DEVELOPEMENT OF AUTOMOTIVE RADIATOR COOLING FAN

Branislav Popović[1], Dragan Milčić[2], Miodrag Milčić[3]

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1. INTRODUCTION

For a company to develop, it is pre-requisite to maintain the existing market and expand it, if possible. To achieve this, it is necessary to meet market demands on a continuous basis, whereas the market tends to place more and more complex demands for productivity, quality, reliability, design and rate at which new products are mastered.

Nowadays, the characteristics of the global market are customers' demands domination and market globalization which result in more intense competition. What has become a problem is to sell the product, and not to manufacture the product. To survive, manufacturers need to shorten the product life cycles, improve product quality and reduce the price. This is explicit in the most demanding industries, car and aviation industry.

As an example of a new product development, this paper describes development of a next-generation engine cooling fan, a system consisting of DC engine and radiator cooling fan. The engine cooling fan motor cools air conditioning system cooler of the IC engine and vehicle air conditioning system.

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.

Collector electro motors (DC engines) with brushes apply 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. These designs differentiate in non-existence or existence of the transmitter-reductor of various types and shapes.

System for motor vehicle cooling is one of the most important systems for safety of internal combustion engine (IC engine), and engine cooling fan motor is a key subsystem of this system. It ensures that engine operating temperature is within allowed limits and it protects engine from failure of entire internal combustion engine, and vehicle in whole. This engine cooling fan motor is a key subsystem for vehicle air conditioning as well, because it cools air conditioning system cooler at the same time.

Engine cooling fan motor and other motor vehicle cooling system components differentiate in load. The motor vehicle cooling system components are stationary and subject to the load of their own weight and vibrations made by the internal combustion engine and vehicle on the move. Besides the above mentioned loads, the engine cooling fan motor has its own heating and rotation which leads to wear and tear of its parts. Thus, the

[1] *Branislav Popović, Ph.D., Regional Chamber of Industry Leskovac, Stojana Ljubića 12, Leskovac, Serbia, branislav.popovic@rpkle.rs*
[2] *Dragan Milčić, Ph.D., Professor, University of Nis, Faculty of Mechanical Engineering, Aleksandra Medvedeva 14, Nis, Serbia, milcic@masfak.ni.ac.rs*
[3] *Miodrag Milčić, University of Nis, Faculty of Mechanical Engineering, Aleksandra Medvedeva 14, Nis, Serbia, miodrag21@gmail.com*

potential failure of this component is far greater. Breakdown of the engine cooling fan motor will result in failures due to the engine overheating. Other components breakdown causes failure as well, but rarely a sudden failure of the internal combustion engine.

DC engine is a subsystem of mentioned systems which has the most important influence on no failure engine cooling fan work, and according to that, on no failure work of engine cooling system and vehicle air conditioning system. The main subject of this paper is development of engine cooling fan from the reliability aspect, in fact, according to required work life of 3000 hours.

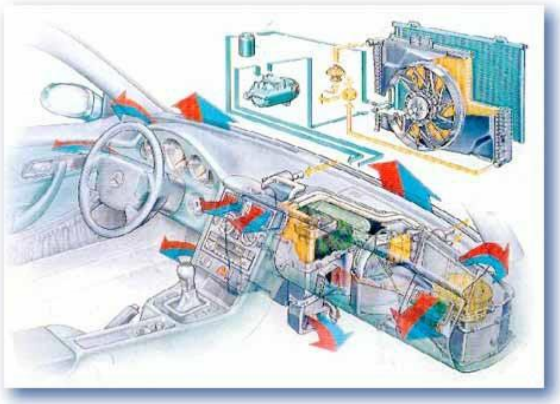

Figure 1 Modern motor vehicle cooling system and IC engine cooling system

TECHNICAL REQUIREMENTS FOR A NEW PRODUCT

According to the prescribed technical requirements, installation data are defined as well:

- Working circuit (engine cooling fan) diameter max 310 mm,
- Engine cooling fan motor length max. 87 mm,
- Stator diameter max. 108 mm,
- Position of three screws for mounting holders, diameter 138 mm, on angle 120°.

The product has to meet TR 9.93160 and it has to be in accordance with regulations and the above said technical requirement. The engine cooling fan motor is tested: in the free air, test chamber and road testing installed in cars. The samples tested according to TR must be fracture or loose free. If there is a fracture or loose, it should be considered that the engine cooling fan motor broke down regardless of being in function and it is regarded as faulty.

Defined functional requirements in free air are:

- Housing temperature, measured after 1 (one) hour work with nominal (V) +15% should be ≤ 45 0C power consumption when nominal voltage is ≤ 8, 5 A, no load,
- Electro motor number of revolutions per minute (rpm) when nominal voltage should be $3000 {}^{+200}_{-100}$ min^{-1},
- Airflow over Q = 2000 m^3/h in free space.

Also, defined characteristics of the electro motor are:

- Power released in the point of functioning, at test speed in the centre of the specified tolerance in the free air – 50W ±10% with no load,
- Maximum power at speed 3000 min^{-1}- 200, W±10% with load (working circuit),
- Current intensity should be ≥14A ±10 at speed 3000 min^{-1}
- Jerk moment, ≥ 75 daN/mm,
- Current intensity ≤ 32 A at start.
- Fan extrusion force (with mounted plastic fan only), after 4 hours at temperature 80 ±2ºC - ≥ 70 daN,
- Noise max. 40 db,
- Vibration testing should be completed without fractions or distortions of components; the electro motor should function in free air within specified tolerances,
- Thermal cycles, 4 hours at +100±2ºC - 4 hours at +40±2ºC –
- 90 ÷ 95 % relative humidity, + 4 hours at - 40°C - no fraction or deformation, functioning free air, max. drop 10% in comparison to the values measured on a new part, product ,
- Low temperature, class 4, - 40±2ºC - regular jerks, speed in free air within specified tolerances, permissible noise is higher at start,
- Jerks in cold mode, 10 jerks lasting 1 s each with nominal test voltage
- Testing environment -40±2ºC - motor, max.drop 10% in comparison to the values measured on a new part,
- Insulation resistance ≥ 1 MΩ, no abnormalities,
- Work life 3000 hours, nominal voltage with max. Tolerance +15%, at environmental temperature 80±2ºC , 1500 hours of continues work and +1500 hours of intermittent work; every 53 s “ON” +7 s “OFF”.
- Insulation resistance ≥ 1MΩ, functioning in free air.
- Max. drop for 15% in comparison to the values measured on a new part.
- Brush worn-out ≤ 95% of useful length.
- Insulations, collector, plastic components, bearings and/or bushes are well maintained,
- Insulation resistance, measured between positive clamper and mass, is ≥ 10 MΩ,
- Disruptive discharge voltage measured between positive clamper and mass is 1000Vef,
- Residual unbalance, quality grade Q = 6,3 ÷ 15 gr mm.

RELIABILTY ENGINEERING IN DEVELOPMENT OF NEW ENGINE COOLING FAN MOTOR

High reliability is a very desirable characteristic of every product, system or facility. In industrial systems and facilities, reliability directly influences inherent availability and return on investment. For commercial products, high reliability can provide to a manufacturer a competitive advantage, which leads to the increase of the market share, and thus to bigger profits.

In all cases, product or system reliability greatly depends on the decisions made during the design and development of the product. The design failures affect all produced objects and designing failures out of the system is more expensive with already developed products. It is not profitable to change design products already released to production. Reliability is a design parameter, and as such, it requires specific design and effort to achieve the required reliability level.

Every suggested solution (whether concept or detail designs) has to be verified before production in conditions defined by regulations or standards. Verification implies analysis and testing which are performed to confirm conformity with the requirements. Reliability engineering is integrated into the product development process. There are two main aspects of the reliability engineering:

1. Reliability engineering is an iterative process.
2. Reliability engineering is a part of the system of engineering processes.

Reliability engineering is a multidiscipline approach simultaneously implemented in each phase of a product life cycle. The design phase includes detail design and design validation before production. All reliability activities performed before production phase are proactive activities. The activities become reactive when the product or system is released to production. Detail design changes made after the product is being released to production is far more expensive and requires more time to implement those changes.

The approach to the product development based on the desired work life, which is used in the development of the engine cooling fan motor, is shown in figure 2.

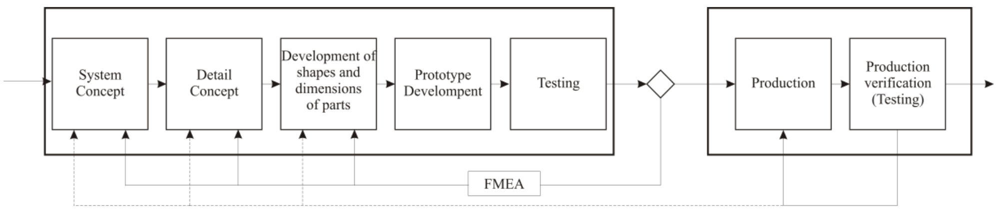

Figure 2 Product development based on the desired work life [1]

In order to prevent, i.e. avoid potential failure effecting the new products, it is necessary to implement the appropriate methods and techniques to minimize the likelihood of those failures in the development phase [4, 5]: FTA (Fault Tree Analysis), design/process FMEA (Failure Mode and Effects Analysis), etc.. In case of development of this new engine cooling fan motor during the development iterative process, it has been used the design and process FMEA, which represents the basis for corrective actions to be carried out on the existing design. The FMEA is the basis for the prototype production as well, after which testing was performed according to the requirements specified in TR.

Figure 3 and 4 show the original and final versions of the engine cooling fan motor.

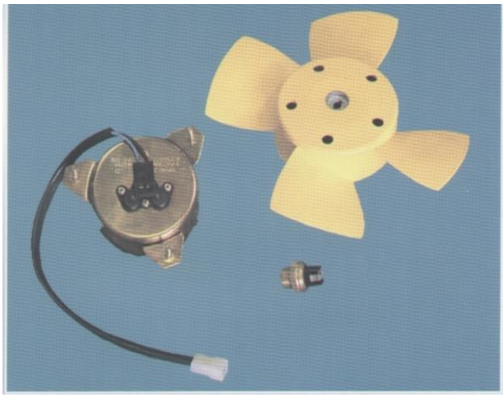

Figure 3 Original version of the engine cooling fan motor

Figure 4 Final version of the new engine cooling fan motor [1]

The test results were verified and the new product was homologated. Homologation was carried out in Zastava Institute, Kragujevac. Three samples were submitted to the testing. Work life test was carried out on the two samples. Test conditions were: 3000h of work at U=13V and T=80°C.

Testing is very important part of the product validation process and it should be conducted before the full production starts. So, every version of the engine cooling fan motor has been tested till failure. Reliability indicator was the work life of the engine cooling fan motor which, as previously said, is to be 3000 hours. The engine cooling fan motor was being developed in the iterative process until the version which fully meets the defined development goal hasn't been developed.

Sample 1 failed after 4100 h due to the worn brush (-), worn out under 2/3 of its length.

Sample 2 failed after 4960 h due to the worn brush (-) as well.

Verification of the newly designed engine cooling fan motor can be performed by parallel testing of the newly developed engine cooling fan motor and competitive engine cooling fan motors. The aim of this testing is to determine similar and different performances of the newly designed engine cooling fan motor and the engine cooling fan motors of similar size, characteristics and use.

The parallel testing included measuring of the physical quantities (pressure and temperature drop) taken at 16 measuring points set up at the safety circuit output, rpm 3000 min^{-1}. The parallel testing was carried out on the newly developed engine cooling fan motor and the engine cooling fan motor rival manufactured. Figure 5 shows the equipment used for the parallel testing.

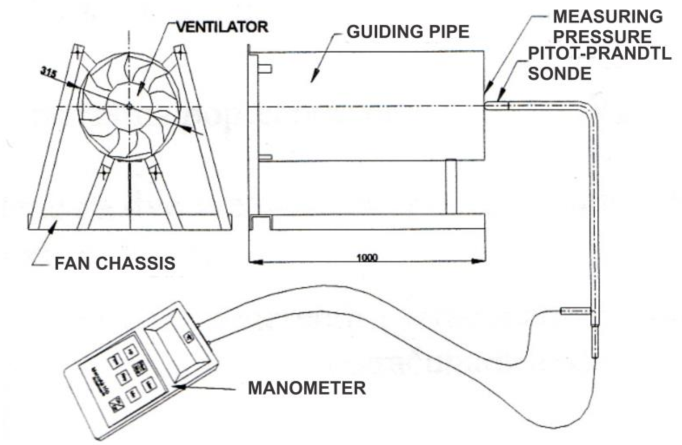

Figure 5 Measuring equipment used for the parallel testing of the engine cooling fan motor

Figure 6 shows the airflow speed values in relation to the measuring points, at n=3000 min^{-1}. The diagram shows the ratio between the airflow speeds of the new engine cooling fan motor and the rival engine cooling fan motor.

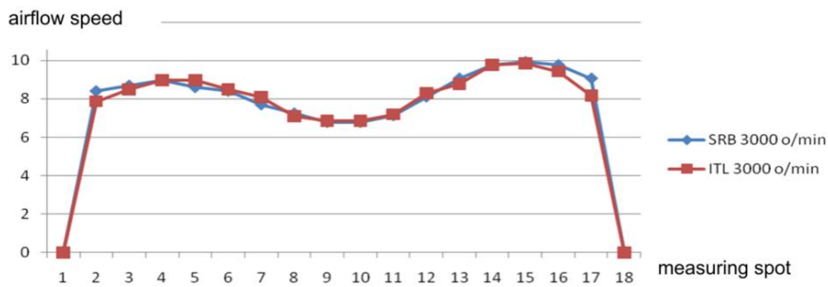

Figure 6 Airflow speed in relation the measuring points

Based on the results of parallel testing [1] it can be concluded that the new product, engine cooling fan motor, doesn't fall behind the similar competitive products, but achieves adequate parameters with the smaller mass.

CONCLUSIONS

On the basis of the realized development of the new product (engine cooling fan motor), which is described in this paper, and results of testing, validation, verification and homologation of the new product at the end of the iteration process, pursuant to the specified work life, it can be concluded:

- New type of DC engine with performance required to be competitive on the world market has been developed.
- New form of the fan and deflector has been developed.

- New type of the engine cooling fan motor with the desired work life of 3000 hours used to cool the IC engine and to regulate the thermal comfort of a vehicle, has been developed.
- Experimental verification of each iterative developmental version of the engine cooling fan motor has been performed until the sample failure in the chambers which simulate operating conditions in service.
- Homologation testing was performed and the final version of the engine cooling fan motor was confirmed in the institution accredited to perform homologation testing.
- New engine cooling fan motor delivering greater power per mass unit has been developed.

This engine cooling fan motor can be installed in cars driven in areas with lots of sunny days (e.g. North Africa, Middle East), and vehicles with air conditioner. The delivered product is highly perspective to be exported to the Russian, European, Far Eastern, etc. markets as well.

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