THERMOECONOMIC OPTIMIZATION OF THE ENERGETIC PLANT WITH INTERNAL COMBUSTION ENGINES BY USING STOCHASTIC PROGRAMMING METHODS

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Abstract: In this paper is presented a wording of the thermoeconomic optimization of the energetic plants with internal combustion engines and the consideration of some stochastic independent variables by using stochastic process optimization methods since the design phase.

Keywords: Thermoeconomic optimization, internal combustion engine, linear programming, mathematical models.

I INTRODUCTION

The optimization of the energetic plants with internal combustion engines may be formulated by two separate situations at those objective functions are determined by different independent variables and restrictive conditions applicable for energetic plant design for internal combustion engines or energetic plant operatings for internal combustion engines.

Thermoeconomical optimization statement problem will be made based on a thermodynamic and economic combined analysis of the energetic plants with the internal combustion engines[1].

II ENERGETIC PLANTS DESIGN OF INTERNAL COMBUSTION ENGINES OPTIMIZATION PROBLEM

By considering energetic plants with internal combustion engine consisted by the following subsystems as: internal combustion engine, power transmission, energetic plant consumer, it results different statements for optimization problem due to different energetic plants with internal combustion engines and having distinct destinations.

In general, the problem is formulated by adopting only one optimization criterion, many criteria matching with restrictive conditions by type of (in) equalities or in other cases even without restrictions. For energetic plants with internal combustion engines used on means of transportation there are adopted levelized operating and maintenance specific costs in their long life-time like durability or working life.

Specific cost independent variables of the energetic plants designed for internal combustion engines are:
- type of internal combustion engines (spark-ignition engine, compresion ignition engine, charged or supercharged engine), $x_1 \in N$;
- constructive characteristics and materials used for internal combustion engine construction), $x_2 \in N$;

- internal combustion engine design technology, $x_3 \in N$;
- manufacturing technology of internal combustion engines, $x_4 \in N$;
- capital investment total rate for internal combustion engine, $x_5 \in R$;
- operating and maintenance cost rate, $x_6 \in R$;
- fuel cost rate or exergetic efficiency for internal combustion engine, $x_7 \in R$ or $x'_7 \in R$;
- type of power transmission (mechanic, hydraulic, pneumatic, electric, combined, etc.), $x_8 \in N$;
- power transmission constructive characteristics and materials, $x_9 \in N$;
- power transmission design technology, $x_{10} \in N$;
- power transmission manufacturing technology, $x_{11} \in N$;
- capital investment total rate of power transmission, $x_{12} \in R$;
- operating and maintenance cost rate, $x_{13} \in R$;
- fuel cost rate or internal combustion engine exergetic efficiency, $x_{14} \in R$ or $x'_{14} \in R$;
- energetic plant consumer type (driving wheels, driving axles, propeller, electric generator, compressor), $x_{15} \in N$;
- constructive characteristics and consumer materials, $x_{16} \in N$;
- consumer design technology, $x_{17} \in N$;
- consumer manufacturing technology, $x_{18} \in N$;
- capital investment total rate, $x_{19} \in R$;
- operating and maintenance cost rate, $x_{20} \in R$;
- consumer exergetic efficiency or corresponding fuel cost rate, $x'_{21} \in R$; $x_{21} \in R$.

The x_1, x_2, x_3, x_4, x_8, x_9, x_{10}, x_{11}, x_{15}, x_{16}, x_{17}, x_{18} are natural independent variables and others like x_5, x_6, x_7, x_{12}, x_{14}, x_{20}, x_{21}, x'_{21} are real numbers [2].

In the case of discrete independent variables there will be consider all combinations between them by choosing the optimal value from the optimization criterion in the context of a complete formulation of the optimisation problem by considering non-discrete variables with real and also in most cases variable values[3].

The mathematical optimization of the energetic plant with internal combustion engines design phase is based on the following specific costs:
- target function optimization(s):

$$optimum\vec{F}(x_1,.....,x_n) = optim\vec{c}x \qquad (1)$$

- restriction conditions:

$$A\vec{x} - \vec{b} \leq 0 \quad \text{sau} \quad A\vec{x} - \vec{b} \geq 0 \qquad (2)$$

- non-negativity of independent variables:

$$\vec{x} \geq 0 \qquad (3)$$

in those:

$A = ((a_{ij})), i = 1,..m; j = 1,....,n,$ matrix $m \times n$;

$\vec{b} = (b_1,...,b_m)^T \in R^m$ where m-dimensional column vector;

$\vec{x} = (x_1,...,x_n)^T \in R^n$ unknown n-dimensional column vector;

$c = ((c_{ij})), i = 1, r, \quad j = 1, n$ independent variables specific cost matrix $r \times n$;

$\vec{F} = (F_1,...,F_r)^T$ vector column with target function component.

In the case of a only one target function it results: $r = 1$ and c become the $\vec{c}$ specific costs vector which for aleatory independent variables, transform the problem into a linear stochastic one.

The optimization problem for many target functions, named vectorial programming could be also applicable for energetic plant with internal combustion engines in those target function to be minimized or maximized in condition of linear or non-linear variables exist .The parameter problems are aleatory variables: $A, \vec{b}, c$.

In case of the single linear target function with aleatory variable coefficient, two deterministic target functions appears: the maximization of the objective mean value as well as the minimization dispersion target function. When the coefficient are aleatory variables, it makes no sense to consider the linear programming problem.[4].

In general, in case of the stochastic programming, the appearing problems are related to: optimal solution of the repartion problem, programming in two uncertain stages or programming with aleatory restrictions.

In the analised case, it could be formulated an optimization problem with many target functions or with a single target function like the mean specific cost which is of main importance within the optimization problem.

III OPTIMIZATION SOLVING METHOD FROM THE DESIGN PHASE OF ENERGETIC PLANT WITH INTERNAL COMBUSTION ENGINES BY UTILIZING THE STOCHASTIC PROCESSES THEORY

By considering a single target function defined by the minimum cost of exploatation energetic plant with internal combustion engines it must be taken into account the following optimization problem [5]:

$$MinZ = c^T \vec{x}\,;\ c : n \times 1 \quad (4)$$

$$A\vec{x} - b \le 0, \qquad A : m \times n\,;\ m \times 1 \quad (5)$$

$$\vec{x} \ge 0,\ x : n \times 1 \quad (6)$$

A, b,c aleatory matrix (with aleatory elements) (7)

$$c = \begin{vmatrix} c_1 \\ . \\ . \\ . \\ c_n \end{vmatrix};\ x = \begin{vmatrix} x_1 \\ . \\ . \\ . \\ x_n \end{vmatrix};\ A = \begin{vmatrix} a_{11} ... a_{1n} \\ . \\ . \\ . \\ a_{m1} ... a_{mn} \end{vmatrix};\ b = \begin{vmatrix} b_1 \\ . \\ . \\ . \\ b_m \end{vmatrix} \quad (8)$$

or as in the presented case:

$$Minc = \sum_{i=1}^{21} c_i x_i \quad (€/h) \quad (9)$$

which is certainly the optimal value of the target function (with the 100 percent probability).
In the case of the aleatory restricting programming, the following problem will appear [6]:

$$Optimum f(c,x) = c^T x \qquad x \geq 0$$

$$P(Ax \leq b) \geq \alpha \tag{10}$$

in those α is a column vector with components between 0 and 1
or:

$$P\left\{\sum_{j=1}^{n} a_{ij}x_j \leq b_i\right\} \geq \alpha_i, \; i = (1,...,m) \tag{11}$$

with $1-\alpha_1$ which represents the permited risc for those aleatory variable values are:

$$\sum_{j=1}^{n} a_{ij}x_j > b_i \tag{12}$$

Aleatory restrictions could also appear as:

$$P(\sum_{j=1}^{n} a_{ij}x_j \leq b_i, i = 1,...,m) \geq \alpha \tag{13}$$

which means that a commun probability level for restrictions to be verified was established.

The problem is solved with the uncertain two stages programming:

$$Optimum f(c,x) = c^T x \qquad x \geq 0$$

$$Ax = b; b = M(b) \tag{14}$$

IV CONCLUSIONS

The optimization problem formulated in this paper with stochastic parameters consideration, confers since the design phase a more correct possibility determination of the thermoeconomical optimization problem for energetic plant with internal combustion engines by considering a only one deterministic value because in the last case we approached much better the objective reality of this equipment types obtaining by considering some aleatory certain values different from their deterministic consideration.

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