figure

Step 2 (major causes): The second step is to identify major categories of causes. These are then drawn at an angle to the root effect arrow as shown by dotted area in Figure.

Step 3 (detailed causes): The next step is to list all the detailed causes as sub-braches on to the major categories, i.e., within each of angled bone (line).

Step 4 (principal causes): The final step is to identify the principal causes among the detailed causes. These are considered as the significant or important causes.

VIII. Root cause analysis for the failures

In order to construct the fishbone diagram for these seven failures, a critical study has been done by questing and inquiring the workers and mechanics working in the field. After refining the data, fishbone diagram was constructed according to the category about which that failure belongs.

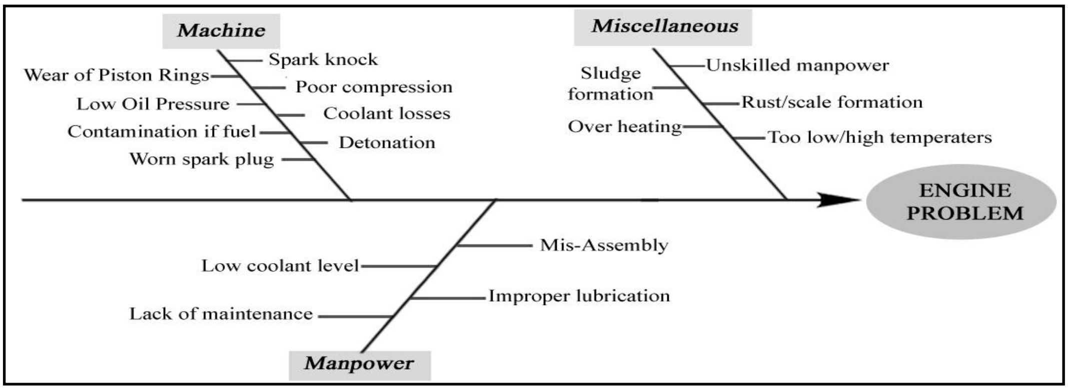

Figure2: Fish bone diagram for Engine problems

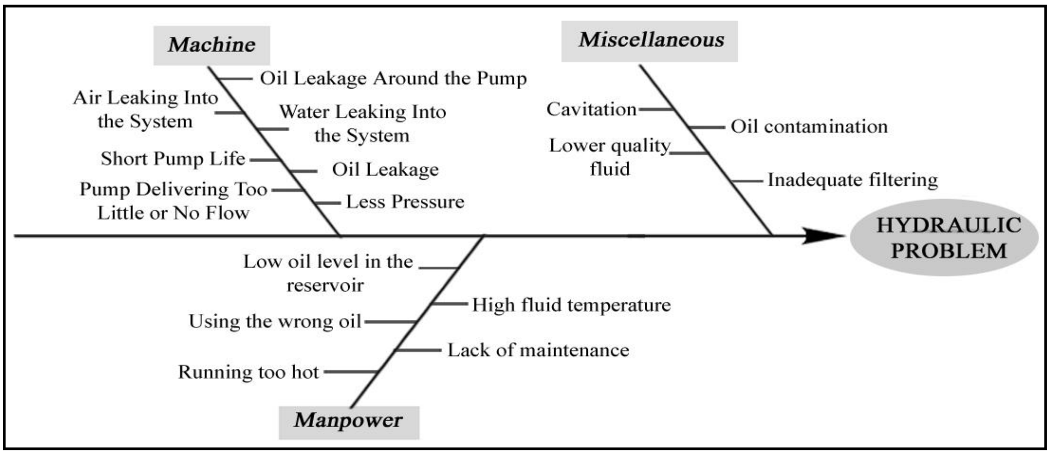

Figure 3: Fish bone diagram for Hydraulic problems

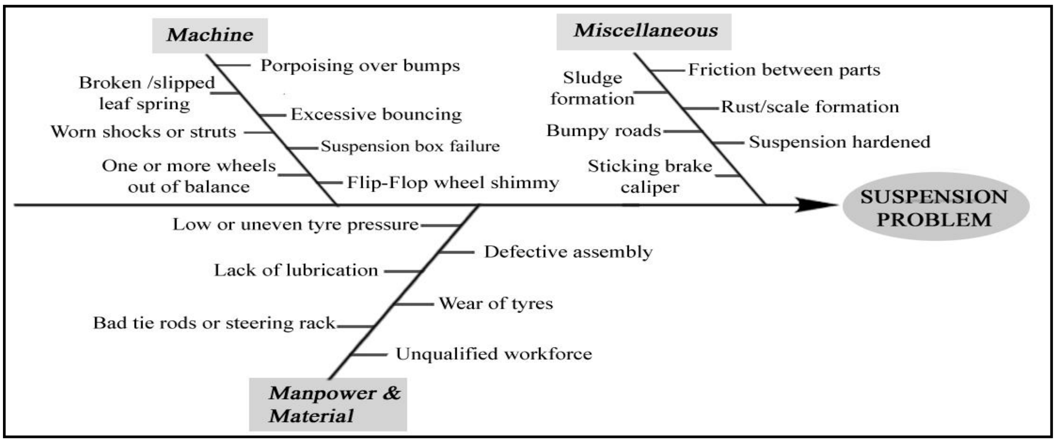

Figure 4: Fish bone diagram for Suspension problems

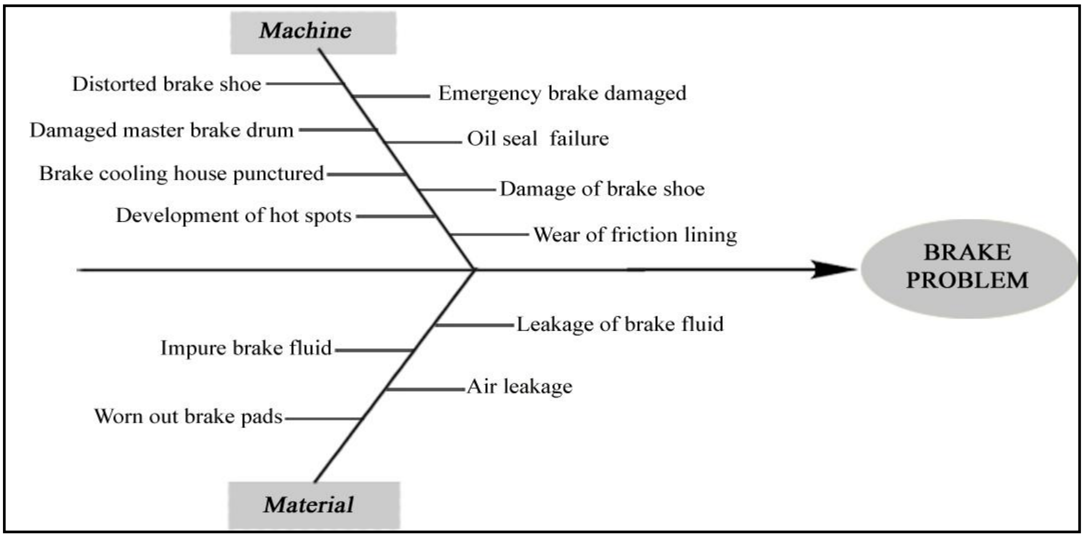

Figure 5: Fish bone diagram for Brake problems

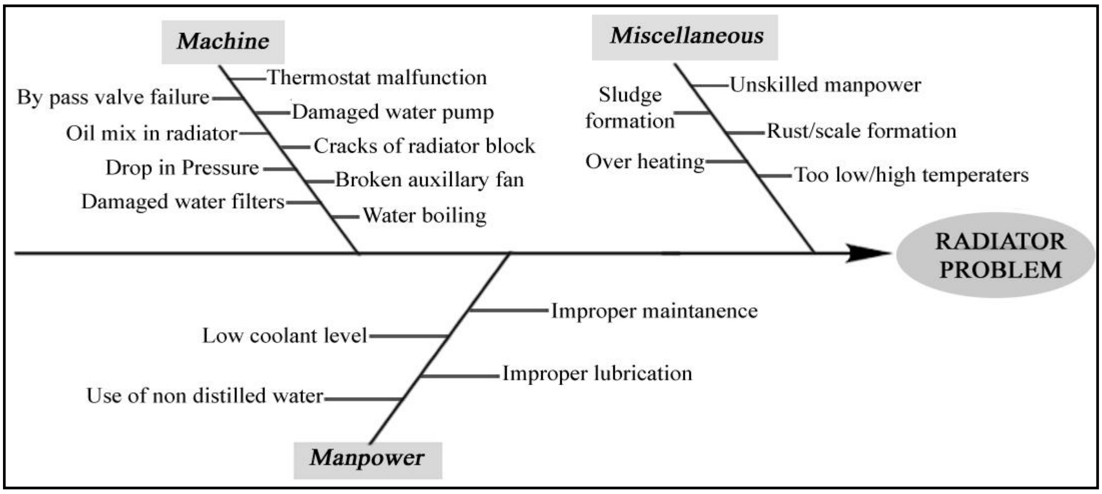

Figure 6: Fish bone diagram for Radiator problems

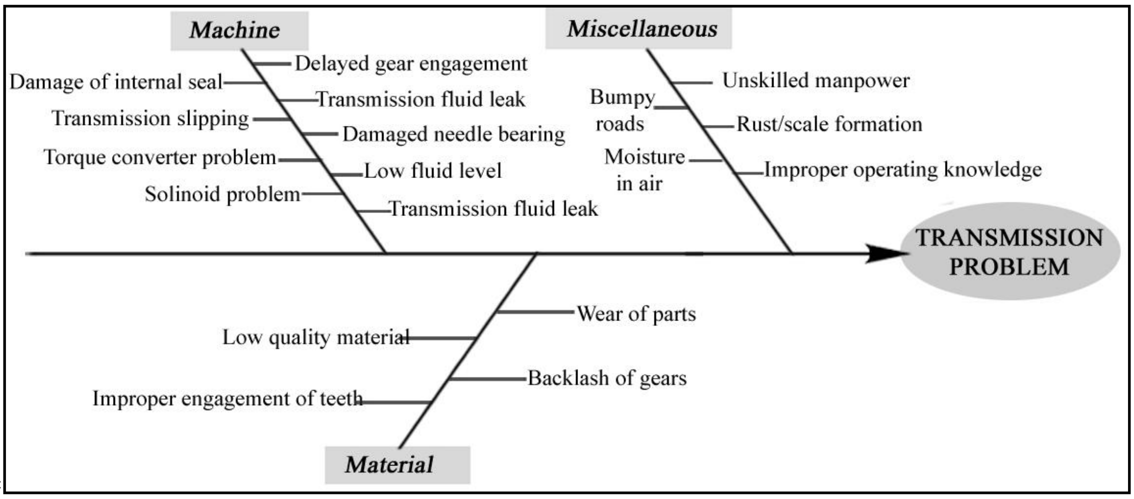

Figure 7: Fish bone diagram for Transmission problems

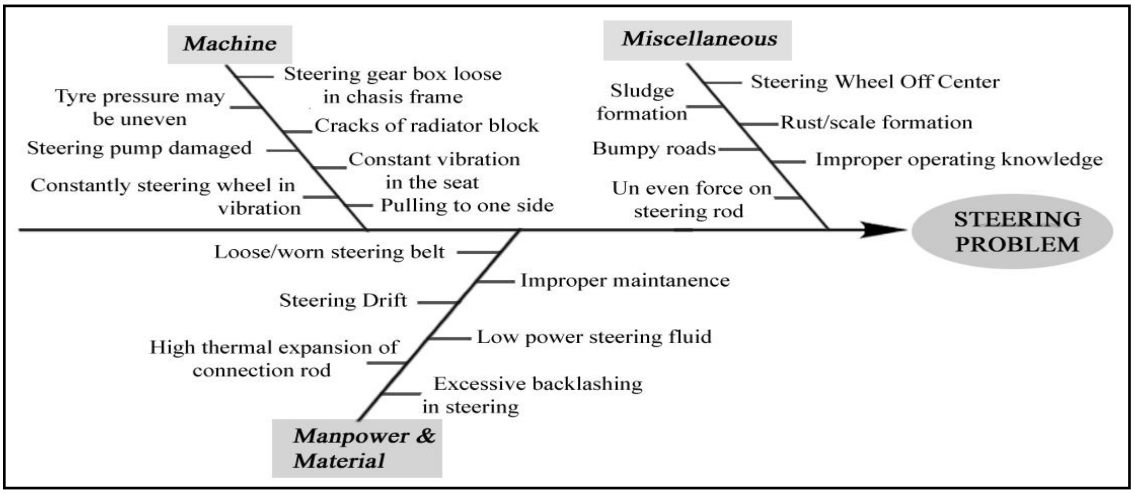

Figure 8: Fish bone diagram for steering problems

IX. VI. FISHBONE DIAGRAM ANALYSIS

Based on the results of C-I-N analysis, it is clear that among all the seven failures, the most critical failures were engine and hydraulic failures. Although there needed attentiveness on all the failures which causes the breakdowns, though major focus should be on the failure which has highest production loss. The objective of this paper is to analyse the criticality and causes of failures using fishbone diagram. All the causes for seven failures were grouped under 4 categories i.e, man, machine, material and miscellaneous. Each failure causes were studied and noted under the category which it belongs. After drawing the network of fishbone diagram for all the failures, it was observed that, steering and suspension problem have the highest number of causes when compare the other failures. And analysing the causes according to the category, the machine category related has more number of causes.

Table 3: Fishbone diagramCauses categorization

S. No.	F. No.	Failures	Man	Machine	Material	Miscellaneous	Total
1	3	Engine Failures	4	8	-	5	17
2	6	Hydraulic & Hoist Failures	5	7	-	4	16
3	2	Suspension Failures	3	7	3	6	19
4	1	Brake Failures	-	8	4	-	12
5	7	Radiator Failures	4	9	-	5	18
6	4	Transmission Failures	-	9	4	5	18
7	5	Steering Failures	3	7	3	6	19
			19	55	14	31	

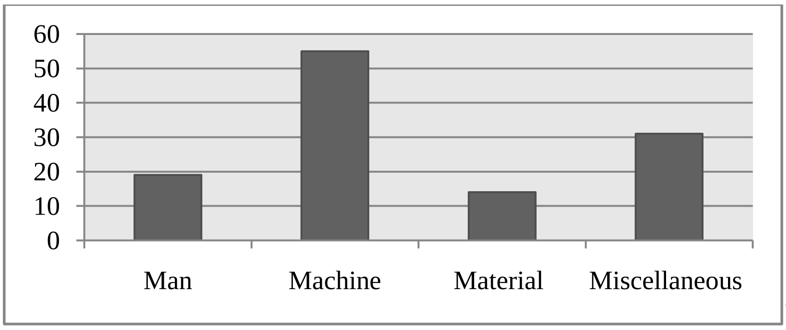

Figure 9: Contribution of man, machine, and material for causes of failures

X. CONCLUSION

Fishbone analysis provides a template to divide and categorise possible causes of a problem by allowing quality circle to focus on the content of the problem, rather than the history. It is useful tool, which is increasingly being used in production, manufacturing and safety engineering. In this paper, cause and effect diagram is used to identify the root causes for the breakdowns that occurred in the dumpers used in the open cast mines. Initially the breakdowns (failures) were investigated and categorised as seven major failures. These seven failures were sorted and categorised as critical failures, important failures and normal failures. This is achieved by applying C-I-N analysis to the failures of the dumpers. Engine failures and Hydraulic failures have found in top 2 places in the list which indicate that are the most critical failures.After C-I-N analysis,a thorough study has been done for each failure and their various causes were noted down in the form of fishbone diagram. The diagram has been categorised as man based, machine based, material based and miscellaneous.Then each cause regarded to a particular failure has been mapped with the category about which it belongs. After the construction of fishbone diagram for each failure separately, it has been found that failures which belong to machine category has more number of causes. Also it was observed that among all the failures steering problem and suspension problem has more number of causes.The focus on the failures with highest criticality and focus on the causes with highest number can considerably improve the production rate and enhance the quality and reliability of the system.

XI. REFERENCES

[1] Dr. N.V.S Raju/ Industrial Engineering and Management/ Cengage Learning

[2]. Dr. N.V.S Raju/ Total Quality Management / Cengage Learning

[3] M. Pradeep Kumar, Dr. N.V.S. Raju, Dr. M.V. Satish Kumar, Quality of Quality Definitions –An Analysis, International Journal of Scientific Engineering and Technology/ISSN:2277-1581 / Volume No.5 Issue No.3, pp: 142-148

[4] M.Pradeep Kumar, Dr. N.V.S Raju, K.Amarnath, When Technology Ends Art Begins -The Art and Science of TQM, International Journal of Scientific & Engineering Research, Volume 7, Issue 6, June-2016 ISSN 2229-5518

[5] Joanna Phillips/Using fishbone analysis to investigate problems/ Nursing Times 16.04.13/ Vol 109 No 15 / www.nursingtimes.net

[6] Kiran M, Cijo Mathew, Jacob Kuriakose/ Root Cause Analysis for Reducing Breakdowns in a Manufacturing Industry/ International Journal of Emerging Technology and Advanced Engineering/ Volume 3, Issue 1, January 2013

[7] Joymalya Bhattacharya / Root Cause Analysis – A Practice to Understanding and Control the Failure Management in Manufacturing Industry/ International Journal of Business and Management Invention ISSN (Online): 2319 – 8028, ISSN (Print): 2319 – 801X www.ijbmi.org Volume 3 Issue 10 ‖ October. 2014 ‖ PP.12-20

[8] Ishikawa, K. (1985). What is total quality control. New Jersey: Prentice Hall

[9] Wilson, P. F., Dell, L. D., & Anderson, G. F. (1993). Root Cause Analysis: A Tool for Total Quality Management . Milwaukee: ASQC Quality Press

[10] Analysis of Breakdowns and Improvement of Preventive Maintenance on 1000 Ton Hydraulic Press, International Journal of Emerging Technology and Advanced Engineering, Praveen Kumar R, Rudramurthy, Volume 3, Issue 8, August 2013,638

[11] M.A. Khattak , N.Zareen , AniqueMukhtar , S.Kazi , AmenaJalil ,Zaheer Ahmed , Miraj Muhammad Jan (2016) Root cause analysis(RCA)of fractured ASTM A 53 carbon steel pipe at oil & gas company Case Studiesin Engineering Failure Analysis7(2016)

[12] Chandna, P., & Chandra, A. (2009). Quality Tools to Reduce Crankshaft Forging Defects: An Industrial Case Study. Journal of Industrial and Systems Engineering, 3