Automotive Water Cooling System Analysis Subject to Time Dependence and Failure Issues

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ABSTRACT

In an automobile engine, the heat transfer cannot be possible without cooling system support. The cooling system has a great importance in the engines. It coolants overheat of the engine, and prevents it from breakdown, that’s why a highly reliable cooling system is the necessity of every engine but there are many failure issues with a cooling system which are time dependent. This paper investigates the performance of a water cooling system with the consideration of their significant components by taking the attention of three types of time dependent failure issues while the water cooling system is maintained by the sufficient repair facility. It is obvious that in the lack of maintenance, failure issues in water cooling system lead with the increment of time. Maintenance and operating costs of water cooling system affect the economy of overall engine very much, so, it is necessary to be aware about overheating of engines during peak ambient conditions when it is operated with full capacity. Hence, a Mathematical model of water cooling system is proposed by using the Markov process and supplementary variable technique.

KEYWORDS
Cost Analysis, Failure Factors, Radiator, Reliability, Sensitivity, Stochastic Simulation, System Engineering, Water Cooling System

INTRODUCTION

Now-a-days, all of us are depending on machines for almost all works. So, the machine has a progressive prominence. The engine has a great importance in the appropriate functioning of any machine, but to prevent the engine from over-heating, water cooling system plays a very critical and significant role in the functioning of any engine. Hence, the performance and maintenance of the
cooling system are tremendously important for every machine. High reliability of the water cooling system becomes more significant issues in daily life and necessary in relation to the machine and the automation of industrial process. Reliability of the water cooling system is a key element in performance evaluation and life testing of engines. Water cooling system’s reliability is one of the fundamental quality characteristics which deal with the behaviour of each apparatus of the water cooling system. Reliability of the designed water cooling system represents the probability of non-failure components, sub-systems and system to perform their required functions for a particular time period in specified environmental condition (Verma et al. 2010; Ram, 2013). Reliability work on the water cooling system introduces two basic concepts that have central prominence, namely modelling of the designed water cooling system and their state transition probability. The extension of reliability includes various system performance levels such as rate of work completion, the response time, or the number of jobs completed in a given time-interval.

Many researchers have done a lot of work on water cooling system and reliability, but no one has measured the performance of the cooling system with reliability characteristics. Setlur et al. (2005) studied the two cooling system actuators having different configuration, with accompanying non-linear control strategy. They also presented non-linear control algorithms for temperature regulation. Fong et al. (2009) constructed a response surface for the passive cooling system and verified it with thermal-hydraulic condition. They analyzed the reliability of passive cooling system and uncertainty of response surface and also found their sensitivity. Walentynowicz and Krakowski (2010) developed the model of the engine cooling system for high coolant temperatures using AmeSim software and found that filling the cooling system with coolant does not affect the temperature for the different values of implicit pressure cooling system test. Salah et al. (2010) discussed an assembled multiple-loop servomotor based smart cooling system and controlled it utilizing a Lyapunov-based nonlinear controller. They analyzed that control strategy successfully maintained the engine coolant and transmission fluid temperatures to set point values with small error percentage. Amrutkar and Patil (2013) studied the key factors that affect the radiator performance of the cooling system and discussed the several approaches to improve its performance. Torregrosa et al. (2014) performed some experiments on sub-cooled flow boiling in the low velocity range and temperature condition which is very attractive for engine coolant. They found the initial results with the comparison of reference chen-type model and concluded that there seemed evident inconsistencies at higher wall temperature, mostly in the case of the highest inlet coolant temperature while the reference model provided reasonable results for less than 135 degree wall temperature. Pandit and Ali (2012) developed a new approach for the simulation and reliability analysis of Laser-Welded Blanks (LWB) after finishing the metal surface and compare the findings with the analysis of actual developed method and to detect the bottlenecks and optimize the process. Sethi and Kumar (2012) proposed a mathematical model of flank wear with the help of response surface methodology and investigate the tool wear at diverse cutting constraints.

The performance of the water cooling system is affected by several failure issues and maintenance of it depends upon the time and repairs. Water cooling system configured with some sub-system such as radiator, fan, water pump, thermostat and hoses. Because of these components, failure issues can occur in the water cooling system, known as equipment’s failure. Water cooling system failure is assumed to occur when the temperature exceeds a value that is considered acceptable (Walentynowicz & Krakowski, 2010). Here, the authors study the performance of water cooling system under the consideration of three types of failures namely equipment’s, common-cause failure and human error. Common-cause failure is the failure when the water cooling system is failed due to any common reason at a particular time [Dhillon and Anude (1994), Mosleh (1991)]. Human failure is the major contributor to the reliability and safety of the systems. It is the failure of the system that exists by taking an inappropriate or undesirable decision or behaviour [Dhillon and Yang (1993), Dhillon and Liu (2006)]. Equipment’s failures are affecting the performance of its other parts by which performance of the overall cooling system is affected. Performance of radiator is strongly affected by the air and coolant mass flow rate. Cooling air flow is one of the essential factors which affecting the radiator
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