Parameter Optimization of Thermal Barrier Coatings used in Two Stoke Externally Scavenged S.I. Engine using Non-Traditional Optimization Algorithms

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ABSTRACT

Various researchers have studied and introduced, although limited, varieties of thermal barrier coatings (TBC) materials. Each of these TBC materials has their own respective properties. Considering all these properties which one will be the effective choice among the available lot is very difficult to estimate. The optimisation is carried out using non-traditional optimisation techniques namely simple additive weighting method (SAW), weighted product method (WPM), technique for order preference by similarity to ideal solution (TOPSIS) & preference ranking organization method for enrichment evaluations (PROMETHEE) are used to find out the best optimal choice for the specified engine. The results of the above mentioned algorithms are compared and presented in this paper to decide which tbc material will perform comparatively better & give accordingly the good results.

KEYWORDS

MADM, PROMETHEE, SAW, SI Engines, Thermal Barrier Coating, TOPSIS, WPM

1. INTRODUCTION

Ceramic coatings were firstly introduced in the late 1940s & 1950s for the use in gas turbines. Turbine blade materials are nickel based alloys having melting temperatures up to 1589K. the first application of TBCs for aerospace was developed by National Advisory Committee for Aeronautics (NACA) and the National Bureau of Standards (NBS)17.

In case of steam turbines also, the turbine blades are exposed to the high temperature steam which leads to oxidation, thermo-mechanical fatigue, hot corrosion and creep in the blade materials. Appropriate thickness (few hundred microns) is applied on these blades to avoid the aforesaid problems. The TBC materials have been extensively used in internal combustion engines. Of course the working environment in case of steam turbines is very different than that of in IC engines. In former, the service temperature is very high, in the order of 1000°C to 1100°C where as in IC engines it is less than 750°C. The traditional turbine material reaches to its limit of temperature capabilities. Application of the TBCs will not only increases the efficiency but also reduces the requirements of the cooling system. It also helps in developing the overall performance of the system.

While selecting any Thermal Barrier Coating for any applications we have to take into account the following factors: (1) high melting point, (2) no phase transformation, (3) low thermal conductivity, (4) chemical inertness, (5) thermal expansion match with the metallic substrate, (6) good adherence to the metallic substrate and (7) low sintering rate of the porous microstructure18.
Internal combustion engines are indispensable prime mover in various sectors like transportation, agriculture, sports, etc. Engineers always struggle for enhancing the efficiency & performance of these engines. Two stroke SI engines have problems of high level of pollutants and higher fuel consumption as compared to 4 stroke engines. These drawbacks of two stroke engines are due to short circuiting phenomenon. In short circuiting process, there is a mixing of fresh air fuel (charges) with exhaust gases and nearly 35% of fresh charges are lost through exhaust valve. This loss is dead loss and it has to be avoided. Short circuiting can be avoided by adopting proper scavenging system and coating various parts of the combustion chamber. These coating will also help in maintaining the engine emissions within the acceptable range.

In Internal Combustion Engines most of the heat generated during combustion process is absorbed by piston & the walls of the combustion chambers. This is the direct heat loss to the piston & surrounding walls. This reduces the Power generated and in turns the performance of Internal Combustion Engine. To overcome this problem, the thermal barrier coatings are used. Using the coated piston, the required temperature in the combustion chamber will be maintained. This will reduce the heat loss to the piston. This reduction in the heat loss will be used to burn the unburnt gases thereby reducing the polluted exhaust gases.

2. MULTIPLE ATTRIBUTE DECISION MAKING (MADM) METHODS

The Multiple Attribute Decision Making (MADM) methods are used to solve the problems of selecting the best optimal alternatives among the given multiple alternatives which are having multiple attributes. The objective of all these attributes have to be decided based on the problem statements. For some attributes it may be maximization & for some it may be minimization. Again these attributes will have its weight or relative importance. All this information is represented in Table 1.

Various MADM methods include weighted sum method (WSM), weighted product method (WPM), technique for order preference by similarity to ideal solution (TOPSIS), analytic hierarchy process (AHP), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), etc. among these, TOPSIS and PROMETHEE are very widely used. Both these methods give a very close Ideal preference of choices as per the given data.

The TOPSIS technique gives the best optimal alternatives which have the shortest Euclidean distance from the ideal solution. It means that TOPSIS gives a solution which is not only closest to the hypothetically best, but also farthest from the hypothetically worst.

The method, PROMETHEE, is introduced by Brans et al. The literature survey reveals that PROMETHEE has also have a lot of applications in various fields of science & technology. However, it had limited applications in the field of mechanical engineering. Recently in wee years its applications have been increased.

The above decision table consist of alternatives, Ai (for i = 1, 2, . . ., n), attributes, Bj (for j = 1, 2, . . ., m), weights of attributes, wj (for j = 1, 2, . . ., m) and the measures of performance of alternatives, xij (for i = 1, 2, . . ., n; j = 1, 2, . . ., m). After collecting the above information, the decision maker has to apply various MADM techniques to get the best optimal choice/rank of alternatives. All the values in the decision table have to be normalized so that we can consider all the possible attributes in the decision problem.

Step 1: Preparation of Decision Table

For any given problem there may exists multiple attributes. We have to select the relevant attributes such that these attributes play a vital role as per given problem statement. These attributes namely of two types: 1) beneficial and 2) non-beneficial. For beneficial attributes, a maximum
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