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MACHINE DESIGN 2009

THE EDITOR IN CHIEF: PROF. PHD. SINIŠA KUZMANOVIĆ

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ANALYSIS OF THE CAUSE AND TYPES OF THE COLLECTOR ELECTROMOTOR'S FAILURES IN THE CAR COOLING SYSTEMS

Branislav POPOVIĆ
 Dragan MILČIĆ
 Miroslav MIJAJLOVIĆ

Abstract: *The analysis of the causes and modes of failures of the collector electromotors, used for cooling systems of motor vehicles with application of the Fault Tree Analysis – FTA method is presented in the paper. Introduction of the paper points out description of the FTA and significance of the collector electromotors. Based on a detailed review of the structure and operation modes of the observed object and other relevant data, a fault tree for collector electromotor is formed. Thus, a logical relation between the peak event and the basic initiating events from the fault tree is established. In conclusion, the paper presents possible applications of the achieved results.*

Key words: *Reliability, Fault Tree Analysis, Motor Vehicle, Collector Electromotor*

1. INTRODUCTION

The third millennium has been characterized by development of all complex products, with higher level of perfection, with bigger request for working and other features. That demand increase product's functional reliability. The reliability of some products is probability that they shall work in assigned conditions with successful fulfill of demands during cause time period. The simplest product's reliability can be defined by the number of break products during exploitation. However, it is possible to define expect reliability during develop process.

With appropriate analyses product reliability can be forecast and define the weak points of design, with application of quantitative and/or quality methods. Quantitative methods use concepts and steps of mathematics statistics and reliability theory. Those mathematics disciplines provide genesis of special methods for basic reliability calculation index, and those

theories are Bull and Markov theory. The quality methods had assignment to enable systematic investigation of errors and breakdown causes. This group of methods consist FMEA / FMECA (Failure Mode and Effects Analysis / Failure Mode, Effects and Criticality Analysis) and FTA (Fault Tree Analysis).

A subject of research are electro motors with collector type MH-140 KL, products of company Zastava PES Surdulica, implemented for car cooling systems and heating or air conditioning of passenger space in the bus. Production of those electro motors is done according to different technical requests and standards of auto industry. Former request of duration period of electro motors with collectors has been 500 hours of work. Today the most famous world producers of cars and other vehicles demand duration period of 3000 working hours and 10000 hours for buses.

In accordance with producer's regulation task of research is to increase duration time of electro motors with collector from 500 to 3000 hours. To accomplish this task it is necessary to research structure of those motors (electro motors with collector type MH-140 KL) and to define all combinations of possible causes for unwanted event – motor break.

To define possible break causes Fault Tree Analysis (FTA) has been used.

2. FAULT TREE ANALYSIS

Fault Tree Analysis (FTA) is one of the basic and most used methods for analysis of safety and technical system's reliability definition. It is deductive method which define upper event in breakdown form of consider structure or system to reveal causes. Basic of this analysis is translating of physical system into structure logic diagrams. Fault Tree Analysis (FTA) has been developed in early sixties of XX century in USA. The creator was H. A. Watson from company "Bell Telephone Laboratories". During 1961 – 1962, he has developed and applied this method to analyze rocket launch safety system for air force. Since middle of sixties of the XX century till nowadays Fault Tree Analysis (FTA) had a wide application for reliability and safety research and also to define breakdowns of many complex technical systems. This method is particularly applicable for analysis of breakdown with catastrophe consequences for human society or environment.

Fault Tree Analysis uses graphical model for reliability during formation of logical probability. It enables research cause – consequence connection of elements breakdown. With the help of the fault tree it is possible to analyze reliability and safety function and in same time define measurement for parameters improvement in all phases of the duration time.

In the former project phase, creation of fault tree enables identification of potential breakdowns by definition of their causes and creation of the link between them. With project development fault tree starts to spread configuration and on that way all changes in project are scoped. Results of FTA can define critical elements of the mechanical system who affect as limitation for safety and reliable work of the system. By ranging components in the manner of critical designer there is possibility to focus

attention on elements that most effect on reliability, in aim to take all measurements and minimize or completely remove all breakdowns causes. Beside that results can be used for short tests and reliability evaluation.

During safety analysis fault tree serves to define possible causes of different breakdowns with hard consequences for people and environment. Suitable analysis provides discovering such combinations of component's conditions responsible for breakdown and which is not possible to discover on any other way. Tree fault present convenient resource to illustrate advantage of propose solution on others, it is material for argument discussion. If project system contains faults, tree fault can help in finding of weak spots and to show how they lead to unpleasant event. In proper projected system all samples of potential breakdowns can be predicted by tree faults.

Causality system condition defines which lead to breakdowns can be use for evaluation of convenient maintenance and for project of technical system maintenance. During product exploitation phase fault tree can be use as diagnostic mean to establish of most probably appear breakdown causes.

The best result of FTA implementation is when the same is done from develop product team. On that way we have more complete and universal tree fault from the case of individual work.

The worst variant is faults discovering from user side – customer, when the costs are thousand times bigger then at the beginning. This means that costs for organize discovering of potential faults by customer, costs for free service in guarantee period and for eventually replace of product, including lost of customer confidence caused with bad product quality. Results of researches show that the 90% of users, dissatisfied with product quality, will buy that kind of product from competition. The biggest number of faults during develop phase caused indefinite in product plan.

Indefinition of the mechanical system reliability is cause of the fact that breakdowns are very rare and data's collecting of statistic probability is too much expensive and long term project. Except that in earlier product develop phases subject of analyze does not exist and suitable quantitative index for reliability must be estimate according to technical judgment or according to exist information and results of "similar" product testing and that increase indefinite more.

Consequences of indefinite results shortages and faults on quality are seen trough all phases of product's duration time. The world's researches established fact that the bigger number of product quality problems result from faults made during product plan and develop phases, and the smaller number of faults result neglects during duration time.

According to the methodology number and step schedules tree fault analyze of different technical systems had been form methodology tree faults analyze for breakdowns of mechanical system during work period. FTA is one of two tree event analyze and with generalize of noted methodology the tree fault analyze methodology has become with implementation in any technical system. As it shown in the picture, tree event analyze methodology consist:

1. technical system define,
2. establishing of technical system limits and aims,
3. perform event define,
4. systematic collection of system data,
5. tree event creating for establish perform event,
6. tree event checking and adoption,
7. quality and / or quantitative analyze,
8. results considering and checking with demands in view of complete and coincidence,
9. result adoption and
10. represent of results and suggestion for correction measurements.

If the fault tree does not reflect real condition or all important event are not include or do not exist logic connection of basic and perform event, the additional data collected will take and tree fault modification. To eliminate subjectivity during formed tree fault evaluation participate people who know used methodology and subject of investigation and who were not involve in tree producing.

3. SIGNIFICANCE AND ROLE OF VEHICLE COOLING SYSTEM

Security and safety have a special place in all vehicles' types. Safety increase can be achieved by taking measurements of accident prevention (active security) or, taking measurements for minimum consequence in case of accident (passive security). Vehicle cooling system is one of most important system for internal-combustion engine security and safety. It provides that engine's working temperature is in permit limits and without breakdown.

Components of car cooling system (Fig. 1): liquid, radiator, water pump, thermostat, tubes, fan electro motor (in further text electro motor with working circuit), it need to reduce temperature in very short time and to prevent internal-combustion engine damage.

The most important system for vehicle cooling system is electro motor, it moves rotor of working circuit, and in further course it will consider EM structure and functional way.

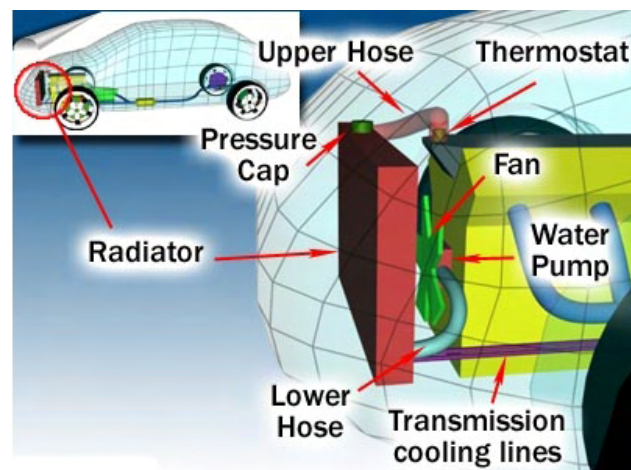


Fig. 1. Diagram of a cooling system

4. COLECTOR ELECTRO MOTORS STRUCTURE AND FUNCTIONAL TYPE

For detail EM sample analysis and breakdown causes analysis is necessary to know structure, functional way and relation of integral elements. Only complete knowledge of EM functional way and its elements, as knowledge of their relation, provide logistic analysis which defines all conditions for object breakdowns.

Figures 2, 3, and 4 show the parts of electro motors which built on car cooling systems.

Similar design solution apply and for wind screen wiper, wind lift, central locking system, seats and back of seats moving systems and on others places in vehicle. Former solutions used one or two electro motors by vehicle, nowadays 20 or 25 by vehicle.

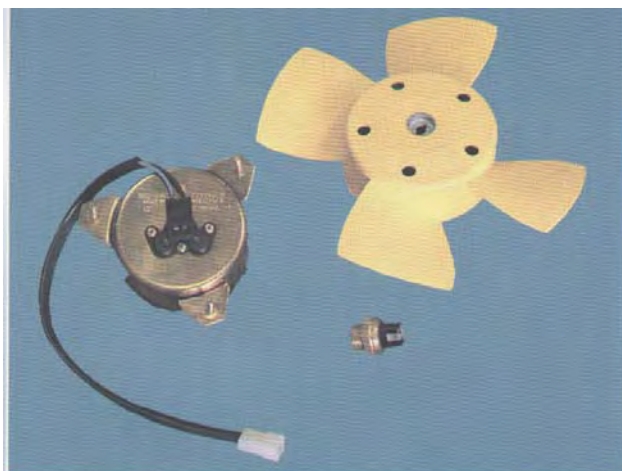


Fig.2. Electro motor, fan and thermostat



Fig. 3. 3D electro motor model

Electric machines with direct current are deceiver of mechanical into electrical energy (generators) and in other way (electro motors). Every electric machine for direct current is reversible; it can work as engine for direct current and as generator of direct current.



Fig. 4 a. Electro motor with rotor (rotor without collector and wire), circuit and electro motor



Fig. 4 b. Electro motor with rotor (rotor without collector and wire), circuit and electro motor

Electro motor with direct current has mass use in car industry and they are with collector. It consist from rotor with shaft, rotor sheet packing, collector, wire coil, stator part of bend frame with ceramic magnets, cover with sinter bearings (bronze or iron) or with so call ball bearings and brush carrier with brushes and wires.

Stator with inductor role has relatively smaller cylinder (frame) with magnetic poles in inside scope. Rotor consist from sheets which is place direct on shaft for smaller machines with preliminary furrow and that is engine surface cooling. Collector consist large number of lamellas (cooper and silver alloy). Each lamella must be isolated from other and metal parts (mass). Brushes have placed in holders with spring for brush pressing on rotor. They are made of amorphous coal, graphite or of metal threshold (cooper or bronze) and their mixture.

Leading of direct current on brushes, through coils shall flow current, machine shall start to move according to rule of left hand in opposite direction. Motor turning direction with direct current can be change if we change current direction through rotor. When it turns start induction of electro motor force in rotor.

5. FAULT TREE SYSTEM FOR COOLING SYSTEM

Purpose of fault tree form of system for liquid cooling is analyzed in detail for potential breakdown and note of all ways of system element faults.

The fault tree for liquid cooling is show in figure 5. Breakdown of this system can appear OR because of some inside breakdown OR because of the outside breakdown. Outside breakdowns can begin because of some outside elements' breakdowns which are not parts of cooling system.

Inside breakdown can be: electro motor's lost of function, thermostat, circuit cooling liquid pumps, safety device burn out, tubes burst and radiator leak. Thermostat is cooling system substructure and in base it is bimetal switch which turn on motor if temperature of cooling liquid over issued value which is between 96 °C and 98 °C depend of motor construction. Thermostat can lose the function from more different causes or because of long term use, or material hidden fault which reduce lasting. Service is not possible only replacement wit new if the fault is in bimetal, if the fault is in connection wires and contacts problem will successfully solve by service. Cause of tube burst is fault which can begin from many reasons: no qualitative rubber, no possible liquid leak or tube material growing old. Fault of radiator leak is possible by mechanical damage, or if radiator is from cooper, corrosion is also possible by touch with cooling liquid use in winter time (antifreeze, etc.). Nowadays radiators produce from aluminum so the corrosion problem has been solved.

Very important substructure of car cooling system is electro motor – fan. Electro motor fault can cause catastrophe breakdown on gasoline motor.

6. FAULT TREE FOR EM WITH COLLECTOR IN CAR COOLING SYSTEM

Full or partial electro motor breakdown can appear in cool liquid cooling system of vehicle. Fault which reduce turn moment mostly are called friction faults. Friction faults appear cause of worn-out friction surface, materials un-homogeneous, dirt or grease surface and etc. total faults appear when motor can not achieve start turn moment: ball bearing faults, connection between connection and wire, collector brushes worn-out or structure part deform. In case of partial faults, working performances are aggravated. That is manifest through turn moment reduce under issued by technical demand.

Main event "Electro motor fault" in electro motor tree fault, show on figure 6, is define to include all events which lead to complete or partial electro motor working capacity and on the same way to car cooling system. Electro motor with collector is incorrigible system as need for car cooling system. This product can not be repair during duration time by its cause and request quality, that means to made working performance during exploitation issued by technical request. EM collector production tendency request of motor to satisfy ppm 1 – on one million produced motors it can be only one fault.

Possible electro motor faults: mechanical connection break, current break, moment reduce under permit and vibrations.

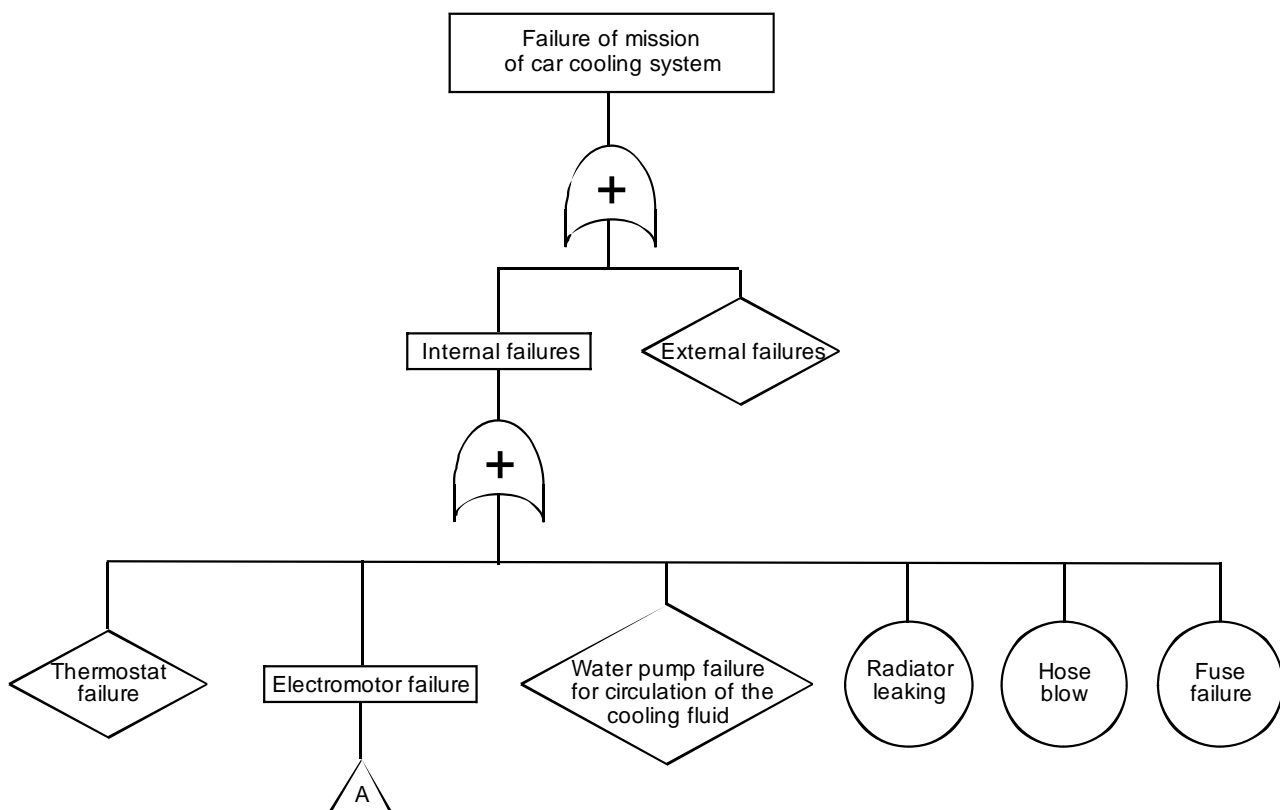


Fig. 5. Tree fault of car cooling system

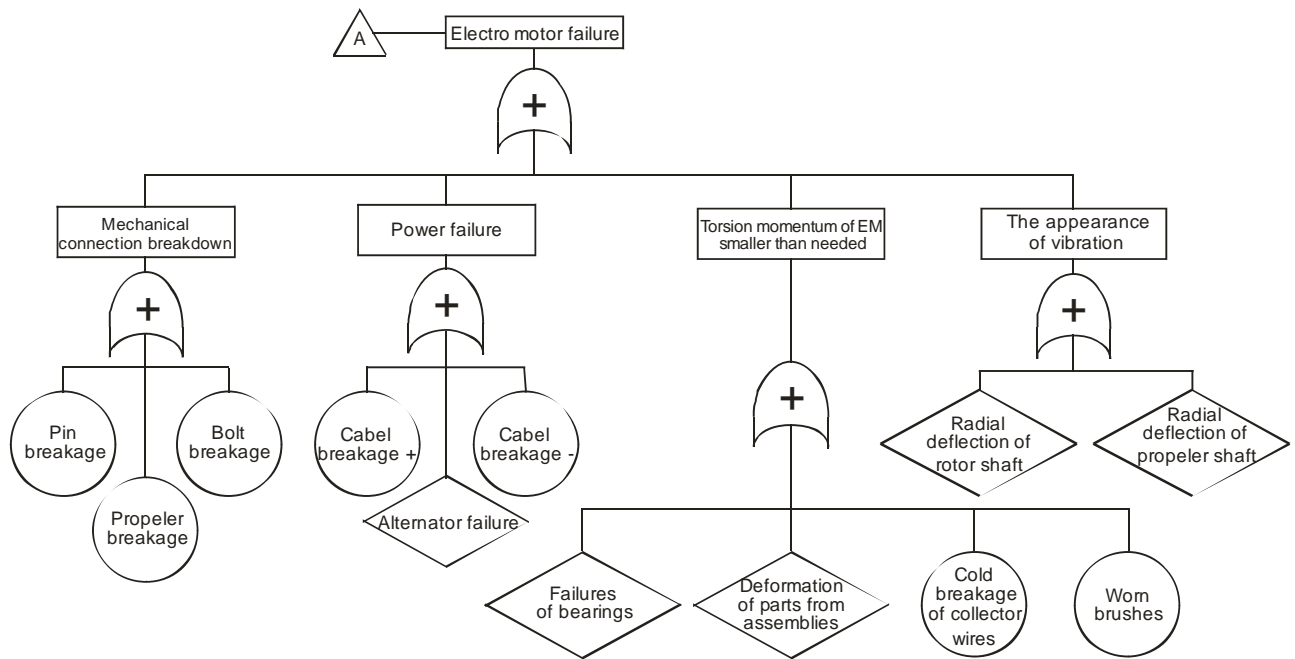


Fig. 6. Tree fault electro motor

Mechanical connection are made by electro motor connecting with screws or rivets, the using screws have welding on motor holder and can be break because of material harden during welding, material faults (hide defect) or increased clearance in holder. Possible connection fault also is bolt break which connects electro motor and fan. Nowadays use of elastic bolt and the only fault caused by material (hide defect) or with bigger shaft hole, and this should not happened on new electro motor cause of 100% control, and also on electro motor with longer working time but that is not now in consideration. Fan break can be cause by screw or bolt break, and also during contact with, for exp. Car motor part (belt, etc.) or with foreign part. These fault leads to electro motor destroy as previous two.

Current break caused by cable break (+) and (-) which can be oxidized at the end, or by their fall. Alternator fault is serious problem which can cause vehicle ignition. Alternator fault, except in mention case, is very rare, it can be repaired and can not cause instant vehicle stop.

EM turn moment reduction can be cause by bearing fault, brushes worn-out, cold solder of collector wire and part deforming.

Vibration faults which happened exceptionally by damaging of electro motor or fan lead to duration time reducing. Those faults are very rare during electro motor duration time and have a small possibility of faults as brushes worn-out and bearing fault.

Correct bearing selection – important for EM reliability. Bearing working conditions: out side temperature from -40 °C to +80 °C, temperature of 140 °C on spot where brushes touched with collector, oil and dust. It is important to choose a quality and reliable bearing, but also it must fulfill and other assumes for reliable work. Vibration – unbalance must be in designed limits and if it possible with strict tolerance field. Out side ring must be softly put in cover for temperature dilatation. This can be solved by putting of distant rubber ring or tolerance metal ring.

So called “cold solder” can be if wire welds with dirty electrodes or by incorrect welding regime caused by electrode worn-out. After welding checking on mΩ fault can be removed 100% if tolerance welding is maximum 1 mΩ.

Brushes worn-out is most complex problem caused by many reasons as bad collector material or brushes, un quality collector processing, impossible lead of heat from brushes caused by holder construction.

Electro motor parts deforming caused as result of increase temperature above permit by bearing blocked – bearing fault, by cold solder or brushes worn-out.

During friction period the surface starts to worn-out. Along with moment reduction noise as also appears caused by metal friction. Important performance of all materials is worn-out intensity.

EM working period depends of material features.

7. CONCLUSION

In accordance to above note it can be concluded:

The most important aims of fault tree of car cooling system, with special attention on electro motor, as key substructure:

- systematic identification of all possible causes combinations which lead to unwonted event;
- determinate of factor which most seriously affect on certain reliability measurement and application need for measurement improvement;

With fault tree analysis of the basic events for collector EM it can be concluded in which direction collector EM development need to go – increasing of working time from 300 to 5000 hours, and except invest in development and material quality control improvement, parts and subparts, new equipment for production, this product does not charge – input price increasing for raw materials (material and parts).

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CORRESPONDENCE



Branislav POPOVIĆ, M.Sc.Eng.
Regional Chamber of Commerce and
industry Leskovac
Stojana Ljubića 12
16000 Leskovac, Serbia
branislav.popovic@komora.net



Dragan MILČIĆ, Prof. D.Sc. Eng.
University of Niš
Faculty of Mechanical Engineering
Aleksandra Medvedeva 14
18000 Niš, Serbia
milcic@masfak.ni.ac.rs



Miroslav MIJAJLOVIĆ, M.Sc. Eng.
University of Niš
Faculty of Mechanical Engineering
Aleksandra Medvedeva 14
18000 Niš, Serbia
miroslav_mijajlovic@masfak.ni.ac.rs

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