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# AN OPTIONAL HYBRID FUNCTIONS METHOD OF AN IDEAL GAS ADIABATIC PROCESS EQUATION DERIVATION

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***Abstract*—*Considered a multi-optional method of finding an ideal gas adiabatic process equation. Specific hybrid optional functions are taken into account at the optimization of an objective functional which includes an entropy uncertainty measure for those specific hybrid optional functions. Required mathematical models of the presented doctrine for obtaining the optimal multi-optional distributions suppose existence of some thermodynamic states options special functions (logarithmic values of the specific volumes), certain hybrid optional functions (temperatures) relating to the options special functions and an intrinsic parameter of the process (ratio constructed with the specific heat capacities). This is a new insight into the scientific substantiation of the well-known dependency derived in another way; also it is a plausible explanation of the widely used in theoretical thermodynamics phenomenon.*

**Index Terms**—Adiabat; ideal gas; process parameters relation; optimization; entropy extremization principle; multi-optionality; hybrid optional functions; optimal distribution; variational problem.

## I. INTRODUCTION

For mathematical modeling processes and systems it is always very important to propose an explainable, apparently the simplest acceptable, scientifically substantiated although, ideological concept describing the most significant properties of the studied processes and systems.

This is easily being traced in many divergences of the scientific applications, for instance, likewise in the problems relating with the features of an accuracy assessment of the non-orthogonal redundant measuring instruments based upon the inertial sensors [1].

The other example is an attempt to increase the efficiency of the alternative energy sources use with the help of the analysis of the wind turbine blades angular positions controlling ways [2]. In actual fact the research results presented in reference [2] recall and prolong the investigated direction of the wind power system with combined rotor design described in reference [3]. The same is to the following line of the investigations taken in publications [1] and [4], where the features of the tracking modes control are considered.

The issues touched upon in the works of [1] – [4] has to be considered in the framework of the multi-optional optimality doctrine with taking into account the options objectively existing optimums with respect to options related functions uncertainty.

Similar remarks can be made to the problems studied in a publication concerned with the technical and organizational possibilities with an aim to increase the situational awareness and sea travel safety on the entry to the Polish seaports on the base of the aerostat radar system on the platform [5].

Regarding aviation transportation there are opportunities for optimums searching in the area of the aircraft noise, its assessment, prediction, and control [6], also in the fields of the aero-engines elements restoration, as mentioned in reference [7], and estimation of quality parameters in the radio flight support operational systems [8], as well as in air navigation systems with respect to the socio-technical decision support [9].

Continuing with the literature sources survey one may find it is worth of optimum multi-optionality doctrine implementing to the problems of both the education [10] and single air navigation space [11] integration. Fundamental sciences give a wide range of the corresponding conditional optimizations problems settings. Theoretical engineering thermodynamics [12], [13] as well as its practical realizations [14] are not exclusions.

The presented paper objectives are to demonstrate the proposed multi-optional hybrid functions conditional optimality doctrine applicability. The developed herewith approach resembles the Subjective Entropy Maximum Principle (SEMP) [15] – [17], however differs from SEMP in the conceptual framework of that in the objectively existing optimums there are no anyone’s subjective individual preferences [18] – [21]. The model that has been chosen as the multi-optimal optimality doctrine implementation illustration here is the thermodynamic adiabatic process [12], [13].

The presented paper problem is stated as a problem of finding a plausible explanation to an ideal gas thermodynamic adiabatic process [12], [13] of being an optimal one in terms of [18] – [21].

## II. Solution of the Problem

### A. Traditional Theory Approach

As it is well-known an ideal gas thermodynamic adiabatic process [12, 13] is characterized with the following equations, [12, pp. 53, 54, (3.18, 3.22–3.25)]. Especially, [12, P. 53, (3.18)]:

$$dq = c_v dT + pdv, \tag{1}$$

where $dq$ is a small amount (portion) of the heat $q$ transmitted in the adiabatic process; $c_v$ is specific heat capacity for an ideal gas isochoric process, it is supposed that a working body of the process is an ideal gas with a constant specific heat capacity; $dT$ is temperature differential of the body absolute temperature $T$ in the process; $p$ is pressure; $dv$ is specific volume differential of the body specific volume $v$ in the process.

Equation (1) is obtained on the basis of the first law of thermodynamics equation for an ideal gas since the internal energy $u$ of an ideal gas depends upon the temperature [12, P. 53]:

$$du = c_v dT. \tag{2}$$

From equation (1) for adiabatic process $(dq = 0)$ [12, P. 54, (3.22)]:

$$pdv = -c_v dT. \tag{3}$$

Dividing equation (3) into the Clapeyron's equation $pv = RT$, where $R$ is specific gas constant, in members one can find [12, P. 54, (3.23)]:

$$\frac{dv}{v} = -\frac{c_v}{R}\frac{dT}{T}. \tag{4}$$

Since [12, P. 36, (2.67)]: $R = c_p - c_v$, where $c_p$ is specific heat capacity for an ideal gas isobaric process, equation (4) yields [12, P. 54, (3.24)]:

$$(k-1)\frac{dv}{v} = -\frac{dT}{T} \quad \text{and} \quad \left(\frac{v_{II}}{v_I}\right)^{k-1} = \frac{T_I}{T_{II}}, \tag{5}$$

where $k = c_p/c_v$, indices $I$ and $II$ pertain with the initial and terminal points of the process.

### B. Multi-Optional Concept

On the other hand one can present the adiabatic process as a multi-optional problem. In this case: 1) "optionality" of the working body thermodynamic state $i$ characterized with the state parameters; 2) relating to the options special functions; 3) relevant to those hybrid optional functions; 4) intrinsic value of the process; 5) conditions of uncertainty of the hybrid optional functions; and 6) additional constraints implanted into the extremized objective functional.

Such multi-optional hybrid doctrine allows constructing, in regards to the adiabatic process of an ideal gas, the objective functional of the following kind:

$$G_T = -\sum_{i=1}^{2} T_i(v_i)\ln T_i(v_i) - \beta\sum_{i=1}^{2} T_i(v_i)\ln(v_i) + \sum_{i=1}^{2} T_i(v_i), \tag{6}$$

where $\beta$ is the mentioned above intrinsic value of the process.

The values of $T_i$ and $v_i$ in the objective functional (6) allow the logarithmic mathematical operation on assumption.

For extremum conditions of the objective functional (6)

$$\frac{\partial G_T}{\partial T_i} = -\ln T_i - 1 - \beta \ln v_i + 1 = 0, \quad \forall i \in \overline{1,2}. \tag{7}$$

Then from conditions (7)

$$\ln T_1 + \beta \ln v_1 = \ln T_2 + \beta \ln v_2. \tag{8}$$

Hence

$$\ln\frac{T_1}{T_2} = \beta \ln \frac{v_2}{v_1}, \quad \frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{\beta}, \quad \beta = \frac{R}{c_v}. \tag{9}$$

The most important here is to understand that there must be some optimality in the framework of the nature things "optionality". The approach similar to SEMP seeking after preferences in subjective analysis [15] – [17] and applied to hybrid optional functions optimal distributions, likewise in works [18] – [21], even for continuous options parameters densities findings, allows implementing the objective functional (6) following the doctrine (6) – (9) in pursuit of the same result as in (1) – (5).

## III. Conclusions

Proposed approach engaging an uncertainty measure in type of entropy, applied for hybrid optional functions conditional optimization, allows finding an ideal gas adiabatic process thermodynamic relation, without a differential principle determination, in a new multi-optional way. The postulated thing here is the supposition that there exist a value of a thermodynamic parameter relating with an ideal gas adiabatic process, which in respect to its own uncertainty measure is suspected in delivering an extremal value to some objective functional.

As a result, it is revealed that for the adiabatic process of an ideal gas the logarithmic values of the specific volume are the thermodynamic states options special functions whose hybrid optional functions are the temperatures of the states and the essential parameter of the process is the ratio constructed with the specific heat capacities.

Such conceptual approach and the doctrine interpretations broaden the horizons of scientific plausible explanations for occurring ideal gas thermodynamic adiabatic process optimality; and it encourages further research in the field of hybrid optional functions optimal distributions.

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**А. В. Гончаренко. Метод виведення рівняння адіабатного процесу ідеального газу із залученням опційних гібридних функцій**

Розглянуто багатоопційний метод знаходження рівняння адіабатного процесу ідеального газу. Специфічні гібридні опційні функції взято до уваги при оптимізації цільового функціоналу, котрий включає ентропійну міру невизначеності для тих специфічних гібридних опційних функцій. Потрібні математичні моделі представленої доктрини для отримання оптимальних багатоопційних розподілів містять припущення про існування деяких опційних спеціальних функцій термодинамічних станів (логарифмічних значень питомих об'ємів), певних гібридних опційних функцій (температур), пов'язаних із тими опційними спеціальними функціями та невід'ємного параметру процесу (відношення побудованого із питомих теплоємностей). Це є новим поглядом на наукове обґрунтування добре знаної залежності, виведеної в інший спосіб; також це є правдоподібним поясненням широковживаного в теоретичній термодинаміці явища.

**Ключові слова:** адіабата; ідеальний газ; відношення між параметрами процесу; оптимізація; принцип екстремізації ентропії; багатоопційність; гібридні опційні функції; оптимальний розподіл; варіаційна задача.

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**А. В. Гончаренко. Метод вывода уравнения адиабатного процесса идеального газа с привлечением опционных гибридных функций**

Рассмотрен многоопционный метод нахождения уравнения адиабатного процесса идеального газа. Специфические гибридные опционные функции приняты ко вниманию при оптимизации целевого функционала, который включает энтропийную меру неопределенности для этих специфических гибридных опционных функций. Требуемые математические модели представленной доктрины для получения оптимальных многоопционных распределений содержат допущение о существовании некоторых опционных специальных функций термодинамических состояний (логарифмических значений удельных объемов), определенных гибридных опционных функций (температур), связанных с этими опционными специальными функциями и неотъемлемого параметра процесса (отношения построенного из удельных теплоемкостей). Это является новым взглядом на научное обоснование хорошо известной зависимости, выведенной другим способом; также это является правдоподобным объяснением широко используемого в теоретической термодинамике явления.

**Ключевые слова:** адиабата; идеальный газ; отношение между параметрами процесса; оптимизация; принцип экстремизации энтропии; многоопционность; гибридные опционные функции; оптимальное распределение; вариационная задача.

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