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Application of Reliability Analysis for Validating the Results obtained by Failure Mode and Effects Analysis for Air Conditioner

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ABSTRACT

Failure Mode and Effects Analysis (FMEA) is a means of identifying the probable threats a product may phase and how to prevent them so that the product can be made reliable for the customers. Reliability Analysis gives the confidence to the manufacturer about the success of the product in the market. Giving a reliable product in the market establishes the reputation of the company.
In this paper an effort has been made to calculate Risk Priority Number (RPN) for conducting the FMEA for Air Conditioners used for domestic purposes. The Reliability Analysis, which follows the FMEA, is performed to establish the recommendations of FMEA.

Keywords: Failure Mode and Effects Analysis, Reliability, Risk Priority Number.

1 INTRODUCTION

Introduction:
Failure Mode and Effects Analysis (FMEA), is a group of activities intended to recognize and evaluate, the potential failure of a product or process and its effects, and to identify actions that could eliminate or reduce the chance of the potential failure occurring.

FMEA is an analytical technique (a paper test) that combines the technology and experience of people in identifying foreseeable failure modes of a product or process and planning for its elimination. FMEA is designed to assist the engineers to improve the quality and reliability of design. FMEA provides the following benefits. They are:

- Improve product/process reliability and quality
- Increase customer satisfaction
- Early identification and elimination of potential product/process failure modes
- Prioritize product/process deficiencies and their elimination
- Emphasizing problem prevention
- Documenting the risk and the actions taken to reduce risk
- Minimizing changes at later stages and associated cost [Besterfield D.H. et al.]

Product reliability is an indicator that the product will perform satisfactorily over its intended useful life when operated normally. It is of great interest to both customers and manufacturers. From a customer perspective, poor product reliability increases the frequency of failures and implies higher maintenance costs over the life of the product. From a manufacturer perspective, poor reliability affects sales through customer dissatisfaction, results in higher warranty costs, and affects the reputation and the bottom line. Often, the inability of a product to perform satisfactorily can have safety implications (Murtey D.N..P.). Sometimes equipment failure can have a major impact on human safety and/or health. Automobiles, planes, life support equipment, power generating plants are a few examples (Engineering Statistics Handbook).

2 METHODOLOGY

2.1 For the development of FMEA

Air conditioners work on the simple principle of refrigeration that is

- Liquids absorb heat when changed from liquid to gas
- Gases give off heat when changed from gas to liquid.

The air conditioners use the cycle of compression, condensation, expansion, and evaporation in a closed circuit. The same refrigerant is used to move the heat from one area, to cool this area, and to expel this heat in another area.

2.2 Possible Failure Categories in Air Conditioner:

The possible failures in an Air Conditioner are grouped into the following categories:

- Refrigeration System
- Condensed Air
- Evaporator
- General
- Electrical Systems

The possible failures in each of the above categories are listed below.

Possible failures in Refrigeration System

- Refrigerant Shortage
- Refrigerant Overcharge
- Presence of non condensables
- Restrictions
- Capillary Tubes
- Strainers
- Inefficient Compressor
- Frosted inside coil
- Frosted outside coil

Possible failures in Condensed Air

- Low ambient temperature
- High ambient temperature
- Obstructed coil
- Inoperative fan Motor
- Slow fan Motor
- Fan motor reversed
- Poor location
- Faulty Installation

Possible failures in Evaporator

- Obstructed air filter
- Room too large
- Obstructed coil
- Grills mis-directed
- Poor location
- Air leak

Possible General Failures:

- Thermostat setting
- Switch setting
- Sound level

Possible general Installation Failures

- Improper Mounting
- Improper location

Possible failures in Electrical Systems

- Switch
- Overload relay
- Compressor capacitor
- Compressor motor
- Fan motor capacitor
- Fan motor

The probable defects which may cause the failures in the system or subsystem of AC are broadly classified, for the study purpose, into seven categories:

1. Compressor and fan motor defects
2. Condenser defects
3. Choked Capillary
4. Starting Capacitor failure
5. Starting Relay failure
6. Strainer choking
7. Thermostat failure

The next step in the study was the field visit, to collect the data of failure of ACs for the above mentioned seven categories of failures. The service centers in Mumbai and Navi Mumbai are visited for the purpose. The record book of the service station is referred and the maintenance works of last fifteen days were observed. During this period, if the report of failure was available for the selected seven subsystems then details of the record were observed by finding the answers of the following questions.

What is the problem? (Not working/Not cooling properly/ Noisy operation/ Other)

Which component failed? (Compressor/Condenser defects/Capillary/Starting Capacitor/Starting Relay /Strainer /Thermostat)

Why it has failed?

Is it being repaired or replaced?

All the observations were based on the possible failure categories and the components used in the study. The same process is repeated at every service station and total 1720 observations were made. This work is carried out in the months of April and June 2010. The data is summarized in the following table.

Table 1: Data collection from service stations- categorization for FMEA

Components	No. of Claims	Per-cent	Ranking
Compressor and Fan Motor Defects	289	16.80	2
Condenser Defects	829	48.19	1
Capillary Choked	101	5.87	6
Starting Capacitor failure	136	7.91	4
Starting Relay failure	111	6.45	5
Strainer Choking	197	11.45	3
Thermostat Failure	55	3.19	7
Total	1720	100	

The data shows that the highest number of defects occur in the Condenser, followed by the Compressor. The failures of strainer are ranked third and likewise other defects have been allotted the ranking based on the collected data. This ranking is further used for the calculation of Risk Priority Number in Failure Modes and Effects Analysis charts.

2.3 Development of Failure Modes and Effects Analysis chart

The next step in the study is the development of FMEA Chart. For each defect classified earlier, the causes of potential failure modes and their effects are recognized. For every cause, the possibility of “Detection” at the design stage is recognized. Similarly for every effect the “Severity” of its happening is found out. The data collected through service station is used as “Occurrence” of the failure mode. The Risk Priority Number (RPN) is obtained by multiplying the values of Severity, Detection and Occurrence.

For example, for the component strainer, the chances of detection of the potential cause of failure, worn out particles is very remote during the design stage, therefore a value of ‘9’ is given to detection. The effect of this cause is choked capillary and it has very high ranking when potential failure mode affects safe operation and failure occurs with warning. The value of ‘9’ is assigned for such severity. The value of occurrence of failure is ‘9’ for the strainer as per the data collected from the service station. Therefore RPN comes out to be equal to 9*9*9=729. Table No. 2 shows the FMEA for strainer and RPN calculations for reference.

In the similar manner FMEA has been carried out for all the seven components. The Table No.3shows the various possible causes of failure and their RPN is shown in descending order.

2.4 Conclusion drawn from FMEA:

The Risk Priority Numbers obtained in the FMEA shows that the particular causes of failure should be taken care of during the design stage. For this certain recommendations are suggested. These recommendations are to be validated by the people working in the field for reliability analysis.

3. Reliability Analysis

To perform the reliability analysis the opinions of experts are collected for the recommendations suggested during FMEA, with the help of a questionnaire. Following questionnaire shows the recommendations made by FMEA and the response of experts.

3.1 Calculation for Reliability Improvement Factor:

The data obtained in the survey is utilized for calculating the reliability Improvement Factor. For the calculation first of all the failure rate for each component is calculated. It is taken as number of times the component has failed by the average life of the component (Obtained from the survey results). Then it is multiplied by “Yes” value. Now the summation of Failure rates of all the components is obtained. The improvement factor is calculated as the ratio of difference of total Failure Rate and component failure rate and total failure rate. Theoretically the improvement value should be more than one and in the study also the improvement factor for all the recommendations made for various causes of failure results to be more than one.

4. Conclusion:

To increase the reliability of the product the rate of failure is to be minimized, so that the working life hours can be increases. In this study also the reliability improvement factor for the recommendations for various causes of failure recognized by the Failure Mode and Effects Analysis, is obtained more than one. Hence, it can be concluded that recommendation will definitely help in reducing the Risk Priority Number.

REFERENCES

[1] Besterfield D.H. et al., “Total Quality Management “, Seventh Indian Reprint,2005,Pearson Education.

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[3] Engineering Statistics Handbook, Safety and Health Considerations

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Strainer							
Item/Function	Potential Failure Mode	Potential Effects of Failure	Severity (S)	Potential Cause/Mechanism of Failure	Occurrence (O)	Detection (D)	Risk Priority Number (RPN) =S*O*D
To absorb moisture	Fails to absorb moisture	No cooling effect	8	Too much moisture in refrigerant	9	5	360
To Collect dust particles	Choke up	Presence of impurity prevents flow of refrigerant	9	Dust particles in refrigerant		9	729
				Worn out particles from the compressor parts		9	729

Table No.2

Sr.No.	Potential Failure Mode	Part in which occurs	RPN
1	Dust particles in refrigerant	Strainer	729
2	Worn out particles from the compressor parts	Strainer	729
3	Poor Installation	Condenser	720
4	Dirty fan blades	Condenser	560
5	Dirt on coil	Condenser	480
6	Reduced air quantity	Condenser	480
7	Electrical Problems	Starting Capacitor	448
8	Restricted air inlet and outlet	Condenser	400
9	Too much moisture in refrigerant	Strainer	360
10	Motor windings are weak	Starting Capacitor	336
11	Fails to provide starting torque	Starting Capacitor	280
12	Motor does not start at all	Starting Capacitor	280
13	Internal springs get stuck	Thermostat	252
14	Thermostat not kept in proper position	Thermostat	252
15	Arcing results in contact getting welded	Thermostat	224
16	Carbon deposits on contact surface	Thermostat	216
17	Continuous Running	Compressor and Motor Defects	216
18	Corrosion	Starting Relay	192
19	No Servicing of Motor	Compressor and Motor Defects	192
20	Circuit Problem	Thermostat	160
21	Incorrect rotation of fan	Condenser Defect	160
22	Oil in the refrigerant	Capillary Tube	160
23	Loose Connection	Compressor and fan motor defects	144
24	Frequent Starting and Stopping	Compressor and fan motor defects	128
25	Fan Capacitor Weak	Compressor and fan motor defects	112
26	Excess load on relay	Starting Relay	108
27	Pitting of contact surfaces	Thermostat	108
28	Winding of relay gets overheated.	Starting Relay	96
29	No Varnishing of Motor	Compressor and Motor defects	72
30	Shaft Balance and Bearing Problem	Compressor and Motor defects	72
31	Insulation Defects	Compressor and Motor defects	56
32	Incorrect selection of Capillary bore and length	Capillary Tube	40
33	Design Problem	Thermostat	28

Table 3: Risk Priority Number in descending order

Table No.4 Questionnaire for Survey of Reliability Analysis, with Opinion

Sr.No.	Particular	Description		
I	Type		Window	Split
			100	100
II	Brand	Brand 1	8	38
		Brand 2	10	36
		Brand 3	4	6
		Brand 4	6	10
		Brand 5	6	4
		Brand 6	6	4
		Brand 7	8	2
		Brand 8	52	0
III	Approximate date of installa-tion of the AC:	less then 1yr	2	12
		less than 2 yr	14	14
		less then 3 yr	52	40
		less then 4 yr	22	22
		less then 5 yr	4	4
		less then 6 yr	4	4
		less then 7yr	2	4
	Annual Mainte-nance Contract is there	Yes	17	36
		No	83	64
IV	First indication of failure as report-ed by the cus-tomer	Inoperative	6	14
		Overheating	16	4
		Burning Smell	18	6
		No Cooling	18	40
		Noisy Operation	28	8
		Other	14	28

V	Name of the part which failed	Compressor and fan motor	26	28
		Condenser	30	34
		Choked Capillary	4	3
		Starting Capacitor	14	10
		Starting Relay	10	8
		Strainer	14	16
		Thermostat	2	1
VI	Status of the part	New	92	82
		Repaired	6	14
		Replaced	2	4
VII	Reason of Failure			
1		Dust particles in refrigerant (Strainer)	3	6
2		Worn out particles from the compressor parts (Strainer)	4	2
3		Too much moisture in refrigerant (Strainer)	7	8
4		Poor Installation (Condenser)	7	9
5		Dirty fan blades/ (Condenser)	9	10
6		Dirt on coil (Condenser)	9	10
7		Reduced air quantity (Condenser)	5	5
8		Electrical Problems (Starting Capacitor)	6	5
9		Motor windings are weak (Starting Capacitor)	2	2
10		Fails to provide starting torque (Starting Capacitor)	1	1
11		Motor does not start at all (Starting Capacitor)	5	2
12		Continuous Running (Compressor)	5	8
13		Loose Connection (Compressor)	9	10
14		Frequent Starting and Stopping (Compressor)	7	6
15		No Varnishing of Motor (Compressor)	3	1
16		Insulation Defects (Compressor)	2	3
17		Excess load on relay (Starting Relay)	5	4
18		Winding of relay gets overheated (Starting Relay)	5	4
19		Oil in the refrigerant (Capillary Tube)	4	3
20		Other	2	1
			100	100

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Table 4 B: **Expert Elicitation**

Sr. No.	Particular	Probable Action	Comment	
			Yes	No
1	Dust particles in refrigerant	In house cleaning before installation; Changing the refrigerant if required during maintenance	100	
2	Worn out particles from the compressor parts	Electromagnet at the outlet of compressor	88	12
3	Too much moisture in refrigerant	Evacuating the system before filling the refrigerant and performing chemical analysis to check the level of moisture.	65	35
4	Poor Installation	Self locking lever system to maintain straight upright position.	78	22
5	Dirty fan blades	Dual operating fan to operate the fan as blower also.	81	19
6	Dirt on coil			
7	Reduced air quantity	Condenser leakage is to be rectified	88	12
8	Electrical Problems	Reducing the back pressure by delay switch will help in effective functioning.	82	18
9	Motor windings are weak			
10	Fails to provide starting torque			
11	Motor does not start at all			

12	Continuous Running	Leakage problem of condenser leads to continuous running of the compressor. If leakage is rectified the condenser problem will be solved automatically	63	37
13	Loose Connection	When unit is maintained at straight upright position the vibrations will be reduced without affecting the connections	68	32
14	Frequent Starting and Stopping	Delay start switch to regularize the pressure of the compressor so that back pressure is reduced in the system.	73	27
15	No Varnishing of Motor	New varnishing materials are available with more affinity to material and to make the surface smoother.	80	20
16	Insulation Defects	Secondary and tertiary coatings are recommended	62	38
17	Excess load on relay	Delay start switch	74	26
18	Winding of relay gets overheated.	Delay start switch will reduce the back pressure therefore overheating of the windings		
19	Oil in the refrigerant	Evacuation and chemical analysis	72	28