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COMPOSING OF DEVELOPMENT TESTING PROGRAMS FOR ROCKETRY ITEMS TAKING INTO ACCOUNT THE GROUP DECISION MADE BY AN EXPERT COMMITTEE

The analysis of existing methods of determining the expert competence coefficient is carried out. Based on the results of the analysis, it is suggested that experts' evaluation is made on the basis of objective characteristics and also it is suggested to make a group decision with a margin according to the Harrington desirability function. Approaches are proposed for the components of the expert's competence coefficient that allow taking into account the objective characteristics of each expert – period of familiarity with the problem, the academic degree and position, as well as the number of publications, reports, etc. on the problem. Thus, we get the value of the expert's competence coefficient taking into account his objective characteristics, which will significantly reduce the subjectivity of the experts' evaluation and improve the quality of the expert committee. The proposed group decision made by an expert committee (regarding a problem considered based on the ratio of difference between the sum of competence coefficients of supporter experts and that of dissident experts to the sum of competence coefficients of the experts with a margin according to the Harrington desirability function, which shall be more than 0.8) will allow taking into account the constructive opinions of the dissident experts. This group decision and determination of the expert's competence coefficient taking into account the objective characteristics of each expert will reduce the influence of human factor, thus ensures more optimal composing of programs for development testing of rocketry items. An example of practical application in comprehensive development testing program (CDTP) of items of the rocket space complex of a proposed group decision made by an expert committee will allow taking into account the constructive opinions of the dissident experts to introduce subclasses in status of qualifications, which take into account the logic of development test the component parts, that contributes to the optimization of CDTP.

Keywords: *comprehensive development test programs, status of qualification, coefficient of expert competence, group decision; expert opinion "weight" coefficient, problem familiarity coefficient, argumentation coefficient, desirability function.*

Preface

The article is more detailed consideration of expert evaluation methods (EEM) use problem in ground development testing for rocketry items given in article [1]. When using the EEM for solution of different problems (e.g., number of test objects, phases, required levels of assemblies as well as assigning the qualification status [1-3] to the item to be tested) the professionals group (classified as experts committee) is formed, which follows, as a rule, a couple of the closest expert opinions. In this case the supporter and dissident experts are considered using expert competence coefficient, however, the typical methods for its calculation such as self-rating, mutual rating and testing are highly influenced by human factor [4]. The group decision by expert committee regarding the problem (composing of development testing program for rocketry items) complies with the biggest sum of competence coefficients of the supporter experts. However, this approach does not take into account possible constructive opinions of dissenter experts, this causes problems of high-quality group decision by expert committee and decrease of human factor influence.

Solution method

The expert committee group decision on the given problem depends upon composition of the expert committee and method of making the group decision that will exclude the human factor effect. In this case, the following is proposed:

– selection of expert candidates based on objective characteristics (academic degree, period of familiarity with the problem, number of published works, etc.) [4];

– the group decision shall be made with margin per Harrington desirability function [5] to account for possible constructive opinions of dissenter experts.

Nowadays, four typical approaches are used for determining expert competence coefficient.

The first approach is based on determining expert competence coefficient K_c by means of objective characteristics of each expert [4, 6, 7].

In [4] expert competence coefficient K_c is set equal to the value of complex self-rating coefficient of an expert

$$K_{sr} = 0.5\left(K_{arg} + K_w K_{fam}\right), \quad (1)$$

where K_w is expert's opinion "weight" coefficient;

K_{fam} is problem familiarity coefficient;

K_{arg} argumentation coefficient.

Possible values of expert "weight" coefficient interpreted for research-and-production company from [6] are given in Table 1.

Problem familiarity coefficient can take the following values: 1.0; 0.8; 0.6; 0.4; 0.2. The value 1.0 corresponds to an expert working in this area; the value 0.2 corresponds to an expert encountering this problem for the first time [7, 8]. Since the interim values of problem familiarity coefficient do not correspond to any criteria, the coefficient is proposed to be determined according to the following formula

$$K_{fam} = 1 - \exp\left(-\log_2 \sqrt{n_{years}}\right), \quad (2)$$

where n_{years} is the number of years an expert is familiar with the problem.

One should note that in formula (2) the base of the logarithm is taken as 2, since the expert can have two opinions (right and wrong). The results of calculation of problem familiarity coefficients comply with Harrington desirability function [5]. Function values matching to problem familiarity coefficient are given in Table 2.

Argumentation coefficient is determined based on the results of previous examinations as a ratio of the number of correct hypotheses K_{ch} proposed by the expert to the total number of examinations K_{all} the expert has taken part in. The number of articles, reports at international conferences, books, monographs, etc. regarding the problem considered is not taken into account [6]. Therefore, it is proposed to add 0.05 to the value of argumentation coefficient for each article and report and 0.01 – for one conventional printed sheet of a book, monograph, etc. The resultant formula for determining argumentation coefficient will be as follows

$$K_{arg} = \frac{K_{ch}}{K_{all}} + 0.05\left(K_{art} + K_{rep}\right) + \\ + 0.01\left(K_{book}^{cps} + K_{mon}^{cps}\right), \quad (3)$$

where K_{art} and K_{rep} are numbers of articles and reports at international conferences, respectively, regarding the problem considered, e. g. for the last 5 years;

K_{book}^{cps} and K_{mon}^{cps} are numbers of conventional printed sheets in a book or monograph, respectively, regarding the problem considered, e. g. for the last 5 years.

In [7] expert competence coefficient corresponds to weight coefficient accounting for five factors presented in Table 3. Weight function is determined as a ration of the sum of weight coefficients K'_w per each factor for each expert to the sum of weight functions per all factors and experts.

Table 1

Values of expert "weight" coefficient for research-and-production company

Position	Expert "weight" coefficient			
	Without degree	Candidate of sciences	Doctor of sciences	Academy member, corresponding member
Lead engineer or lead design engineer	1			
Researcher	1	1.5		
Head of group	1.5	2.25	3	
Head of sector, head of laboratory	2	3	4	
Head of department and deputy head of department	2.5	3.75	5	
Head of division or complex and deputy head of division or complex	3	4.5	6	
Director and deputy director, research manager	4	6	8	12

Table 2

Matching of total probability assessment to Harrington desirability function

Value of desirability function f_x	Result	Problem familiarity coefficient
$0.8 < f_x \leq 1.0$	Very good	$0.8 < K_{fam} \leq 1.0$
$0.63 < f_x \leq 0.8$	Good	$0.63 < K_{fam} \leq 0.8$
$0.37 < f_x \leq 0.63$	Satisfactory	$0.37 < K_{fam} \leq 0.63$
$0.2 < f_x \leq 0.37$	Bad	$0.2 < K_{fam} \leq 0.37$
$0 < f_x \leq 0.2$	Very bad	$0 < K_{fam} \leq 0.2$

Table 3

Factors and values of expert's weight function per factor criteria

Factors	Factor criterion and value of weight function		
Education level	Secondary, $f_w = 0.2$	Specialized secondary, $f_w = 0.3$	Higher, $f_w = 0.4$
Length of working experience	From 1 to 5 years, $f_w = 0.2$	From 5 to 10 years, $f_w = 0.3$	Over 10 years, $f_w = 0.5$
Length of working experience in the area considered	None, $f_w = 0$	From 1 to 5 years, $f_w = 0.3$	Over 5 years, $f_w = 0.6$
Academic degree	Without degree, $f_w = 0$	Candidate of sciences, $f_w = 0.4$	Doctor of sciences, $f_w = 0.6$
Research works for the last 5 years	None, $f_w = 0$	Up to 5 articles, $f_w = 0.4$	Over 5 articles, $f_w = 0.6$

One should note that the method for determining expert competence coefficient proposed in [7] is not entirely correct, since the expert without degree may be practitioner and excluding him from the experts is unreasonable, at the same time taking into account only the articles as research works is incorrect.

The second approach involves determining expert competence coefficient based on 15 parameters given in Table 4 [8]. However, due to the opinions of the management and self-rating this approach is prone to the influence of human factor.

The third approach stipulates that competence coefficient of each expert corresponds to "weight" coefficient of his/her opinion according to the following formula [9]

$$K_w = 0.5\left(K_{fam} + K_{arg}\right), \quad (4)$$

where $K_{arg} = 0.5\left(K_{con} + K_{com}\right)$ is argumentation coefficient;

Table 4

Expert competence parameters

First group (status)	Second group (experience in expert activities)	Third group (experience in research activities)	Fourth group (academic productivity)
Position (1...5 scores)	Number of reviews for the last 3 years	Age	Number of published papers for the last 5 years
Academic degree (0...2 scores)	Number of participations in examinations for the last 3 years	Total length of working experience	Number of references for the last 10 years
Opinion of judges	Self-rating (0...10 scores)	Length of working experience in given area	Number of awards
Opinion of management (1 or –1 score)		Length of working experience in the company	
		Number of public speeches for the last three years	

Table 5

Values of coefficients K' and K''

Expert level and his/her specialization	Problem level	
	Complex	Specialized
	K'	K''
Wide area expert	1	0.5
Expert specializing in the problem given	0.5	1

Table 6

Values of compliance coefficient

	over 15	5...10	less than 5
Number of published works	$K_{com} = 0.25$	$K_{com} = 0.1875$	$K_{com} = 0.125$
Number of research or engineering activities performed as a manager	$K_{com} = 0.25$	$K_{com} = 0.1875$	$K_{com} = 0.125$
Number of research or engineering activities performed as a team member	$K_{com} = 0.25$	$K_{com} = 0.1875$	$K_{com} = 0.125$
Number of conclusions issued regarding the problem considered	$K_{com} = 0.25$	$K_{com} = 0.1875$	$K_{com} = 0.125$

$K_{con} = K' + K''$ is confidence coefficient;

K' is coefficient characterizing the level of expert's specialization regarding the problem considered (1 – specialization level complies with the problem, 0.5 – does not comply);

K'' is coefficient characterizing the level of the problem and expert's specialization area regarding the problem considered (1 – level and area comply, 0.5 – do not comply;

K_{com} compliance coefficient (accounts for the number of published works and conclusions, the role of expert in the activities performed).

The values of coefficients K' and K'' are given in Table 5.

The K_{com} value for each expert is determined according to Table 6 by the sum of all K_{com} values complying with the filled cells of the given Table 6.

The value of K_w is determined according to [8, 9] as for the first approach.

One should note that compared to the first approach this one allows to obtain the values of competence coefficient faster but with shorter collection of objective characteristics.

The forth approach is based on determining competence coefficient for each expert using paired comparison method. As a result of comparison, such kind of contradiction in evaluation of objects may appear – the first one is more preferable than the second one, the second one is more preferable than the third one and the third one – more preferable than the first one. Therefore, the following formulas are used for assessing expert competence [1]

for odd n

$$K_c = 1 - \frac{24d}{n^3 - 4n}, \quad (5)$$

for even n

$$K_c = 1 - \frac{24d}{n^3 - n}; \quad (6)$$

where d is the length of contradiction chain for each expert (for the given example $d = 3$).

In case of no contradiction $K_c = 1$, and in case of corresponding $d - K_c = 0$.

The positive distinction of the forth approach is its applicability not only for assessing competence coefficient for each expert but also for determining the group decision of expert committee. However, this approach does not account for possible constructive opinions of dissenter experts in the group decision of expert committee.

In order to account for possible constructive opinions of dissenter experts for determining the resultant assessment of expert committee, it is proposed to use integrated decision criterion based on Table 2

$$K_{\Sigma} = \frac{\sum_{i=1}^{m_s} K^i_{sr} - \sum_{j=1}^{m'} K^j_{sr}}{\sum_{l=1}^{m} K^l_{sr}} > 0.8, \quad (9)$$

where m is the total number of experts;

m_s is the number of supporters of committee's common opinion;

m' is the number of dissenter experts;

$\sum_{l=1}^{m} K_{sr}^{l}$ the sum of competence coefficients of the whole expert committee;

$\sum_{i=1}^{m_s} K_{sr}^{i}$, $\sum_{j=1}^{m'} K_{sr}^{j}$ – the sum of competence coefficients of supporter and dissenter experts, respectively.

Thus, the following is recommended:

– using formula (1) for determining expert competence coefficient K_c;

– using Table 1 for determining expert "weight" coefficient, using formulas (2) and (3) for determining problem familiarity and argumentation coefficients, respectively;

– following Table 2 for determining the group decision of expert committee accounting for possible constructive opinions of dissenter experts. In this case, the decision of the expert committee will not be final unless the condition (9) is satisfied.

When forming the expert committee composition after determination of the competence coefficient for each expert, it is recommended to consider the following rule: the competence coefficient value of the most competent expert shall not be more than a sum of competence coefficients of the least competent experts.

Use of group decision made by the expert committee taking into account possible constructive opinions of the dissident experts

As a practical use of the proposed criteria of the generalized solution (9), let us consider the solution of the problem on development testing of B, C and D items' qualification statuses [1].

When using the method for composing of the CDTP, considered in [1-3] (taking into account the hierarchy of Space Launch System items given in Fig. 1) the company expert committee is formed. The expert committee consists of the experts in three areas: project designing, design-engineering and experimental.

For each area the expert groups (consisting, as a rule, of three specialists of three levels – the lowest level (engineer), mean level (group leader) and the highest level (sector leader, laboratory leader, head of department and etc.)) are formed.

The main task of the project designing area experts is evaluation of the item structure; the main task of the design-engineering area experts is design evaluation of the item parameters and the main task of the experimental area experts is evaluation of possibility for specification and confirmation of the preliminary evaluation.

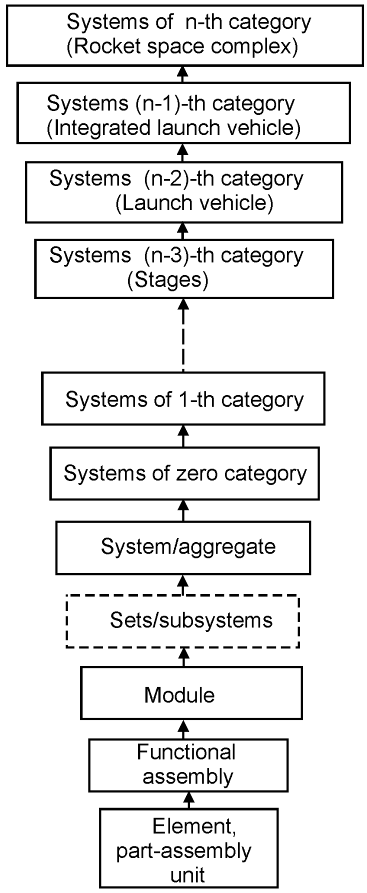

Fig. 1. Levels of units to be test

In this case, the experts are selected by the competence coefficient according to priority of the given coefficient components:

– specialization;

– work experience in the given area (familiarity coefficient with the problem by formula (2));

– expert "weight" coefficient according to Table 1;

– reasonableness coefficient by formula (3).

Except the experts of the abovementioned areas, the wide area experts of two groups are involved: the first group coordinates the different types and categories of the tests using CDTP and the second group monitors the cost and duration of the entire development testing (managers). As a rule, two or more wide area experts are involved.

Thus, the minimum number of experts in committee is 11.

The formed committee made a decision on specification of criteria on qualification statuses of the items to be tested (given in Table 7). This Table includes the qualification statuses of the items B, C and D divided into subclasses taking into account the dissident experts' opinions that is explained by the development testing logic. In this case, the determination of qualification statuses of the items B, C and D, considered in [1], are supplemented by the subclasses' criteria that will allow optimal composing of the cost and duration development testing/test programs for the rocketry items.

Conclusion

Selection of group decision made by an expert committee based on the ratio of difference between the sum of competence coefficients of supporter experts and that of dissenter experts to the total of competence coefficients of the experts, which shall be more than 0.8, allows accounting for possible constructive opinions of dissenter experts. Determination of expert competence coefficient based on experts' objective characteristics reduces the influence of human factor, thus ensures more optimal composition of expert committee and, accordingly, selection of higher quality. This will contribute to more optimal composition of development testing programs for rocketry items in terms of cost and duration.

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Table7

Specified criteria of qualification status of items to be tested

Qualification status		Determination
A		Assembly units (items of any level) tested and borrowed from another projects (do not require modifications) which passed qualification tests for use in conditions not less severe than those required for this project
B	B1	Items which passed qualification tests for use in conditions not less severe than those required for this project (require qualification tests for check of operability in new operational conditions)
	B2	Items requiring check tests
C	C1	Modified systems from n-th to $(n-3)$-th category (stages, launch vehicle, integrated launch vehicle)
	C2	Other modified items of the highest level* (systems of i-th category, systems, aggregates, sets/subsystems)
	C3	Modified items of the mean level*
	C4	Modified items of the lowest level*
D	D1	Assembly units (items of any level) of new development as well as assembly units manufactured using new technology and (or) new materials
	D2**	Items to be sufficiently modified according to the following features: – functional (0.67 of operational characteristics and (or) operational conditions does not meet the requirements); – circuit-structural (consisting less than 0.33 of items with A qualification status); – manufacturing (0.67 of manufacturing operations of this item shall be changed)
Notes: * explanations of hierarchy for items of the highest level (system, aggregate, System of n-th category), mean level (functional assembly, module, mechanism, device, instrument, appliance, unit and etc.) and the lowest level (element, part-assembly unit and etc.) are given in Figure 1 (considered in [10] in details); ** items of D2 subclass may require sufficient modification both for one of the abovementioned features and for the several ones		

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СОСТАВЛЕНИЕ ПРОГРАММ КОМПЛЕКСНОЙ ЭКСПЕРИМЕНТАЛЬНОЙ ОТРАБОТКИ ИЗДЕЛИЙ РАКЕТНОЙ ТЕХНИКИ С УЧЕТОМ ГРУППОВОГО РЕШЕНИЯ КОМИССИИ ЭКСПЕРТОВ

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Проведён анализ существующих способов определения коэффициента компетентности экспертов. По результатам анализа предложено осуществлять оценку экспертов на основании объективных характеристик и принимать групповое решение с запасом по функции желаемости Харрингтона. Предложены для составляющих коэффициента компетентности эксперта подходы, которые позволяют учесть объективные характеристики каждого эксперта – длительность знакомства с проблемой, учёная степень и должность, а также количество публикаций, докладов и т. д. по проблеме. Таким образом, получим значение коэффициента компетентности эксперта с учётом его объективных характеристик, что существенно снизит субъективность оценки экспертов и повысит качество комиссии экспертов. Предлагаемое принятие группового решения (по отношению разницы сумм коэффициентов компетентности экспертов-сторонников и экспертов-диссидентов к сумме коэффициентов компетентности экспертов с запасом по функции желаемости Харрингтона) позволяет учесть конструктивные мнения экспертов-диссидентов. Данное групповое решение и определение коэффициента компетентности эксперта с учётом объективных характеристик каждого эксперта уменьшает влияние человеческого фактора и способствует оптимальному составлению комплексных программ экспериментальной отработки изделий ракетной техники.

Ключевые слова: комплексная программа экспериментальной отработки, квалификационный статус, коэффициент компетентности эксперта, групповое решение, коэффициент «веса» мнения эксперта, коэффициент знакомства с проблемой, коэффициент аргументированности, функция желаемости.

СКЛАДАННЯ ПРОГРАМ КОМПЛЕКСНОГО ЕКСПЕРИМЕНТАЛЬНОГО ВІДПРАЦЮВАННЯ ВИРОБІВ РАКЕТНОЇ ТЕХНІКИ З УРАХУВАННЯМ ГРУПОВОГО РІШЕННЯ КОМІСІЇ ЕКСПЕРТІВ

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Проведено аналіз існуючих способів визначення коефіцієнта компетентності експертів. За результатами аналізу запропоновано здійснювати оцінку експертів на підставі об'єктивних характеристик і приймати групове рішення з запасом по функції бажаності Харрінгтона. Запропоновано для складових коефіцієнта компетентності експерта підходи, які дозволяють врахувати об'єктивні характеристики кожного експерта – тривалість знайомства з проблемою, вчений ступінь і посаду, а також кількість публікацій, доповідей з проблеми. Таким чином, отримаємо значення коефіцієнта компетентності експерта з урахуванням його об'єктивних характеристик, що істотно знизить суб'єктивність оцінки експертів і підвищить якість комісії експертів. Запропоновано прийняття групового рішення (по відношенню різниці сум коефіцієнтів компетентності експертів-прихильників і експертів-дисидентів до суми коефіцієнтів компетентності експертів з запасом по функції бажаності Харрінгтона), що дозволяє врахувати конструктивні думки експертів-дисидентів. Дане групове рішення і визначення коефіцієнта компетентності експерта з урахуванням об'єктивних характеристик кожного експерта зменшує вплив людського фактора і сприяє оптимальній розробці комплексних програм експериментального відпрацювання виробів ракетної техніки.

Ключові слова: комплексна програма експериментального відпрацювання, кваліфікаційний статус, коефіцієнт компетентності експерта, групове рішення, коефіцієнт «ваги» думки експерта, коефіцієнт знайомства з проблемою, коефіцієнт аргументованості, функція бажаності.

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