A Failure Mode and Effect Analysis (FMEA) for a Commercial PC Cooling Fan

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Abstract *- This paper analyses the possible failure modes and the effects that can occur for a PC cooling fan. The fan chosen for this analysis is a commercial one that can be found in most PCs. The analyzed fan uses a brushless DC motor and a magnetic bearing. The FMEA is made at a component level taking into account the defects that can appear for each component of the system (cooling fan) and the effects of those defects to the operation of the system.*

Keywords – *Reliability, Failure Modes, FMEA, PC Cooling Fan, Electric Motor, BLDC*

1. INTRODUCTION

The fans are rotating machines used to increase the air flow by changing the mechanical energy received at the motor shaft. The main components of a fan are the motor, the housing and the fan blades. [1]

Most fans are powered by an electric motor, but other power sources can also be used, including internal combustion engines and hydraulic motors. [2]

The fan is a very important component in a PC, whether it is used for cooling the video board, the CPU, the power supply unit or the entire housing because without cooling the components would overheat and cause important damage to the PC in some of the worst cases leading to the unavailability of the PC.

For this study an axial fan was used which is powered by a 24V brushless DC motor (BLDC). Figure 1 shows the architecture of the fan.

The speed of an axial fan can reach up to 19,000 RPM and can be controlled by sensors and integrated circuits that can bring down the speed if the temperature is in the normal limits, feature that leads to a less noisy operation, extended life and lower power consumption than the fans with fixed speed. [3]

Unlike the brushed DC motor in which the brush /commutator system continually switches the phase of the windings to keep the motor turning, the brushless DC motor (BLDC) is an DC electric motor in which an electronic controller replaces that assembly. The controller does the similar timed power distribution by using a solid-state circuit rather than the brush/commutator assembly. [4][5][6]

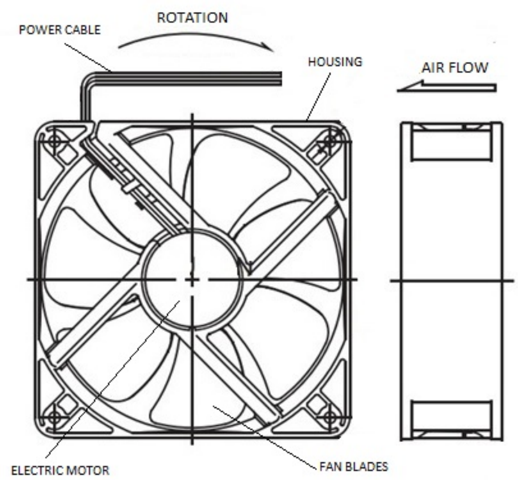

Fig. 1 – Cooling Fan Architecture

The FMEA is a significant part of reliability and security assessment of the systems. FMEA delivers a very good method to evaluate the potential failures. This consists of breaking down the system into components to determine what can fain, why it fails and eventually to determine the effects of every single fail. A very important part of FMEA is the criticality assessment because it shows the critical parts that must be changed in order to improve the reliability of the system.

The FMEA is one of the most common methods used in reliability assessment. In a survey published by the Reliability Analysis Centre, 70% of the people questioned identified the FMEA as one of the most important tools is assessing the reliability of a system. [7]

Usually the FMEA is made according to the widely accepted standards, but some companies develop their own guidelines in performing such analysis. The most frequent international standards are MIL-STD-1629 and SAEARP5580. [8]

The advantages of using the FMEA are [9]:

- The increase of customer satisfaction because of product improvement;
- More robust design of the products that can support operating environments that are not ideal;
- More efficient testing of the products;
- Improved maintenance based on failure modes and effect importance;
- Less changes in production process where the costs can increase significantly.

The disadvantages of the FMEA are [9]:

- Every failure mode is considered to occur individually, assuming that the other parts of the system are working without any defect;
- The negative effects against the system functions due to multiple defects.

2. FMEA PROCESS

The process of FMEA consists of analyzing the system from the bottom to the top. It starts from the lowest desired level, a component or process step and it goes up determining all the possible failures. The next step is to assess the effect of the failure and in the end the severity, likelihood and detection are determined. One of the objectives of the FMEA is to evaluate all components of the system to ensure that the reliability and system safety are accomplished. [8]

Another major objective of the FMEA is to anticipate the most important problems that can arise in the design stage and to prevent them or to minimize the consequences. Therefore the FMEA ensures a systematic approach and gives aid in evaluating, tracking and updating the work done in developing the product or the system. [8]

For this analysis a software tool that is specialized in reliability analysis was used: Relex Reliability Studio [7][8][9].

The first step in the analysis of the cooling fan is to define the System Tree in order to identify the components that make up the fan. The System Tree of the fan is presented in Figure 2.

After having identified the components of the system the next step would be to determine the possible failure modes of each component and depending on what level the analysis is made, to assess the effects of those defects. It is to be noted that in this paper the effects are assessed at the product level only which is the cooling fan. Following effect assessment the causes of failure can be identified.

Finally having this information the last step is to establish the Occurrence, Severity and Detection parameters of each failure mode in order to calculate the RPN (Risk Priority Number). These parameters have predefined values in Relex and can be selected according to the analyzed system. The RPN gives important information about the critical parts that must be improved.

In the FMEA table presented in Figure 3 was recorded the above mentioned failure data for the cooling fan. Based on this data a series of charts were generated in Relex in order to express the result of the analysis. These charts are presented in the following section.

3. RESULTS

Figure 3 also presents the calculations results of the RPN. The electric motor has been identified to be the critical part in the system, having the highest RPN. This is supported by the high number of defects that can occur at the motor, thus this is the main focus in improving the product.

Although the electric motor has high number of defects that can occur, a critical part of the motor has been improved by the use of magnetic bearings. This improves the reliability of the motor in comparison with the traditional bearings (ball, roller).

The components that have the lowest probability of defects occurrence are the housing and power supply cable. This is due to the fact that these are the components that don't have important functions in the system. This is reflected also in Figures 4 and 5.

Figure 4 shows the severity distributions of the components. This result confirms again that the electric motor has the highest risk of defect occurrence.

System Tree

Name	Part Number	System Tree Identifier	Reference Designator	Description
⊟ PC Fan	FAN	System1	MEC0382V1-000U-A99	24V BLDC Motor Fan
Fan Blade	FAN BLADE	System2	MEC0382V1-000U-A99	PBT Thermoplast Fan Blade
Power supply cable	SUPPLY CABLE	System10	MEC0382V1-000U-A99	2-Wire Power Supply Cable
Housing	HOUSING	System11	MEC0382V1-000U-A99	Housing
Control Board	CONTROL BOARD	System40	MEC0382V1-000U-A99	Control Board
⊞ Electric Motor	MOTOR	System3	MEC0382V1-000U-A99	24V Brushless DC Motor

Fig. 2 – Cooling Fan System Tree

Item Identifier	Item Description	Mode Identifier	Failure Mode	Local Effect	End Effect	Cause of Failure	Mode Percentage	Occurrence	Severity	Detection	RPN	Item Failure Rate
PC Fan	24V BLDC Motor Fan	Fan Blade	blocked fan blade; noisy operation; melted fan blade	overheating	overheating	dust	0.40	Remote	Critical	8	1400	176.143655
		Electric Motor	cracks in the motor; vibrations; short circuits; winding rupture	overheating; blocked motor; the motor doesn't start doesn't start anymore; RPM decrease	overheating; blocked motor; the motor doesn't start anymore; RPM decrease	external shocks	98.90	Occasional	Catastrophic	8	4000	
						vibrations						
						overload						
						improper instalation						
						dust						
						improper operation						
						overheating						
		Power supply cable	interrupted cable; short circuit	the fan doesn't start anymore	the fan does't start anymore	dust	0.11	Extremely Unlikely	Catastrophic	9	0	
						improper instalation						
		Control Board	shortcircuit at component level; component failure	the fan doesn't start anymore; RPM variations	the fan doesn't start anymore; RPM variations	dust	0.53	Remote	Critical	7	1225	
						BIOS incompatibility						
		Housing	cracked housing; melted housing	faulty operation; loss of performance	faulty operation; loss of performance	dust	0.06	Extremely Unlikely	Critical	6	0	
						overheating						
						external shocks						

Fig. 3 – Cooling Fan FMEA Table

A defect at the motor level can bring the entire system down where a defect at the fan blade or housing for example can lead to loss of performance only.

The existing reliability standards impose a criticality modes analysis to be undertaken following the results presented in Figures 4 and 5. The critical values for each component of the system are presented in Figure 5.

These critical values were calculated in Relex using the following equation [9]:

$$C_m = \beta \alpha \lambda_p t \qquad (1)$$

where:

- C_m – Critical value of the component;
- β – The probability of defect effect;
- α – Failure mode;
- λ – Failure rate;
- t – Number of duty cycles in hours.

Again this result highlights the importance of the electric motor in the system and supports the above presented results.

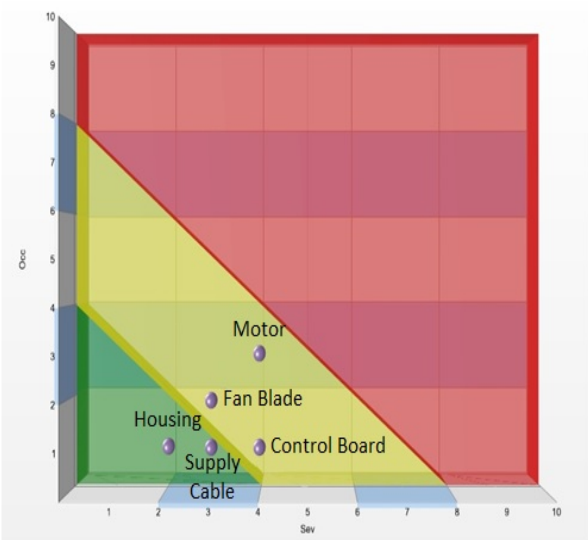

Fig. 4 – Severity Distribution of Components

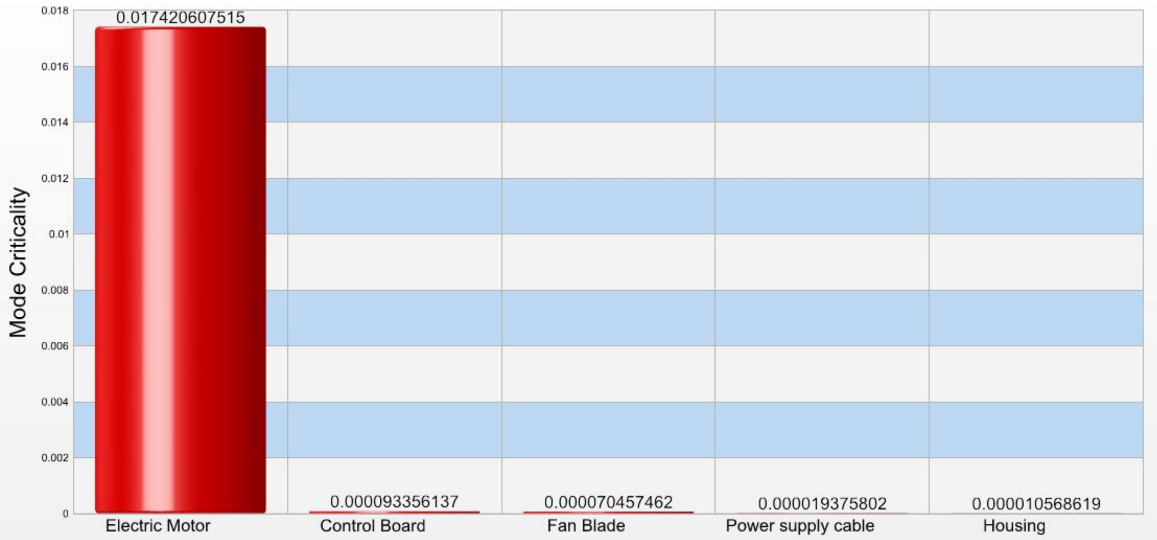

Fig. 5 – Mode Criticalities

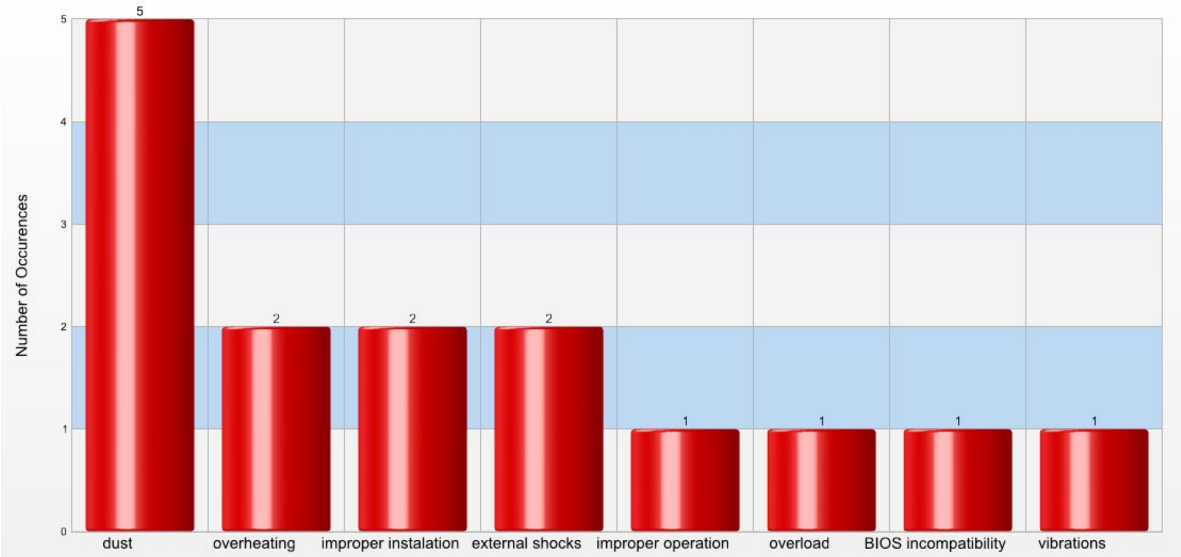

Fig. 6 – Cause of Failure

Furthermore, a study on the causes that lead to the failure of the system can be conducted (Figure 6). On one side, this study can aid the manufacturer by helping them develop the best products and on the other side the consumer as well by helping them maintain the product in the best condition and therefore improving the life expectancy of their product.

From this figure we can see that the dust is the main cause of the cooling fan failure. This leads to overheating and eventually to the loss of the system because of air flow reduction. This cause is due to the fact that the users don't perform proper and timely maintenance. Because of this a lot of defects occur that could be avoided and thus improving the availability of the product.

4. CONCLUSIONS

This paper presents the FMEA of a PC cooling fan that uses a BLDC motor and a magnetic bearing.

The FMEA represents an important study for the manufacturer. This gives important information on how the product can be improved and to consumers on how this product can be maintained to optimal performance in order to maximize the life expectancy.

The findings show that most of the defects that occur on this cooling fan are because of the users and improper maintenance.

This algorithm can be used on other types of cooling fans as well and can give design alternatives in order to produce the best suited product for the market.

In addition this study can be extended on the entire PC in order to determine the causes of fan failure on the PC.

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