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Introduction

In the 21st century, the number of passengers who prefer to travel by air is increasing every year. In the cockpits of modern aircraft supported by various parameters of the internal environment such as pressure, temperature and humidity [1]. The air characteristics in aircraft cabins are similar to the indoor air parameters of residential buildings and office premises. However, aircraft cabins differ from buildings in many respects, in particular, space per passenger, the need to seal the cabin, a forced lack of activity during the flight, etc. [1].

Modern aircraft are equipped with an Environmental Control System (ECS), which provides safe, comfortable, and healthy flights for both passengers and the crew. Factors affecting the quality of internal air in aircraft can be divided into the following categories: pressure; temperature; humidity; oxygen content; concentration of pollutants in the air of the cockpit [2, 3].

A sudden change in the level of one or more of these factors or the interaction between them can cause a deterioration in the quality of internal air and, therefore, can have a negative effect on the health of passengers and crew [3-5]. Therefore, research in the field of ensuring air quality in aircraft cockpits is an urgent problem. This paper considers the development of multifactor mathematical models that take into account the influence of aircraft parameters on air quality in the cockpit.

10.1. Common problems of modeling

Modeling corresponds to replacement of one object (original) with other object (model) and fixation and analysis of model characteristics. The replacement is executed for simplification, reduction in a cost, for acceleration of original characteristics analysis [6].

In the general case as the object–original may be considered natural or artificial, real or imaginary system. It has parameters set S_0, and it is defined with certain characteristics. Characteristics set Y_0 is quantitative measure for system features, the system displays its characteristics under influence of external actions X.

The set of parameters and their values S reflects its internal content, namely the structure and operation principles. S characteristics are generally its external attributes, which are important during its interaction with other S. S characteristics are in functional subjection to its parameters. Each characteristic of system $y_0 \subset Y_0$ is defined generally by limited number of parameters $\{S_{0k}\} \subset S_0$. Remaining parameters are noncritical for the value of this S characteristic. As a rule, only some characteristics $\{y\} \subset Y_0$ of S are interesting for a researcher at specific exposure on the system $\{x_{mn}\} \subset X$.

The model is also the system with its own parameters set S_m and characteristics set Y_m. Some parameters of the original and the model are similar and some parameters are different. Replacement of one object with other object is legitimate in the case if interested for the researcher characteristics of the original and the model are defined with one–type subsets of parameters and are connected with theses parameters by means of identical dependences [6, 7]:

$$y_{ok}=f(\{S_{oi}\},\{x_{on}\},T); \quad (1)$$

$$y_{mn}=f(\{S_{mi}\},\{x_{mn}\},T_m) \quad (2)$$

where, y_{mn} – к–th model characteristic, $y_{mn}\subset Y_m$; x_{mn} – external action on the model, $x_{mn}\subset X$; T_m – simulated time.

Substantially cognition of every system (S) comes to its model creation. A model–design of each device is developed before its manufacturing. Mathematics achievements resulted in spreading of mathematical models for different objects and processes. It was noticed that functioning dynamics of different in physical nature systems is described with one–type dependences. This fact permits to model them by means of computers [8].

Methodology development of simulation modeling by means of computers raised modeling to the new level. Now it is difficult to specify an area of human activity without modeling application. Models for cars manufacturing, wheat growth, functioning of human separate organs, atomic explosion, etc were developed.

Automatic control systems for technologic complexes, economic–organizing complexes, designing processes, data banks are used widely in practice. But every from these systems wants for information about controlled object and controlled object model, modeling of controlling decisions.

Usually development process of complicated system is executed iteratively with utilization of design decisions modeling. In the case if the characteristics dissatisfy demands, then the design is corrected by results analysis and modeling is repeated.

During operating systems analysis by means of modeling it is determined system serviceability borders. It is executed simulation of experimental conditions that can appear in the process of system functioning. Artificial generation such conditions at natural system is difficult and can bring into a state of catastrophe [6-8].

Physical models. Model abstracting degree from the original is assumed as classification principle. Preliminary all models may be separated in 2 groups, namely physical and abstract (mathematical) models.

Physical model is usually the system that equivalent or similar to the original. This model may have other physical nature.

Natural models are real researched systems (prototype, pilot model). They have perfect adequacy with the system–original, however they are very expensive.

Quasinatural models are a collection of natural and mathematical models. This form is used in the case, if the model of system part cannot be mathematical owing to its description complexity (the model of person–operator) or if system part must be researched in interaction with other parts, however these parts are not existing or their inclusion is very expensive (computing polygons, automatic control system).

Scale model is the system with the same physical nature that the original. This model scale differs from original scale. Similarity theory is methodological foundation of scale modeling. During BC designing scale models may be used for analysis of layout decisions.

Analogous models are the systems with physical nature that differs from the original and with functioning processes that are similar to the original. Mathematical description of researched system is necessary for creation analogous model. Mechanical, hydraulic, pneumatic and electric systems are used as analogous models. Analogous modeling uses computer aids at the level of logic elements and electric circuits, and also at system level in the case if system functioning is described, for example, by means of differential or algebraic equations.

Mathematical models are formalized presentation of the system by means of abstract language, mathematical relationships that reflect the process of system functioning. Whatever mathematical means, namely algebraic, differential, integral calculus, set theory, algorithm theory etc. may be used for mathematical models creation. Substantially all mathematics was created for composition and researching of models for objects and processes.

10.2. Types of multiple classification

1. Deterministic analysis is the procedure of factors influence research. Association of these factors with effective indicators is functional, i.e. effective indicator is expressed as product, quotient, and algebraic sum of factors.
2. Stochastic analysis is the procedure for factors research in the case if association of these factors with effective indicators is probabilistic (correlation).
3. Procedure of direct factor analysis. In this case the research is executed from general case to particular case (deductive approach).
4. Procedure of inverse factor analysis. In this case the research is executed from particular case to general case (inductive approach).
5. Procedure of single–stage factor analysis. In this case the factors of one level (degree) are researched without subordination.
6. Procedure of multi–stage factor analysis. In this case the research is executed with factor detailing. Thus it is researched influence of the factors with various levels of hierarchy.
7. Procedure of statistical factor analysis is used during the analysis for relevant date.
8. Procedure of dynamic factor analysis is the procedure of research for cause–effect relations in dynamics.
9. Procedure of retrospective factor analysis is used for research of increase reasons for effective indicators of past periods.
10. Procedure of perspective factor analysis is used for research of factors and effective indicators behavior in perspective.

10.3. Multifactor mathematical models

During modeling of complicated technical devices or technological processes in dynamics it is necessary to work with multifactor dependences. In this case the value of one indicator or indicators group is defined by behavior of many factors simultaneously, rather than one factor. Really, if we take any indicator in complicated technical device and look after factors, influencing onto this indicator, we will see that all indicators are formed under influence of many various reasons and conditions.

It is most difficult to find single–factor dependence rather than multifactor dependence for the task of forecasting for complicated technical devices. It is obvious that in sense relationship single–factor model reflects the processes in complicated technical devices more exactly than trend model. However during creation of single–factor model it is necessary to simplify simulated reality presentation. In this case only one factor is selected instead of modeling of many factors action on predictable indicator. This factor is assumed by the forecaster as most basic. In this situation every single–factor model is so conventional and rough, that its application in forecasting may give only very approximate reference points. If an expert wants to execute exact forecast by means of mathematical model, then he must select such model that reflects the essence of current events and describes they to the best advantage. As far as virtually all indicators are formed under many factors influence, then the model for forecasting must be multifactor model.

Therefore multifactor model can give greater accuracy than single–factor model, as far as it models reality more detailed. The task of creation of mathematical models for some objects and phenomena on the base of experiments or observations for forecasts creation may be solved successfully by means of *correlation–regression analysis* (KRA). Regression models are mathematical relationships of defined type between indicators of object operation or characteristics of observed phenomenon Y_1, Y_2 ,… Y_m and conditioning values X_1, X_2,..., X_n . Models may be classified as single–factor and multifactor models depending on quantity of X_i (*independent factors*), whose influence must be determined, on conclusive (*dependent factor*) Y of the model.

10.4. Stages of construction for multifactor regression model

The process of correlation–regression analysis (KRA) consists from followings stages:

- *Preliminary treatment of statistical data and choice of factor indicators.*

The factors, included in developed regression model, must meet following requirements:

- each factor must be grounded theoretically;
- the factors must be most significant, they must render essential influence on researched dependent factor. It is recommended that the quantity of model factors was no more than a tierce from value of observations in the sample;
- the factors must be not linear dependent among themselves. Presence of such dependence signifies that these factors characterize analogous features of researched factor (phenomenon of multicollinearity);
- it is recommended to include into the model only such factors that can be numerically measured;
- cumulative factor and particular factors, formed it, must be not included into one model. Simultaneous including of such factors results in their increased influence on dependent factor, in distortion of actual reality.

Preliminary treatment of statistical data is ended with compiling of *the matrix for correlation coupled coefficients*. The matrix for correlation coupled coefficients is quadratic and symmetric in regard to leading diagonal. Correlation coupled coefficients are used for quantitative evaluation of interconnection for two data sets, given in dimensionless form.

Sample correlation coefficient is the covariance of two data sets, divided on the product of their standard deviations.

Correlation analysis gives possibility to determine whether data sets are associated by magnitudes; i.e. large magnitudes from one data set are connected with large magnitudes from other data set (*positive correlation)* or small magnitudes are connected with large magnitudes from other data set (*negative correlation),* or data of both ranges are not connected (*approximate to zero correlation*);

- *evaluation of connection tightness between factors and detection of connection forms.*

Evaluation of connection tightness between factors is executed by means of Cheddock scale [6, 8] on the base correlation coefficients (from correlation matrix):

Table 1

Relationships between factors on the Cheddock scale based on correlation coefficients

Indications of connection tightness (correlation coefficient)	0.1–0.3	0.3–0.5	0.5–0.7	0.7–0.9	0.9–0.99
Characteristic of connection strength	weak	moderate	appreciable	high	very high

Evaluation of correlation connections permits to define influence degree of each independent factor on dependent factor. Such independent factors, which have very weak connection tightness with researched dependent factor (correlation coefficient is lower than 0.1), may be deleted as inessential.

Choice of connection form is complicated problem, as it is necessary to find such function in infinite set of functions, which expresses really existing connections between researched dependent factor and independent factors better than other functions.

The correlation coefficients of 82 parameters with respect to the concentration of PSA (Phthalic anhydrid) (ppb) were calculated. After analyzing the experimental data on the basis of the Cheddock scale (Table 1), 15 factors were selected for the further development of mathematical models.

1. Takeoff, climb, cruising.
2. Cruising , descent, landing.

Table 2

15 factors for the further development of mathematical models

Takeoff, climb, cruising			cruising, descent, landing		
parameter	Column Excel	correlation	parameter	Column Excel	correlation
2161F5101– AIR1 ZCAB	E	0,853488	2120F2401– AIR PCK2 FLAP OUTPOS	AG	0,894244
2120P4701– AIR1_PCK1_INCP_TEMP	AJ	0,849876	2120H2401– AIR_PCK1_FLAP_OUTPOS	AF	0,884633
2120P6201	N	0,822761	2120K1101	I	0,74571
31D120001– ALT PFD1	D	0,803895	31D120001– ALT PFD1	D	0,687719
2120K1101	I	–0,8004	7232O160A–OIT2_CHA	CE	0,664577
2120H2301– AIR1_PCK1_OUTCP_TEMP	AN	0,795786	7231N160A– OIT1 CHA	CD	0,660497
2120N6201–	O	0,783943	2120P6201	N	0,659451
2120C2401– AIR1_PACK2TEMP_DMD	Y	0,743352	2120N6201	O	0,628326
2120C2501– AIR1 PACK1TEMP DMD	X	0,720851	31W1N4001– ENG1 EPRA FWC1	BV	0,625405
2120P6301– AIR1_FD_UPTRMVLVTEMP	BE	0,72021	31W1O4001– ENG2_EPRA_FWC1	BW	0,608462
2120H2101– AIR1 PCK1 OUT TEMP	AR	0,711061	3612G4101– BLD1 PCL OUTTEMP2	L	0,51148
2120D7101– AIR1_CKPT_DUCT_TEMP	BD	0,691584	3612G4001– BLD2_PCL_OUTTEMP2	M	0,489962
2120P6101	AH	–0,6903	7231N440A–N2A1 CHA	BX	0,473356
2120F2301– AIR1 PCK2 OUTCP TEMP	AO	0,683686	7231J650A–ENG1A_T3	CB	0,466671
2120N6101	AI	–0,67797	7232O440A–N2A2 CHA	BY	0,463755

Multifactor linear connection

1. Direct

a) at increase of factor and effective attributes

$$Yxz = Ymin\left[1 + B\left(d_{\frac{Xi}{X\min}-1} + d_{\frac{Zi}{Z\min}-1}\right)\right].$$

б) at decrease of factor and effective attributes

$$Yxz = Ymax\left[1 - B\left(d_{1-\frac{Xi}{X\max}} + d_{1-\frac{Zi}{Z\max}}\right)\right].$$

2.Inverse

a) at increase of factor attributes and decrease of effective attribute

$$Yxz = Ymax\left[1 - B\left(d_{\frac{Xi}{X\min}-1} + d_{\frac{Zi}{Z\min}-1}\right)\right]$$

б) at decrease of factor attributes and increase of effective attribute

$$Yxz = Ymin\left[1 + B\left(d_{1-\frac{Xi}{X\max}} + d_{1-\frac{Zi}{Z\max}}\right)\right]$$

3. Combinational

a) at direct dependence *Y from X* and inverse dependence *Y* from *Z*:

$$Yxz = Ymin\left[1 + B\left(d_{\frac{Xi}{X\min}-1} + d_{1-\frac{Zi}{Z\max}}\right)\right]$$

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б) at inverse dependence *Y from X* and direct dependence *Y* from *Z*:

$$Yxz = Ymin\left[1 + B\left(d_{1-\frac{Xi}{X\max}} + d_{\frac{Zi}{Z\min}-1}\right)\right]$$

Calculation of comparison coefficients for effective attribute is executed with taking into account of the change of its values:

а) at increase $\frac{y_i}{y_{\min}} - 1$;

б) at decrease $1 - \frac{y_i}{y_{\max}}$.

Following formulas are used for computation of dependence parameters, estimation of the tightness and stability:

Dependence parameters

a) for single–factor dependence

$$b = \frac{\sum\left(\frac{Yi}{Y\min} - 1\right)}{\sum\left(\frac{Xi}{X\min} - 1\right)} = \frac{\sum d_y}{\sum d_x};$$

б) for multifactor dependence

$$B = \frac{\sum\left(\frac{Yi}{Y\min} - 1\right)}{\sum\left(\frac{Xi}{X\min} - 1\right) + \sum\left(\frac{Zi}{Z\min} - 1\right)} = \frac{\sum d_y}{\sum d_x + \sum d_z}.$$

Single–factor correlation coefficient

$$r_{yx} = \frac{\sum d_x d_y}{\sqrt{\sum d_x^2 \sum d_y^2}}.$$

Correlation index (single–factor and multifactor)

$$R = \sqrt{1 - \frac{\sum\left[\left(\frac{Yi}{Y\,min} - 1\right) - \left(\frac{Yx_i}{Yx_{min}} - 1\right)\right]^2}{\sum\left(\frac{Yi}{Y\,min} - 1\right)^2}} = \sqrt{1 - \frac{\sum\left(d_y - d_{yx}\right)^2}{\sum d_{yi}^2}}.$$

Coefficient of connection stability

$$K = 1 - \frac{\sum\left|d_y - bd_x\right|}{\sum d_y},$$

10.5. Linear multifactor model

Each function of many variables may be reduced to linear form by means of taking the logarithm or variables change. Taking into account this fact *the equation of multiple regression* is constructed in *linear form*:

$$y = a_0 + a_1x_1 + a_2x_2 + ... + a_nx_n, \tag{3}$$

where y – theoretical values of effective attribute, received by means of substitution of appropriate factor attributes into regression equation; $x_1, x_2, ... x_n$ –

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values of factor attributes; $a_0, a_1, a_2, ...a_n$ – equation parameters (regression coefficients).

Each equation coefficient: $a_0, a_1, a_2, ..., a_n$ (regression coefficient) indicates influence stage of appropriate independent factor on analyzed factor at fixed state (at middle level) of other factors. Dependent factor varies on appropriate regression coefficient together with change of each factor on the unit;

- *Development of multifactor model for researched phenomenon and its analysis.*

Creation of regression model is executed by means of electronic technology of *Data analysis* batch in Excel.

It is necessary to analyze following data for determination of statistical significance for received regression equation:

- the value of *multiple correlation coefficient R* that indicates on the connection tightness between dependent variable and aggregate of all independent factors;
- the magnitude of coefficient R^2 (R^2 must be >= 80%);
- F–statistics: Fp (F calculated) must be less Fk (F critical tabular value) – Fp < Fk;
- *Remainders* $e_t = y - \hat{y}$ are the difference between observed values and regression line (predicted values). The remainders must be independent.
- Presence or lack of autocorrelation phenomenon defined by means of Darbin–Watson criterion.

Regression equation parameters may be determined by means of the least–squares procedure. In this case such model parameters are determined, at which it is minimized the sum of deviates squares of empirical (actual) values for effective attribute from theoretical values, received in accordance with selected in accordance with regression equation, i.e.

$$S = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2 = \sum_{i=1}^{n} (y_i - a_0 - a_1 x_{1i} - a_2 x_{2i} - \dots - a_m x_{mi})^2 \to \min \tag{4}$$

On the base of extremum condition for the function of many variables $S(a_0, a_1, ..., a_n)$, which represents (1.4), it is necessary to equate to zero part derivatives for these variables or in matrix form it is necessary for past derivatives vector

$$\frac{\partial S}{\partial a} = \left(\frac{\partial S}{\partial a_0}, \frac{\partial S}{\partial a_1}, \dots, \frac{\partial S}{\partial a_m}, \right).$$

If we consider S as parameters function a_i and execute mathematical transformations (differentiation), then we receive the system of normal equations with m unknowns (in accordance with parameters quantity a_i).

$$\begin{cases} \sum y = na_0 + a_1 \sum x_1 + a_2 \sum x_2 + \dots + a_m \sum x_m, \\ \sum yx_1 = a_0 \sum x_1 + a_1 \sum x_1^2 + a_2 \sum x_2 x_1 + \dots + a_m \sum x_m x_1, \\ \dots \\ \sum yx_m = a_0 \sum x_m + a_1 \sum x_1 x_m + a_2 \sum x_2 x_m + \dots + a_m \sum x_m^2. \end{cases} \tag{5}$$

where n – observations quantity, m – factors quantity in regression equation. System solution permits to receive the values of regression parameters a_i.

The solution for system equations (5) may be discovered by means of Gauss method, Kramer method, inverse matrix calculation method or other methods for solution of linear equations systems.

On the ground of stated above it was developed linear correlation–regression model for forecasting of System solution emissions:

1. Takeoff, climb, cruising.

$$\begin{aligned}&\mathrm{YL1}=-33.50228905+a_1\cdot \mathrm{E}+a_2\cdot \mathrm{AJ}+a_3\cdot \mathrm{N}+a_4\cdot \mathrm{D}+a_5\cdot \mathrm{I}+a_6\cdot \mathrm{AN}+a_7\cdot \mathrm{O}+a_8\cdot \mathrm{Y}+a_9\cdot \mathrm{X}+\\&+a_{10}\cdot \mathrm{BE}+a_{11}\cdot \mathrm{AR}+a_{12}\cdot \mathrm{BD}+a_{13}\cdot \mathrm{AH}+a_{14}\cdot \mathrm{AO}+a_{15}\cdot \mathrm{AI},\end{aligned} \quad (6)$$

where $a_1 ... a_{15}$ – regression coefficients; a_1=0.000208738; a_2=–0.095245203; a_3=0.364856759; a_4=0.000792502; a_5=0.287628844; a_6=0.199535917; a_7=–0.148935295; a_8=0.027481093; a_9=–0.236603449; a_{10}=0.454039607; a_{11}=–0.222784416; a_{12}=–0.485501771; a_{13}=1.045999553; a_{14}=–0.074313633; a_{15}=–1.332143551. The error is equal to 5 %, $R^2 = 0,94$.

2. Cruising, descent, landing.

$$\begin{aligned}&\mathrm{YPL1}=24.23834606+a_1\cdot \mathrm{AG}+a_2\cdot \mathrm{AF}+a_3\cdot \mathrm{I}+a_4\cdot \mathrm{D}+a_5\cdot \mathrm{CE}+a_6\cdot \mathrm{CD}+a_7\cdot \mathrm{N}+a_8\times\\&\times \mathrm{O}+a_9\cdot \mathrm{BV}+a_{10}\cdot \mathrm{BW}+a_{11}\cdot \mathrm{L}+a_{12}\cdot \mathrm{M}+a_{13}\cdot \mathrm{BX}+a_{14}\cdot \mathrm{CB}+a_{15}\cdot \mathrm{BY},\end{aligned} \quad (7)$$

where $a_1 ... a_{15}$ – regression coefficients;
a_1=0.986569671; a_2=–0.376956249; a_3=–0.177502136; a_4=–7.13304E–05; a_5=–1.222818509; a_6=0.991524157; a_7=0.113506088; a_8=–0.075409215; a_9=–12.78214729; a_{10}=13.93375454; a_{11}=–0.028261583; a_{12}=0.015099345; a_{13}=0.356149675; a_{14}=0.007847947; a_{15}=–0.441642012;
The error is equal to 6 %, $R^2 = 0,89$.

10.6. Nonlinear multifactor model

Multiplicative (nonlinear) models of forecasting are used widely in practice of estimation. All variables in multiplicative model are multiplied not by their coefficients. Instead of this they are raised to power or they serve as exponents. Then results are multiplied. It is necessary initially to transform the model into additive form for estimation of parameters.

If we have attributes nonlinear dependence, which is reduced to linear form, then coefficients values of multiple regression determined by means of least–square procedure. The distinction is that this method is applied to transformed data rather than initial information.

Let us consider power function

$$y = a_0 \cdot a_1^{x1} \cdot a_2^{x2} \cdot a_3^{x3} \cdot \ldots \cdot a_n^{xn}, \quad (8)$$

where $a_1, ..., a_n$ are regression coefficients;

We transform the function (1.8) into linear form:

$$\ln(y) = \ln(a_0) + x_1 \ln(a_1) + x_2 \ln(a_2) + ... + x_n \ln(a_n), \quad (9)$$

where the variables are expressed in logarithms.

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Further least–squares method is applied as earlier: normal equations system is created and values $\ln(a_0), a_1, ..., a_n$ are determined. We find antilogarithm of $\ln(a)$ and determine the value for parameter a and view for power function equation.

So long as the parameters of power function are elasticity coefficients, they are comparable in accordance with different factors. On the ground of above stated method it was developed nonlinear correlation–regression model for PSA (Phthalic anhydrid) emissions:

1. Takeoff, climb, cruising.

$$YN1 = a_0 \cdot a_1^{E} \cdot a_2^{AJ} \cdot a_3^{N} \cdot a_4^{D} \cdot a_5^{I} \cdot a_6^{AN} \cdot a_7^{O} \cdot a_8^{Y} \cdot a_9^{X} \cdot a_{10}^{BE} \cdot a_{11}^{AR} \times \times a_{12}^{BD} \cdot a_{13}^{AH} \cdot a_{14}^{AO} \cdot a_{15}^{AI}, \quad (10)$$

where $a_0 ... a_{15}$ are regression coefficients;

a_0=0.006842089; a_1=1.000024862; a_2=0.991198893; a_3=1.0222879; a_4=1.00001889; a_5=1.004654298; a_6=1.021243538; a_7=0.999380163; a_8=0.999033173; a_9=1.004514485; a_{10}=1.076381442; a_{11}=0.987488691; a_{12}=0.974034468; a_{13}=0.997858045; a_{14}=0.998046044; a_{15}=0.98574593.

The error is equal to 2 %, $R^2 = 0,98$.

2. Cruising, descent, landing.

$$YPN1 = a_0 \cdot a_1^{AG} \cdot a_2^{AF} \cdot a_3^{I} \cdot a_4^{D} \cdot a_5^{CE} \cdot a_6^{CD} \cdot a_7^{N} \cdot a_8^{O} \cdot a_9^{BV} \cdot a_{10}^{BW} \cdot a_{11}^{L} \cdot a_{12}^{M} \cdot a_{13}^{BX} \times \times a_{14}^{CB} \cdot a_{15}^{BY}, \quad (11)$$

where $a_0 ... a_{15}$ are regression coefficients;

a_0=178.5970; a_1=1.161811; a_2=0.884452; a_3=0.946524; a_4=0.999966509; a_5=0.803535464; a_6=1.207008624; a_7=1.037623115; a_8=0.970508824; a_9=0.057582885; a_{10}=15.16904501; a_{11}=0.992998308; a_{12}=1.005735521; a_{13}=1.076433038; a_{14}=1.001860549; a_{15}=0.911682722; The error is equal to 3 %, $R^2 = 0,92$.

10.7. Method of deterministic stochastic factorial analysis

Deterministic stochastic analysis corresponds to research procedure for study of the factors influence. These factors connection with effective indicator has functional character, i.e. effective indicator of factor model is expressed in the form of factors product, quotient or algebraic sum. There are following methods of factor analysis: chain substitution method, absolute differences method, relative differences method, integral method, method of taking the logarithm.

This form of factor analysis is the most popular. It is sufficiently simple in application (as compared with stochastic analysis), it permits to understand the logic of operation for main factors, to estimate quantatively their influence, to define the factors, which may be changed, to estimate the proportion and appropriateness of this change for improvement of complicated technical system.

Stochastic analysis corresponds to research procedure for study such factors, which have connection with effective attribute, however this connection, in contrast to functional connection, is incomplete (correlation). If we have functional (complete) dependence, then appropriate function change occurs always at argument change. If we have correlation connection, then argument change may give several values for function increment subject to combination of other factors defining this attribute. There are following methods of stochastic factor analysis: approach of pair correlation; multiple correlation analysis; matrix models; mathematical programming; method of operations research.

On the ground of executed correlation analysis for 82 factors it was selected 5 factors, which differ in flight configuration. These 82 factors influence on detection and changing of PSA (Phthalic anhydrid) concentration in the air of airplane cabin. (Takeoff, climb, cruising); (Cruising, descent, landing) [9]. Method implementation is started from selection and calculation of approximating–interpolating functions that describe the connection for each factor. Calculated functions are presented below:

I. Takeoff, climb, cruising

1. Parameter 2161F5101–AIR1_ZCAB

$$y_1 = a + bx + cx^2 + dx^3 + ex^4 + fx^5, \qquad (12)$$

where *a*=–0.20515394; *b*=0.005864127; *c*=–6.5302e–06; *d*=2.94496e–09; *e*=–5.0896e–13; *f*=3.04646e–17.

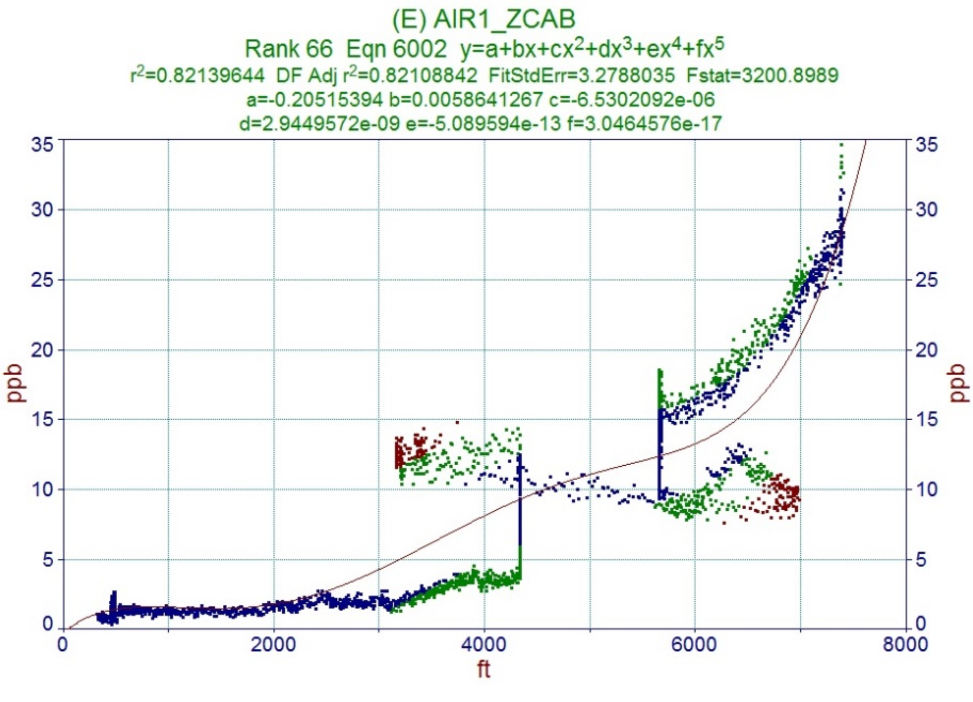

Fig.1.

2. Parameter 2120P4701–AIR1_PCK1_INCP_TEMP

$$y_2 = a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6 + hx^7, \qquad (13)$$

where *a*=–692.387293; *b*=63.75570925; *c*=–2.47853327; *d*=0.052804729; *e*=–0.00066516; *f*=4.94676e–06; *g*=–2.008e–08; *h*=3.43145e–11.

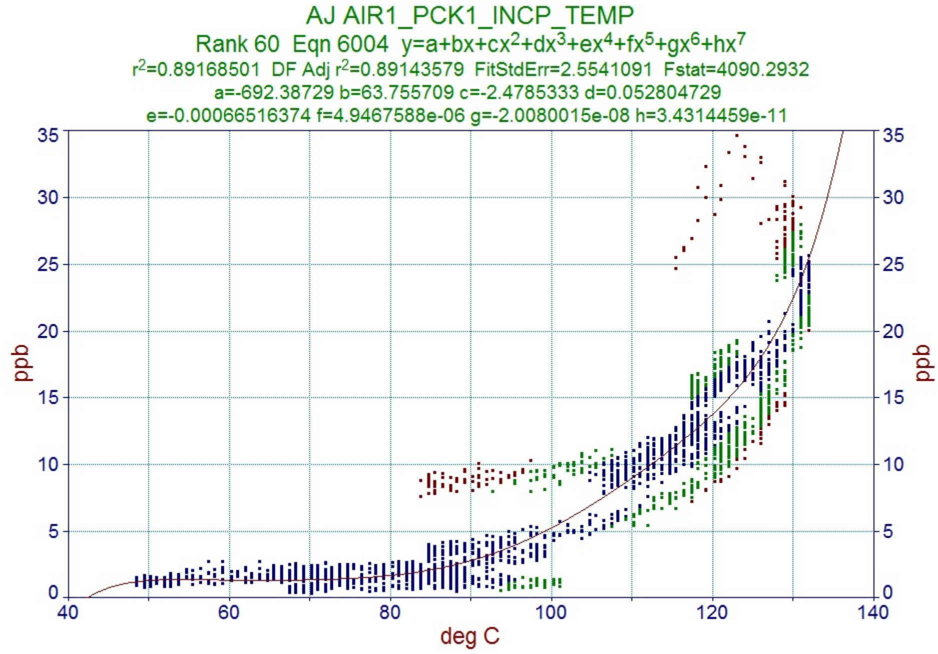

Fig.2.

3. Parameter 2120P6201

$$y_3 = a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6, \quad (14)$$

where a=–229842.993; b=8397.912450; c=–127.322046; d=1.025139880; e=–0.00462236; f=1.10646e–05; g=–1.0982e–08.

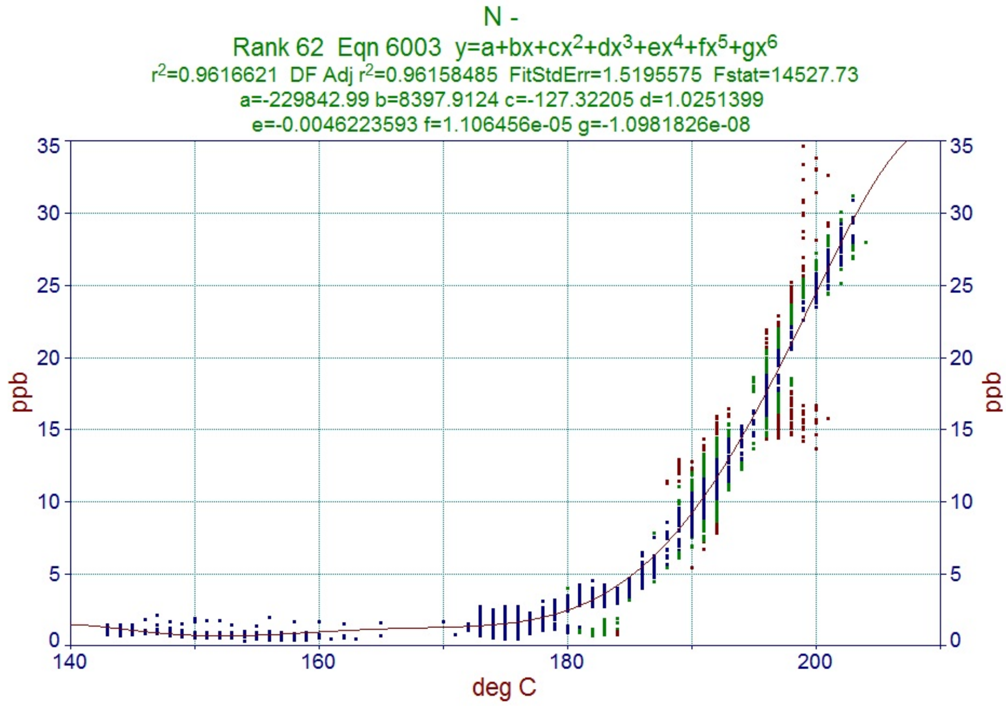

Fig.3.

4. Parameter 31D120001–ALT_PFD1

$$y_4 = a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6 + hx^7, \quad (15)$$

where a=1.148207505; b=0.000771207; c=–3.5994e–07; d=5.93112e–11; e=–4.517e–15; f=1.72589e–19; g=–3.198e–24; h=2.29665e–29.

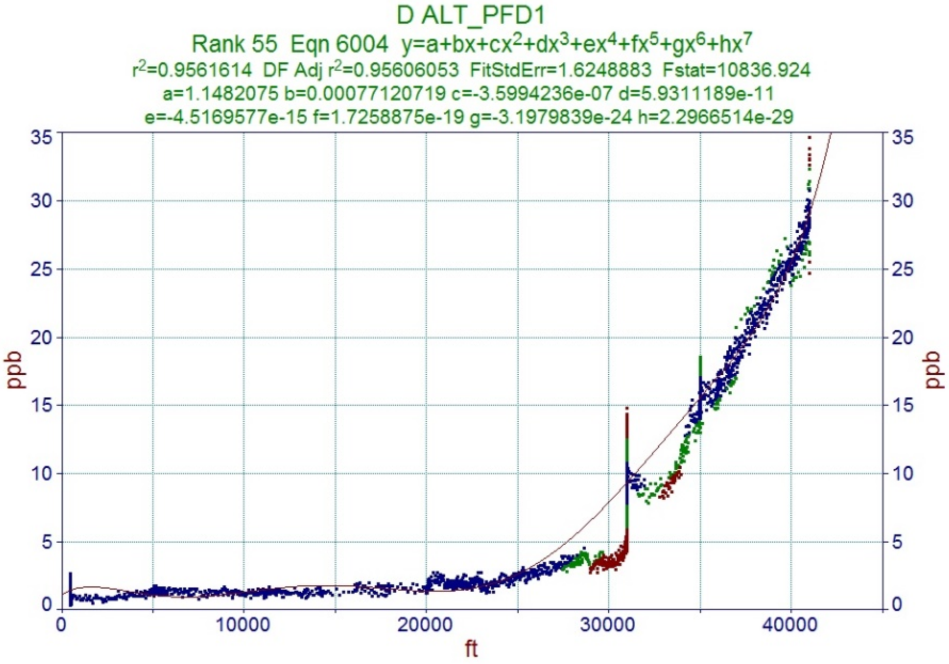

Fig.4.

5. Parameter 2120K1101

$$y_5 = a + bx + cx^2 + dx^3 + ex^4 + fx^5 + gx^6 + hx^7, \qquad (16)$$

where a=0.317724914; b=0.137436621; c=0.026640819; d=–0.00270663; e=–4.2532e–05; f=5.8269e–06; g=2.8342e–08; h=–3.8971e–09;

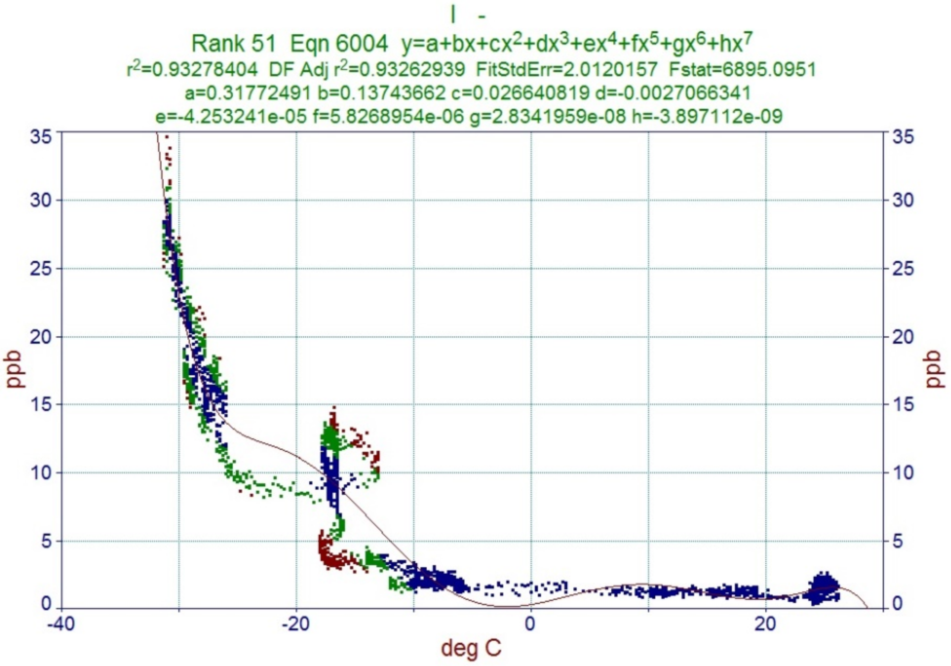

Fig.5.

II. Cruising, descent, landing

1. Parameter 2120F2401– AIR_PCK2_FLAP_OUTPOS

$$y_1 = a + bx^2, \qquad (17)$$

where a=2.886808804; b=0.025384438;

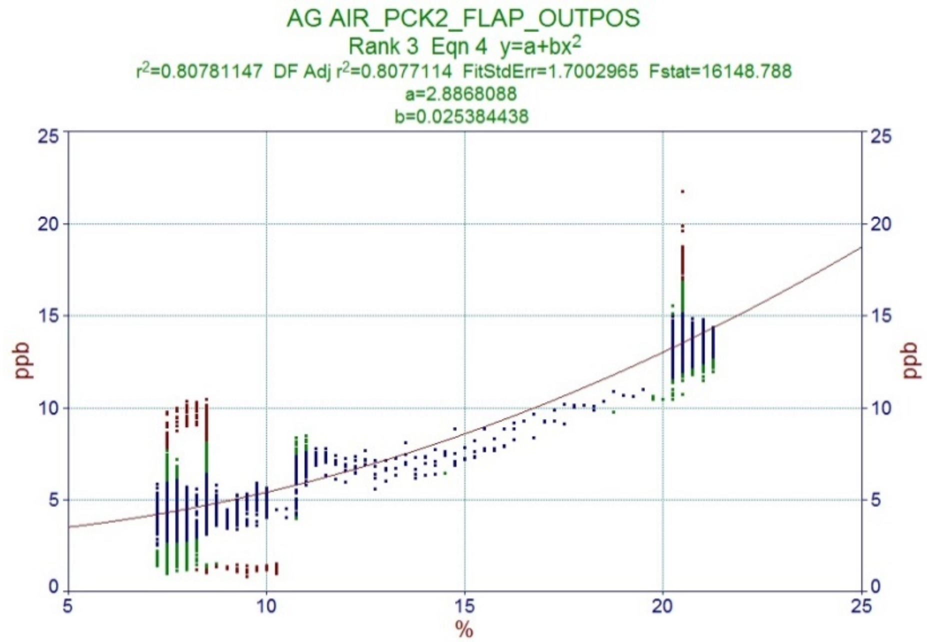

Fig.6.

2. Parameter 2120H2401– AIR_PCK1_FLAP_OUTPOS

$$y_2 = \frac{(a + cx + ex^2 + gx^3)}{(1 + bx + dx^2 + fx^3)}, \tag{18}$$

where a=5.970722012; b=–0.26412007; c=–1.58410213; d=0.022438223; e=0.131778761; f=–0.00058599; g=–0.00320155;

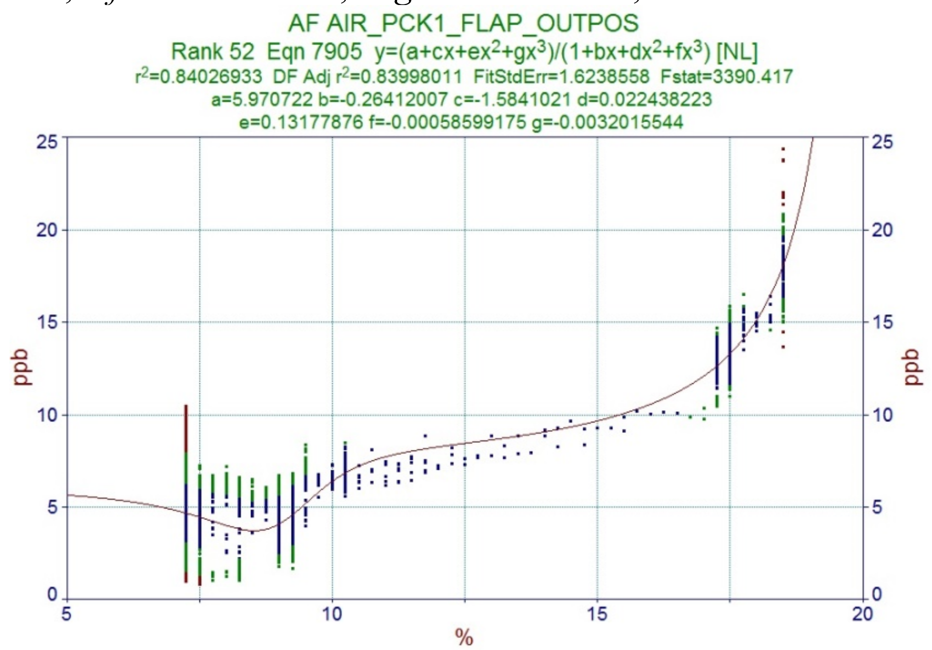

Fig.7.

3. Parameter 2120K1101

$$y_3 = \left(a + bx + cx^2 + dx^3\right)^2, \tag{19}$$

where a=2.324320019; b=0.013792734; c=–0.00075387; d=–8.8517e–05;

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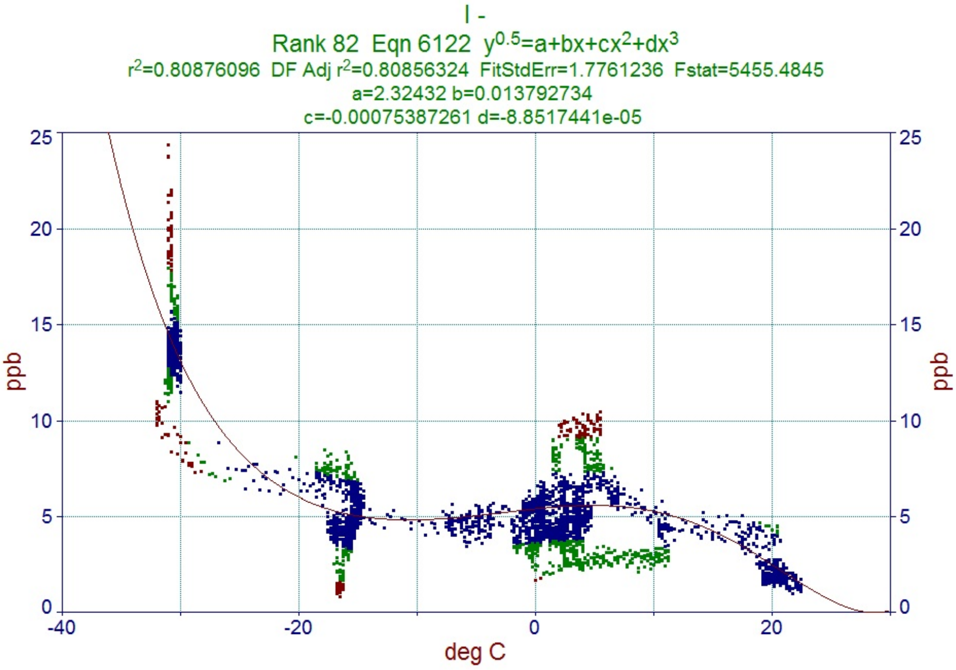

Fig.8.

4. Parameter 31D120001– ALT_PFD1

$$y_4 = a + bx + \frac{c}{x} + dx^2 + \frac{e}{x^2} + fx^3 + \frac{g}{x^3} + hx^4, \qquad (20)$$

where a=358.3005514; b=–0.02756409; c=–2.3421e+06; d=1.13003e–06; e=7.39319e+09; f=–2.3284e–11; g=–8.8982e+12; h=1.92756e–16.

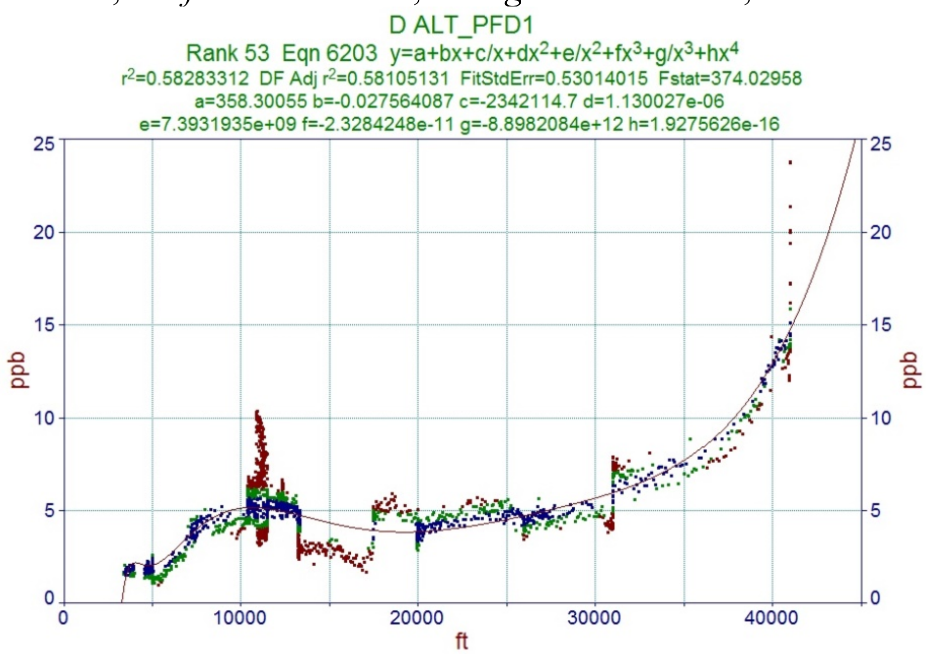

Fig.9.

5. Parameter 2120N6201

$$y_8 = a + bx + \frac{c}{x} + dx^2 + \frac{e}{x^2} + fx^3, \qquad (21)$$

where a=–11875.0106; b=87.55710321; c=793516.2960; d=–0.31823701; e=–2.0857e+07; f=0.000457021.

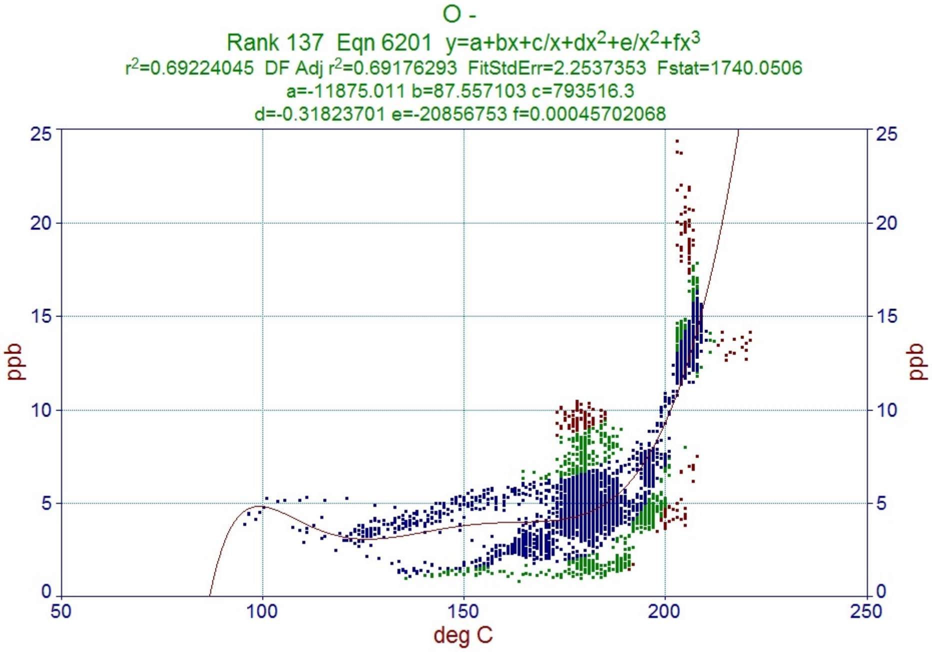

Fig.10.

It is necessary for further computation to determine average value for received coefficients $y_1, ..., y_{15}$

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i , \qquad (22)$$

General view of mathematical model is described by means of following expression:

$$YY_{(I,II)} = \sqrt{\sum_{i=1}^{n} \frac{y_i}{\bar{y}}} ,$$

$$YY_{(I,II)} = \sqrt{\frac{y_1}{\bar{y}} + \frac{y_2}{\bar{y}} + \frac{y_3}{\bar{y}} + \frac{y_4}{\bar{y}} + \frac{y_5}{\bar{y}} + \frac{y_6}{\bar{y}} + \frac{y_7}{\bar{y}} + \frac{y_8}{\bar{y}} + \frac{y_9}{\bar{y}} + \frac{y_{10}}{\bar{y}} + \frac{y_{11}}{\bar{y}} + \frac{y_{12}}{\bar{y}} + \frac{y_{13}}{\bar{y}} + \frac{y_{14}}{\bar{y}} + \frac{y_{15}}{\bar{y}}} \qquad (23)$$

The error of developed model is equal to 0,75 %, $R^2 = 0,985$.

Conclusions

Based on experimental data, mathematical models are developed for predicting the emissions of PSA (Phthalic anhydrid) in airplanes. Three types of mathematical models are obtained. The first mathematical model. The linear correlation-regression model for forecasting PSA emissions (Phthalic anhydrid) for two flight modes: a) takeoff, climb, cruising; b) cruising, descent, landing. The error of this mathematical model is 6%, and $R^2 = 0,89$. The second mathematical model. Non-linear correlation-regression model for forecasting emissions of PSA (Phthalic anhydrid): for two flight modes: a) takeoff, climb, cruising; b) cruising, descent, landing. The error of this mathematical model is 3%, $R^2 = 0,92$. The third mathematical model. A mathematical model based on the method of deterministic stochastic factor analysis proposed by the authors for two flight modes: a) takeoff, climb, cruising; b) cruising, descent, landing. The error of this mathematical model is 0.75%, $R^2 = 0,985$.

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