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A Literature Review on FDD and Reliability calculation for Refrigeration and dynamic systems

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Abstract- Fault detection and diagnosis (FDD) and Reliability engineering are very important tools to access the performance of any dynamic system.. The FDD and reliability concept provide a direct idea about the performance of designed system. For reliability calculation of one or more components of a system, number of theories exists in literatures. But to calculate the reliability of a system for its modification, it is important to apply a general feasible theory of reliability which can be easily applicable to all running systems. Therefore a general and flexible theory will be more applicable to calculate the reliability of a dynamic system with fault detection. In this paper different approaches are elaborated for reliability calculation and hence it gives idea to select more easy method for calculating the reliability of a dynamic system.

Key Words: VCRS, failures, reliability, component and modeling, dynamic system, Fault detection, diagnosis, flexible theory

INTRODUCTION

Fault detection and diagnosis (FDD) is a technique to detect and diagnosis the faults rapidly and intelligently in very short interval of time.

Reliability is the attribute of any dynamic system or machine to perform it consistently according to its specification.

FAULT DIAGNOSIS AND DETECTION

For the first time, the concept of fault library was given by Bailey et al]in year 2000. According to him one can analyse the condition of faulty data using fault analysis in Vapour Compression Refrigeration System (VCRS). He himself collected the data and also included the data already collected in library of Kreiden et al in 1999. Kreiden et al had gathered several data of same area and purpose. These data were all taken in full scale heating, ventilation and air-conditioning.

In 1937 Beruker [3] was the first who got the literature published about the fault conditions in VCRS. In this literature it was explained about the effect of leak of appropriate refrigerant. He found out the results of being less refrigerants in condenser or fouling of heat exchanger .Later on in the same guideline of Beruker, another research in 2006 was done by Kim et al .They also published an important result of fault analysis on 2009.Originally a technologist LeRoy searched and gave the detoriation performance of vapour compression in 1997.Depending upon this research Shen did modeling and provided a technical shape in 2006.

Previously exciting simulation data were unable to give fast diagnosis .So Yuill and Barun again collected the real data to find out the fast diagnosis in 2012.Using these data fast simulation results became available. In 2006 Shen told experimentally about the condition of optimal refrigerant charge level. If in any compressor refrigerant is filled more than it needed or it is over charged then performance of compressor becomes lesser[4],[5].

In 2009 Kim proved that after long running of heat exchangers which are used in condenser becomes faulty at the point where air flows. There the way of that place becomes narrow, and due to less air flow rate , the performance of the system goes to weak. He told that if compressor valve was leaking then refrigerant would also leak .Here the way of discharge will also be narrow and due to failure of complete discharge, the performance of the system will go down.

Rosen in 1951, Thomas in 2002 and Sten in 2006 tried to simulate the faulted condition of VCRS .In this fault detection using simulation they considered the input as the amount of charge, condenser air flow, liquid line pressure and expansion valve condition etc [2]. In 1997, Breuker also published a research paper regarding the leakage of refrigerant and other concerning problems in compressor.

In 2012 Cheung and Barun fixed the orifice inside the packaged unit of 3-Ton R410A and proposed a model relating different components of VCRS. Later in 2006 Shen experimentally tested it .In this field of modeling and testing Shen investigated a lot of facts about VCRS.In 2006 Shen developed ‘Charge tuning equation’ which is very helpful for charging and filling of compressor. In the same year 2006 Yang et al did modeling and got the solution of the problem of air flow and fouling in evaporator. He published the special symptoms of fault detection in evaporator.

In the same way in 2012 Bell et al studied the effect of fouling in condenser and found that due to increase of fouling in heat exchanger pressure drop goes up and because of slow speed of fan which results the decrease of air flow rate (Heating Problem).

Though there is no more literature available for fault detection and its diagnosis but during the survey some common literatures are available as guide line. In 1989 Stouppe and Lau made a detailed study of HVAC-FR and researched out 15716 failures in that. It was done because of being some practical problems to an insurance company in giving claims . The insurance company wanted to

know the reality whether defect claim could be given or not. In the study of Stouppe and Lau . It was found that maximum failure comes from Hermite Air-conditioning unit. Out of this 76% failure by electrical components, 19% failure by mechanical components and 5% failure by refrigeration circuit occur [3].

Mostly failure occurs in electrical components so it was essential to take notice about the causes why electrical components were failing so much? After a long continuous search it was found that failures were due to fault motor winding. In lack of proper insulation in motor winding the chances of deterioration were increasing .So in single phase operation or in short circulating motor goes to burn and flame of fire generates [3].

If we talk about mechanical failures then we find that faults are in compressor, valves, bearing and in connecting rods. These said parts are mostly damaged due to fluctuation of power and un- reliable products. Main causes of mechanical failure are due to fatigue in valve and disturbances in valve springs.

In the same way in 1998 Breuker and Braun analysed some collected database of HVAC servicing company. This database was prepared by a servicing company. From 1989 to 1995 about 6000 repair causes were recorded separately in this database .There was clear information about the repairs of several parts and their failures . During the analysis of Breuker and Braun it was found that 60% problems were raised by electrical and control failure according to database. In database 40% problems was mechanical. It is matter of wonder that failure in compressor was only 5% and it was caused by mechanical problems. Compressor is the most important part of the refrigeration and air-conditioning system. If compressor fails the repair cost increases and it also takes much waste of time in repairing. In detailed analysis of literatures it was found that in the cost of total servicing about 25% servicing amount is of compressor servicing. Breuker and braun again searched and also found the causes of failure in compressor during the year 1998 . They got the cause of failure in compressor is mostly due to motor failure. Lack if insulation or overloading are the causes of failure in motor windings. For the failure of positive displacement type compressor it was found that most failure occurs due to flood back of refrigerant. If there is the flood back of water refrigerant then evaporator coils and condenser coil become choking. Due to overcharging of refrigerants, fault arises in the thermal expansion valve also. There are other causes of compressor failures also as low voltage, fluctuation in voltage and overheating of compressor. When there becomes failure in the fan of condenser or fouling in condenser or down charging of refrigerant or low flow rate of refrigerant then theses failures are the main cause of overheating of compressor. Sometimes the leakage of refrigerant also makes the compressor heat up [5].

After compressor this also came in notice that 20-25% of total service cost is of evaporator and condenser.

In 1997 Rossi and Broun [30] found out that the restriction in liquid line was generally due to closure of valves, which are fixed before expansion device. In 1996 Stylianou and Nikanpour also worked in the same direction and found that the choke in liquid line was due to slow mass flow rate also.

In 1995,Grimmelius et al experimentally simulated and got a result that Fouling in condenser and evaporator can be rectified by down water flow rate.

In 1997 Mckellar identified some faults in domestic refrigerators. Some common faults which he identified were the leakage of valve in compressor, much ice formation due to more cooling in evaporator which mostly choked the capillary tube, failure in fan of heat exchanger and false in the charging of refrigerant. Mckellar found the above due to above said faults, three changes occur in vapour compression refrigeration system. First type of change is in suction pressure or temperature, Second change in discharge pressure and temperature and third change in the change in ratio of discharge to suction pressure. We can very easily detect the fault by monitoring these three changes [8] .

Stallard was very much influenced by the above said research of Mckellar in 1989 he developed an automated system for refrigerator. He studied separately the evaporating temperature , suction temperature , ratio of discharge to suction pressure ,Condenser temperature and condensing temperature etc. and formed a tabulated chart to diagnose the faults in different conditions [3].

In 1991 Kumamaru et al plotted some characteristic curves which were showing the performance of heat pump at different cooling water temperature and various cooling loads. Using this chart, it became very easy to diagnose to various parameters of faults and the combination of variables at that exciting fault.

Similarly according to above study Yoshimura and Ito did another experiment in 1989.In this experiment they took reading of different pressures and temperatures and used it to detect the faults of Air-conditioners.

Entirely separate from all these studies in 1992 Inatsu et al searched the mechanism to detect the defect of refrigerant leak in automatic Air-conditioner. It was not of that kind as Previous models were based. It was experimentally observed data in which liquid to gas flow ratio in liquid line was measured and proposed a new method to diagnose the leakage of refrigerant. Not only the loss of refrigerant could be detected by this method but also the performance of the sensitivity of the system on charging of refrigerant can be known.

In 1995 Gordon and Ng developed a thermodynamic model in which the COP and performance of chiller were made the base of fault detection and diagnosis (FDD).

In 1996 Oeitsman and Bakker developed a black box model which they applied on laboratory chiller for fault detection and diagnosis [24,25].

RELIABILITY

The quality of a product at any time of its life span can be defined and improved by applying the reliability management. It is directly associated to the probability theory of success and failure.

First time the word reliability was used in 1950 by united state defense organization. Later on this word became more popular for military purpose. Basically this term was used for the successful projection of missiles. After 1960 new researches were started by mathematicians to find different theories and approaches for calculation of reliability of any running system[1].

In year 2004 a research paper was presented by H.Karadeniz in 23rd international conference on topic offshore mechanics and aretic engineering in Canada. The main focus of this research paper was to calculate the fatigue reliability with uncertainty modeling of off shore structures with deteriorated members. In this paper the reliability of structures are calculated by computer based modeling on stiffness matrices and load vector variables.

A research paper about the alert level calculation for reliability was published in 2006 by Jan Amborski at Poland. In this paper a new technique is presented for the forecasting of the failure of a system. In this technique the simulation for many group of statistical data is used for calculation. In this coding technique the components are decided by different codes and the reliability is calculated accordingly[1-5].

To decide the proper maintenance schedule and to enhance the reliability of the components of electric transformers a technique was published in journal of electrical system in 2006 by M.Mirzai, A. Gholani and F.Amirifar. In this research paper some extra considerations of effects like insulation problem and environmental effects are also considered to evaluate and enhance the reliability of transformers [8,10].

In year 2010 , a research paper was published by Lin Huang et.al. and members of IEEE. This paper was focused to enhance the reliability of load sharing redundant systems with arbitrary failure distributions. To enhance the reliability of system for life time , the idea is to distribute load from n active to m in- active components of the system(n>m). The re-distribution of load to enhance the reliability of the system has price constraint also [23].

A research paper was published in 2012 by Baired at al. This paper was focused of the conceptual details to describe the probability of success or un success of a component at any time interval of its application. That is the calculation of reliability of a component is possible at any stage of its application with the help of large statistical data[8].

In 2013 a technique using fault tree analysis to calculate the reliability of any system was published by Ahmed Ali Baig, Risza Ruzl and Azizul B. Buang[6]. This method is based on the logical diagram. This method can be applied for any industrial system to enhance its reliability and safety. Using fault tree analysis the cause of failure for an event can easily be traced out by a visual model. In the logical diagram variable symbols like AND Gate , OR Gate , Inhibit Event , Undeveloped event and so on [19,12].

A research paper by B.Abdi, R. Ghasami and Smm Mirtalaei [7], on reliability calculation was published in 2013. This paper includes the calculation of reliability of switch mode power supplies of personal computer. This reliability calculation is based on the basic reliability theory where the failure rate is calculated by multiplying the various factors like quality factor, stress factor, temperature factor environment factor etc. these above factors are calculated separately and after then multiplied to get the desired result [13-17].

CONCLUSION

The concepts of FDD are showing their importance for which they are derived and tremendous development in this field is seen since 1937 to till now. Increasing automation in all types of devices either mechanical or electronic need different powerful theories to find the faults in various components of a dynamic device so that the fault removal action can be applied quickly to deny any further losses.

The reliability theories are providing the multidimensional concepts to enhance the mean time between failure (MTBF) and also to increase the life the working device.

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