MATHEMATICAL MODELING OF PROCESSES AND SYSTEMS

UDC 303.725.36:159.9.015:159.964.21:519.86 (045)

A. V. Goncharenko

ALTERNATIVENESS OF CONTROL AND POWER EQUIPMENT REPAIR VERSUS PURCHASING ACCORDING TO THE PREFERENCES OF THE OPTIONS

Aircraft Airworthiness Department, National Aviation University, Kyiv, Ukraine
E-mail: andygoncharenco@yahoo.com

***Abstract*—*Considered a method of determining the optimal managerial strategies for the multi-alternative operational situationi effectiveness. The options of the equipment maintenance and repair versus purchasing and replacement with the new one are taken into account. Polytropic process index value has been found on the basis of the subjective entropy extremization principle application. Required mathematical models for obtaining the alternatives preferences distributions are introduced. Calculation experiments are carried out. The necessary diagrams are plotted.*

Index Terms—Polytropic process index; polytropic process equation; optimization; subjective entropy extremization principle; multi-alternativeness; canonical subjective preferences distributions; variational problem; extremal; optimal choice.

I. INTRODUCTION

Controlling equipment, as the most other kinds of equipment, functions on purpose though in uncertain conditions. Periodical maintenance, repairs, and replacements have to be performed. Alternativeness of those options generates their preferences and the uncertainty of the preferences.

For example, an airport radar equipment considered in paper [1] sometimes needs either repair or maintenance either replacement.. Another important case for the dilemma, maintenance and repair versus replacement, deals with the aircraft engines operation which follows the ideas of [2].

Various types of power installations including the modern and perspective ones, likewise the wind power systems described in paper [3], as well as the synthesized equipment for the low cost systems dealt with in paper [4], have to undergo a precise assessment on the matter of effectiveness of their future but predicted operations.

All the trouble is that the subjective preference of the options. The theory of subjective preferences [5] – [12] proposes an approach called the subjective entropy maximum principle (SEMP) that allows solving such problems of multi-alternativeness, being taking into account the objective effectiveness functions and subjective preferences functions as quantitative estimations expressed in the explicit view.

The unsolved part of the general problem of the rational operational behavior is on one hand taking into consideration the preferableness of the variants alternatives. Also on the other hand we need to develop the subjective analysis theory with new areas of its applications.

Thus the purpose of the paper is to give a new impulse to the subjective entropy application, the same to the engineering problems of controlling and power equipment maintenance, repair, and replacement.

One of such problems deals with multi-alternativeness approach to the classical thermodynamics problems [13], polytropic process is considered hereinafter; the other problem is dedicated to some optimal choice of equipment treatment.

II. SOLUTION OF THE PROBLEM

A. Polytropic Process Index

In operation aviation engines elements wear out, their performance parameters degrade; as a result of this the engine cannot perform the designed work. Certain restoration procedures or replacement of the engine has to be made. The important thermodynamic parameter here is the polytropic process index n which magnitude must lie within the very narrow designed value diapason.

Polytropic process index n approximate mean value, in real engines thermodynamic processes calculations, can be found from the polytropic process equation (represented actually in any reference, guidance or study book on either theoretical or engineering thermodynamics, like [13, P. 198, § 7.5, (7.78)], either heat engines) provided the values of the pressure p_1, p_2 and volume v_1, v_2 are known at some points 1 and 2 of the process [13, P. 203, § 7.5, (7.106)].

The other concept proposed hereinafter is based upon SEMP [5] – [12] application in the context close to the described in papers [9], [14].

Let us consider the thermodynamic states 1 and 2 of a gas in polytropic process as some alternative states in a certain respect. Thus we come to a multi-alternative problem.

Now, the other sub-problem of the polytropic process given description is to discover the subjective effectiveness functions related to those two alternative states. Let us presuppose the objective effectiveness functions for the considered two-alternative problem of the polytropic process are $\ln v_1$ and $\ln v_2$. This might be reasonably natural with regards to apparent perception of the obvious quantitative characteristic of the existing reality.

With the use of the supposed in subjective analysis [5] optimality, that is applying SEMP, the postulated functional view is

$$\Phi_\pi = -\sum_{i=1}^{2} \pi_i(v_i) \ln \pi_i(v_i) + n \sum_{i=1}^{2} \pi_i(v_i) \ln v_i + \gamma \left[\sum_{i=1}^{2} \pi_i(v_i) - 1 \right], \quad (1)$$

where $\pi_i(v_i)$ are preferences functions; γ – normalizing coefficient.

The first member of expression (1) is the subjective entropy of the preferences. In accordance with [9], [14] such approach yields

$$n = \frac{\ln \pi_1(v_1) - \ln \pi_2(v_2)}{\ln v_1 - \ln v_2}. \quad (2)$$

In case

$$\pi_1(v_1) = x p_2, \qquad \pi_2(v_2) = x p_1, \quad (3)$$

where x is an unknown, uncertain multiplier in type of the Lagrange one, we obtain with the help of the considered procedure (1) – (3) the needed polytropic process index [13, P. 203, § 7.5, (7.106)].

Remarkable here is that the cognitive function has the view of

$$n \frac{\sum_{i=1}^{2} p_i \ln V_{\bar{i}}}{\sum_{i=1}^{2} p_i} \text{ or } n \frac{\sum_{i=1}^{2} p_{\bar{i}} \ln V_i}{\sum_{i=1}^{2} p_i},$$

where subscript $\bar{i}$ means: "*pertaining not to the* i^{th} *but to the other alternative of the two-alternative situation*".

B. Maintenance and Repair Versus Purchasing Alternatives

According to the simplest nevertheless principal statements of operation the functioning equipment works on the purpose of gaining profit. A certain portion of the profit is designated to be accumulated for further either maintenance or repair of the equipment under the operation either for acquiring the new equipment for replacing the equipment which somehow has got obsolete or gone out of order.

Models here are

$$k_1(t) = ae^{-bt} + c, \qquad k_2(t) = d + ft, \quad (4)$$

where $k_1(t)$ stands for the rate of the profit gaining in time at the moment of time t; the rate $k_1(t)$ depends significantly upon the parameters a, b, and c values correspondingly; $k_2(t)$ designates the rate of the restoration funds accumulation accordingly with the values of the modeling parameters of d, and f.

The difference between the rates of (4) yields the rate of the net profit. Integrating the difference at the initial conditions we obtain the net profit value developing in time:

$$Profit_0(t) = 10 + \frac{a}{b} + \left[\left(ct - \frac{a}{b} e^{-bt} \right) - \left(f \frac{t^2}{2} + dt \right) \right], \quad (5)$$

here in equation (5) the member of $10 + \frac{a}{b}$ means that at the initial time $t_0 = 0$ we suppose that the net profit would be 10 conditional units (CU).

The results of modeling according to the concept of (4), (5) are represented in Fig. 1.

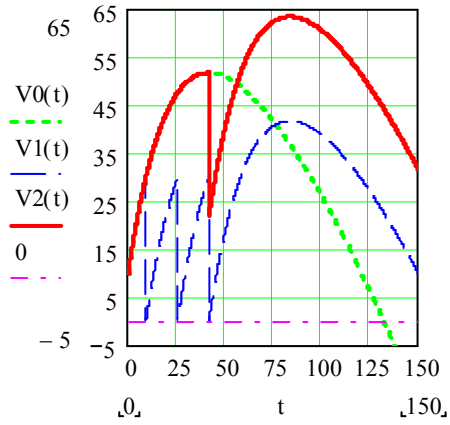

Fig. 1. Values of the net profit accordingly with the alternatives

In Figure 1 $V0(t)$ stands for the operational alternative when there is no replacement of the equipment, just maintenance and repair is being performed. We suppose that ageing of the equipment implies shortening of the periodicity between any

two subsequent treatments with the simultaneous rising of the costs of the maintenance and repair procedures carrying out. That is why after the period of the net profit step by step slowing growth in the interval of $[0\ldots\approx 41]$ CU, there is a period of the profit shrinking down; even we may get inevitable losses at the period of $[\approx 42\ldots\infty[$ CU.

The preferences functions are shown in Fig. 2.

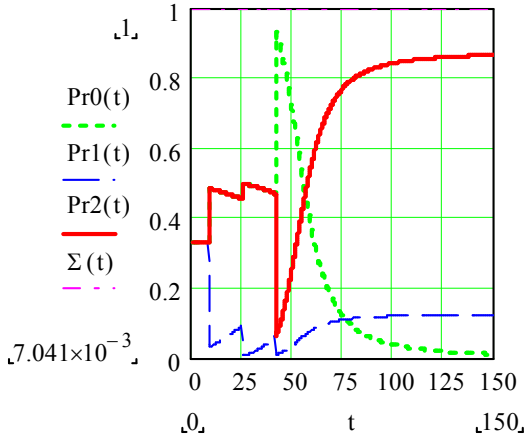

Fig. 2. Preferences functions values

The measure of uncertainty in the view of subjective entropy is illustrated in Fig. 3.

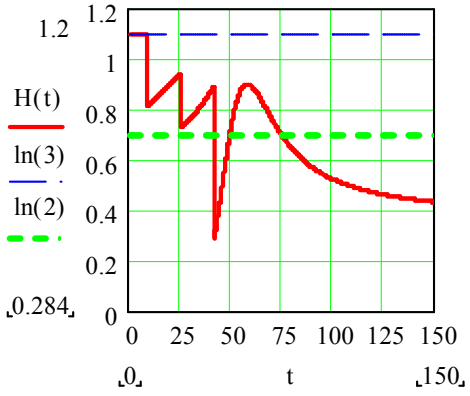

Fig. 3. Subjective entropy value

From Figures 1 – 3 it is visible that there are the relatively shorter period of $[\approx 42\ldots\approx 56]$ CU in case of $V0(t)$ vs. $V2(t)$ alternatives and the other one relatively longer period of $[\approx 9\ldots\approx 76]$ CU in case of $V0(t)$ vs. $V1(t)$ when the option of not purchasing is better.

III. Conclusions

Strategies of operational options with respect to possibilities of maintenance and repair opposed to acquiring and replacement of equipment are conveniently chosen with the use of the subjective preferences theory. Also SEMP allows finding the polytropic process index in the new way.

Such approach with the preferences functions is worth of application to further research of other more complicated problems with alternatives.

References

[1] O. Solomentsev, M. Zaliskyi, and O. Zuiev, "Estimation of Quality Parameters in the Radio Flight Support Operational System." *Aviation*. 2016. vol. 20, no. 3. pp. 123–128.

[2] S. Dmitriyev, A. Koudrin, A. Labunets, and M. Kindrachuk, "Functional Coatings Application for Strengthening and Restoration of Aviation Products." *Aviation*. 2005. vol. 9, no. 4. pp. 39–45.

[3] V. M. Sineglazov, A. A. Ziganshin, M. P. Vasylenko, "Computer-Aided Design of Wind Power System with Combined Rotor." *Electronics and Control Systems*. 2016. vol. 3(49). pp. 73–78. (ISSN: 1990-5548)

[4] O. A. Sushchenko, "Features of Control of Tracking Modes." *Electronics and Control Systems*. 2016. vol. 3(49). pp. 40–47. (ISSN: 1990-5548)

[5] V. A. Kasianov, *Subjective Analysis*: Monograph, Kyiv, Ukraine: National Aviation University, 2007, 512 p. (in Russian)

[6] V. A. Kasianov and A. V. Goncharenko, *Variational Principles of Subjective Analysis. Modified Euler-Lagrange Variational Principle. Entropy Approach*: Monograph, Kyiv, Ukraine: Publishing House "Pryoritety", 2015, 112 p. (in Russian)

[7] V. A. Kasianov and A. V. Goncharenko, *Light and Shadow. Proportions of Shadow Economy. Entropy Approach*: Monograph, Kyiv, Ukraine: Publishing House "Kafedra", 2013, 86 p. (in Russian)

[8] V. Kasyanov and K. Szafran, "Some Hybrid Models of Subjective Analysis in the Theory of Active Systems." *Transaction of the Institute of Aviation*. 2015. vol. 240, no. 3. pp. 27–31. (ISSN 0509-6669)

[9] A. V. Goncharenko, "Optimal Managerial and Control Values for Active Operation." *Electronics and Control Systems*. 2016. vol. 3(49). pp. 112–115. (ISSN: 1990-5548)
http://er.nau.edu.ua:8080/handle/NAU/22359

[10] A. V. Goncharenko, "Operation of active transport systems in conditions of multi-alternativeness and uncertainty": Dissertation … Doctor of Sciences (Engineering): 05.22.20. Kyiv, Ukraine, 2016, 328 p. (in Ukrainian)
http://er.nau.edu.ua:8080/handle/NAU/22359

[11] A. V. Goncharenko, "Operation of active transport systems in conditions of multi-alternativeness and uncertainty": Abstract … Doctor of Sciences (Engineering): 05.22.20. Kyiv, Ukraine: National Aviation University, 2016, 39 p. (in Ukrainian)
http://er.nau.edu.ua:8080/handle/NAU/22359;
http://er.nau.edu.ua:8080/handle/NAU/22627

[12] A. V. Goncharenko, "Several Models of Artificial Intelligence Elements for Aircraft Control," 2016 *IEEE 4th International Conference "Methods and Systems of Navigation and Motion Control (MSNMC)"*: Proceedings of the Conference. (Oct. 18-20 2016, Kyiv). Kyiv, Ukraine: National Aviation University (NAU), 2016, pp. 224–227.

[13] V. A. Kirillin, V. V. Sychov, and A. E. Sheindlin, *Engineering Thermodynamics*, Moscow, Russia: "Energoatomizdat", 1983, 414 p. (in Russian)

[14] A. V. Goncharenko, "Some Identities of Subjective Analysis Derived on the Basis of the Subjective Entropy Extremization Principle by Professor V. A. Kasianov." *Automatic Control and Information Sciences*. 2014. vol. 2, no. 1. pp. 20–25. DOI: 10.12691/acis-2-1-4.

Received September 09, 2016.

Andriy Goncharenko. Doctor of Engineering.
Aircraft Airworthiness Department, National Aviation University, Kyiv, Ukraine.
Education: Odessa Institute of Marine Engineers, Odesa, Ukraine (1984).
Research area: Operation and control in active systems, Flight safety, Variational principles.
Publications: 95.
E-mail: andygoncharenco@yahoo.com

А. В. Гончаренко. Альтернативність ремонту контрольного та енергетичного обладнання проти придбання відповідно до переваг такого варіанту вибору

Розглянуто метод визначення оптимальних стратегій керування для ефективності багатоальтернативних експлуатаційних ситуацій. Варіанти вибору технічного обслуговування та ремонту обладнання проти придбання та заміни новим взято до врахування. Значення показника політропічного процесу знайдено на основі застосування принципу екстремізації суб'єктивної ентропії. Введено потрібні математичні моделі для отримання розподілів переваг альтернатив. Виконано розрахункові експерименти. Побудовано необхідні діаграми.

Ключові слова: показник політропічного процесу; рівняння політропічного процесу; оптимізація; принцип екстремізації суб'єктивної ентропії; багатоальтернативність; канонічні розподіли суб'єктивних переваг; варіаційна задача; екстремаль; оптимальний вибір.

Андрій Вікторович Гончаренко. Доктор технічних наук.
Кафедра збереження льотної придатності авіаційної техніки, Національний авіаційний університет, Київ, Україна.
Освіта: Одеський інститут інженерів морського флоту, Одеса, Україна (1984).
Напрям наукової діяльності: експлуатація та керування в активних системах, безпека польотів, варіаційні принципи.
Кількість публікацій: 95.
E-mail: andygoncharenco@yahoo.com

А. В. Гончаренко. Альтернативность ремонта контрольного и энергетического оборудования в противовес приобретению соответственно предпочтениям такого варианта выбора

Рассмотрен метод определения оптимальных стратегий управления для эффективности многоальтернативных эксплуатационных ситуаций. Варианты выбора технического обслуживания и ремонта оборудования в противовес приобретению и замене новым приняты в учет. Значение показателя политропического процесса найдено на основе применения принципа экстремизации субъективной энтропии. Введены требуемые математические модели для полученных распределений предпочтений альтернатив. Выполнены расчетные эксперименты. Построены необходимые диаграммы.

Ключевые слова: показатель политропического процесса; уравнение политропического процесса; оптимизация; принцип экстремизации субъективной энтропии; многоальтернативность; канонические распределения субъективных предпочтений; вариационная задача; экстремаль; оптимальный выбор.

Андрей Викторович Гончаренко. Доктор технических наук.
Кафедра сохранения летной годности авиационной техники, Национальный авиационный университет, Киев, Украина.
Образование: Одесский институт инженеров морского флота, Одесса, Украина (1984).
Направление научной деятельности: эксплуатация и управление в активных системах, безопасность полетов, вариационные принципы.
Количество публикаций: 95.
E-mail: andygoncharenco@yahoo.com