

Using GUI of Matlab and fuzzy principles for evaluating of some process quality

S.Hrehova, J. Mizakova

Abstract—Quality is becoming a key factor in customer choice among several products. Knowledge of the achieved level of quality of the production process is becoming an important element in attracting and retaining marketing. It is therefore desirable to give this information to managers in an acceptable form, to have enough relevant information in obtaining of orders for your business.

The paper deals with design of graphical user interface to evaluate the achieved quality of the production process using tools of Matlab. In conjunction with the principles of fuzzy logic, which can be converted numerical value into verbal expressing are expanding their area of application. There are evaluated data which are gained through process and which are written to a file. They are subsequently evaluated using fuzzy toolbox of Matlab system. The rules designed for individual decision-making processes reflect the experience of experts in the field. These tools allow easy application of fuzzy rules by Fuzzy Toolbox and the connection with Simulink and its tools allow display the results.

Keywords— quality, fuzzy principles, Matlab

I. INTRODUCTION

EACH product has a certain dimension which is highly important for it. This means that if the size is out of the tolerance limits, the product is classified as non-compliant, as a waste. As a result, companies have losses and therefore they put increased emphasis on compliance with these requirements. Statistics is a science which plays an important role in quality control and improvement. The evaluation of the individual processes through the use of statistical methods is an effective tool for optimizing these processes [3]. The most applied tools of statistical evaluation of processes are the tools of statistical process control (SPC), which play an important role in practice.

The ability to produce products of required quality is a priority for each production company. Great competitive pressure is forcing these companies to use techniques that analyze the production process for compliance to quality.

Operating a company's ability to respect the required criteria of quality of production has thus become critical potential for success in the market.

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The power system for evaluating the quality of production process is statistical process control. It is a set of tools to maintain process stability and to improve its capability by reducing process variability. The theory of statistical process control is based on the existence of variation parameter in the production process which is influenced by a number of effects which make it impossible to produce completely two identical products. The aim of SPC should be to maximize the number of real faults detected, minimize the time taken to detect real faults. This requirement can be expressed in terms of a cost function to be minimized [2].

To ensure effective using gained information it is necessary to express it in an acceptable form for managers who need it. Acceptable form how we can represent expert knowledge is to express the obtained numerical values in the form of verbal evaluation. In this context, the ideal solution is using the tools of fuzzy logic.

In this paper is analyzed a production process in terms of evaluation the achieved level of quality using the principles of statistical process control and fuzzy logic. The evaluating of achieved quality of production process was divided into two parts. The first is evaluating own production process and the second is evaluating possible costs. There are the individual coefficients describing the achieved quality and losses that may arise from non-compliance with quality requirements. There is considered a loss function and estimation of non-conforming products.

The aim is to design simple user interface to get understandable information about achieved quality of production process and to allow for a deeper analysis of an observed process using tools of Matlab.

II. APPROACHES TO EVALUATION OF PROCESS USING SPC

A. Indices of capability

The role of indices of capability is to express the relationship between the target value T , specification limits Upper specification limit and Lower specification limit and actual process expressed by the median μ , standard deviation σ of measured values of selected quality characteristic of the process.

C_p index (the process capability index) compares the required tolerance limits with natural tolerance limits of a process. It is assumed the normal distribution [2].

$$C_p = \frac{(USL - LSL)}{6\sigma} \quad (1)$$

where σ is standard deviation of process - standard deviation measures the variability of the observations around the mean. It is the most widely used measure of dispersion in quality control.

USL - Upper Specification Limit

LSL - Lower Specification Limit

Cpk index is an indicator of current capability of the process. It responds to the deviation of the mean volume of the process from the centre of the tolerance interval, eventually from the target value of the reference indicator of quality. The disadvantage of *Cpk* index is that if the desired target value is not equal to the centre of the tolerance limits, the process does not capture the deviation from target values.

$$C_{pk} = \min\left\{\frac{(USL - \mu)}{3\sigma}; \frac{(\mu - LSL)}{3\sigma}\right\} \quad (2)$$

where μ is the arithmetic mean of the measured values.

The index *K* indicates that if the required target process is not identical with the centre of the tolerance range than it captures the mean deviation from the desired value *T*, which is very important information.

$$K = \frac{2(T - \mu)}{(USL - LSL)} \quad (3)$$

T - required value

In this case we assume required value *T* such as centre of tolerance limits.

It may occur

$K = 0$ - the mean value of the process is identical to the desired target value

$0 < K < 1$ - mean the process is within tolerance limits

$K > 1$ - the mean value of the process is out of the tolerance limits.

Detailed description of these indices in terms of applications of fuzzy approach is presented in [3].

Another input to evaluation of the production process can be a percentage of the values - *P* that are out of the upper, respectively, lower control limit.

B. Control chart

The most important use of a control chart is to improve the process. Control charts may also be used to estimate the parameters of a production process, and, through this information, to determine process capability. The control chart may also provide information useful in improving the process. It may not be possible to completely eliminate variability, but

the control chart is an effective tool in reducing variability as much as possible [4].

Control chart is a graphical tool for monitoring the activity of processes. It is important management control tool. In this chart are indicated three lines. Central line, which represents the average of process values and upper control limit (UCL) and lower control limit (LCL). These limits are chosen so that probability of the sample points falling between them is almost 1 if the process is in statistical control. However, a point that plots outside of the control limit is interpreted as evidence that the process is out of control. There exist rules for determining out of process conditions. These rules focus on nonrandom or systematic behavior of a process as evidenced by a nonrandom plot pattern [5].

It is customary to connect the sample points on the control chart with straight-line segments, so that it is easier to visualize how the sequence of points has evolved over time.

The control chart will only detect assignable causes. Management, operator, and engineering action will usually be necessary to eliminate the assignable causes.

$$UCL = \mu + 3\frac{\sigma}{\sqrt{n}}$$

$$CL = \mu$$

$$LCL = \mu - 3\frac{\sigma}{\sqrt{n}} \quad (4)$$

The quantity $\frac{3}{\sqrt{n}} = A$ is a constant that depends on *n*, which has been tabulated.

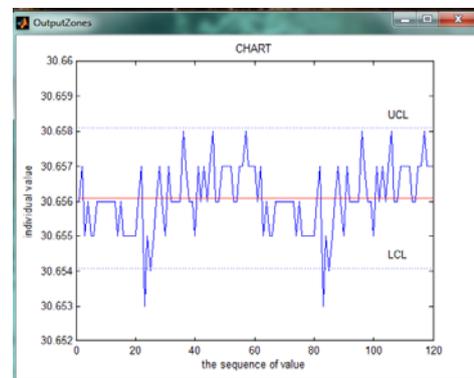


Fig.1 Graph of evaluation values

The graphical evaluation of observed production process represents fig. 1. If the process is in the statistical control, virtually all subgroup occurrences-per-unit should be between the control limits and they should fluctuate at random about the center line [6].

Values which are out of control limits do not mark such as defective products, but may indicate possible errors in the process. To assess the quality of evaluation production process will evaluate these values as a percentage.

C. Loss of process

Costs of nonconformance typically include internal and external failure costs. It is possible that greater cost-saving opportunities might lie in reducing the cost of conformance. In this regard, the process-cost approach could be helpful by eliminating process steps, to reduce the cost of conformance and can reduce the hidden quality costs [6].

Loss function is a mathematical function that reflects a financial loss. This loss is caused by the variability of the true value of quality characteristics of the desired (target) value. The value of the loss function is determined by the financial constants to be determined in each case separately.

Taguchi recognized that in an industrial process it is vital to produce a product on target, and the variation around the mean caused poor manufactured quality leading to economic losses and they can be quantified using the following equation [7].

$$L = k(X - T)^2 \quad (5)$$

where

L - is the loss in money

k - is a constant that depends on the magnitude of the characteristic and the monetary unit involved

T - target value,

X - quality features of selected product

The constant k is solved according (5):

$$k = \frac{A}{\Delta^2} \quad (6)$$

where A - costs for repair,

Δ - deviation of specification from target value

By Taguchi losses grow quadratically with the deviation characteristics of the product from its nominal value T . Minimizing losses is possible only by reducing the variance of these values around the nominal value. Achieve nominal value and steadily reduce the variance is the task for the continuous improvement of quality.

Estimate the probability p that the value of a random variable X with a normal distribution lie outside the desired tolerance interval (LSL , USL) is:

$$p = \Phi\left(\frac{LSL - \mu}{\sigma}\right) + \left[1 - \Phi\left(\frac{USL - \mu}{\sigma}\right)\right] = 1 - \left[\Phi\left(\frac{USL - \mu}{\sigma}\right) - \Phi\left(\frac{LSL - \mu}{\sigma}\right)\right] \quad (7)$$

where $\Phi(u)$ is the distribution function for a standard normal distribution $N(0,1)$. The probability p that the values of the monitored quality indicator X which have a normal distribution, lie outside the desired tolerance range, if the process is centered is 0.0027. This means that if the index $Cp = 1$, 0.27% of the products lie outside of the desired tolerance range. Given that the index Cp not captured position

the average of process to the middle of the tolerance range, the values are considered only a minimum estimate of the proportion of non-conforming products. From the interpretation can be confirmed that the process is the best one that produces only products placed inside the tolerance interval [8].

III. BRIEFLY DESCRIPTION OF USED FUZZY PRINCIPLES

Fuzzy Logic provides a different way to approach a control or classification problem. The Fuzzy Logic tool was introduced in 1965 by Lotfi Zadeh. It is a mathematical tool for dealing with uncertainty. It offers to a software computing system the important concept of computing with words. It grants a technique to deal with vagueness and information granularity. Fuzzy systems are capable to emulate the imprecision and incertitude that are characteristic to human behavior. Also, this can intervene in most of real world applications, using for this a number of if-then rules. The fuzzy systems depend largely on the acquisition process from the human expert and have serious problems of adaptation [9].

A. Identification of linguistic variables

Linguistic rules describing the control system consist of two parts; an antecedent block (between the IF and THEN) and a consequent block (following THEN). Depending on the system, it may not be necessary to evaluate every possible input combination, since some may rarely or never occur.

An important term in this area is linguistic variable. Linguistic variables represent crisp information in a form and precision appropriate for the problem. It is a type of variables, whose values are the words of natural language. The linguistic variable is determined by arranged foursome (X , $T(X)$, U , M) where X is the name of linguistic variable, $T(X) = \{A, B, \dots\}$ is set of verbal linguistic variable values, U is universe of linguistic variable, where each linguistic variable $A \in T(X)$ is expressed by fuzzy set $A = \{(x, \mu_A(x)); x \in U\}$ a collection of these fuzzy sets is a set of M [10].

In this paper are three variables interpreted by the verbal as: **Wrong**, **Good** and **Very Good** for production system and for loss of process there are **NoLoss**, **Sufficient** and **Insufficient**

B. Membership function

To quantify a linguistic term is used a membership function. Membership functions allow us to graphically represent a fuzzy set. The x axis represents the universe of discourse, whereas the y axis represents the degrees of membership in the $[0,1]$ interval [11]. In this case was chosen a Gamma function.

The next figure shows a membership function design for index Cp . For another indices of capability were designed the membership functions some ways.

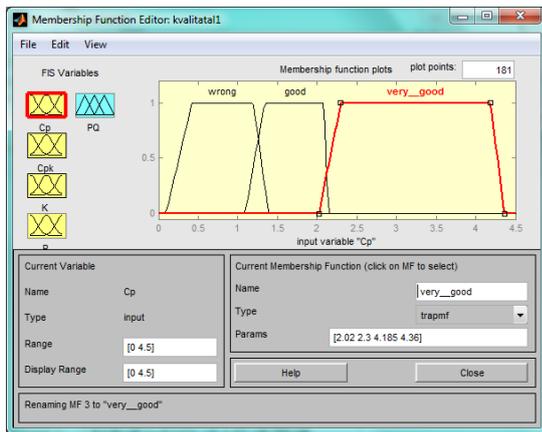


Fig. 2 Membership functions for evaluating index Cp

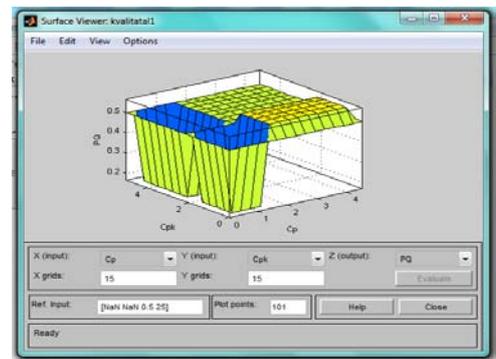


Fig. 5 Surface viewer for evaluating a process

C. Using fuzzy principles for observed process

The evaluation of own production process using fuzzy principles represents designed block scheme described fig.3.



Fig.3 Block diagram of the production process control using a Fuzzy controller1

The rules for evaluation of observed production process were designed using the Fuzzy toolbox of Matlab. Such as inputs were used indices of capability and percentage of the values which are out of the upper, respectively, lower control limit. The follow windows display these rules.

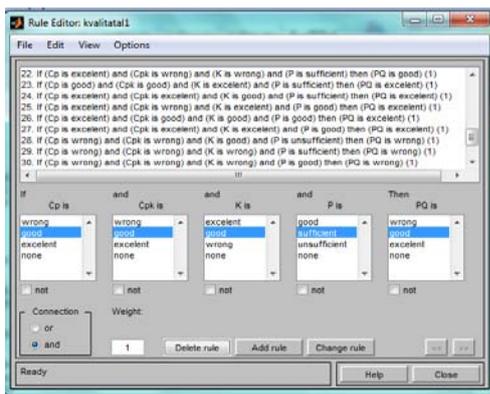


Fig. 4 Rules for evaluating a process

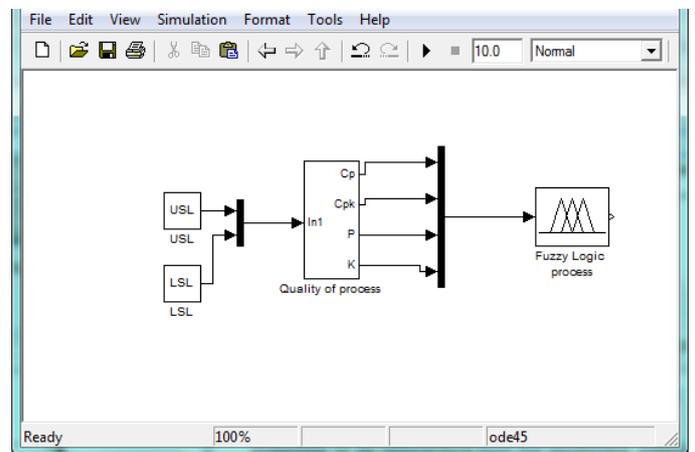


Fig. 6 Simulation scheme of evaluation production process

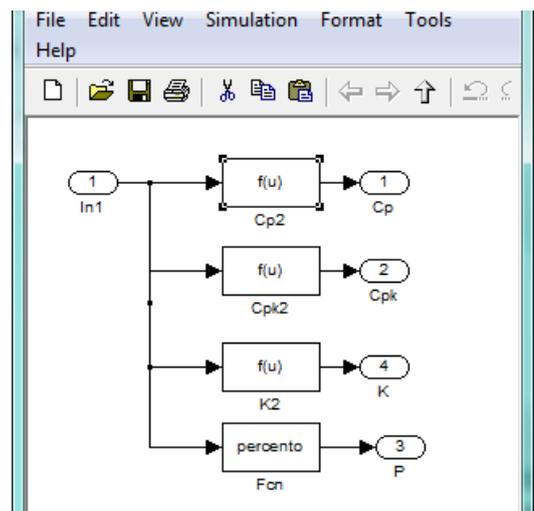


Fig. 7 Detail of block with Fcn functions

Individual input values needed to calculate these values are imported from basic setting of Matlab, where they are stored. Other index values are calculated in a similar way. The next figure shows calculation of index of capability Cp.

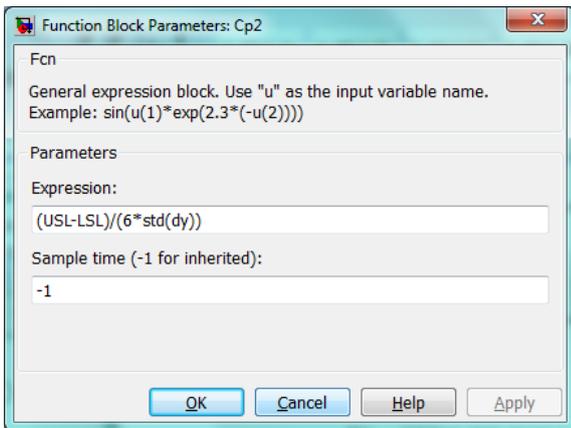


Fig. 8 Calculation Cp index

The loss function and non-conforming products are inputs for evaluating the achievement level of quality in terms of possible economic losses. The block diagram is shown in fig. 9.

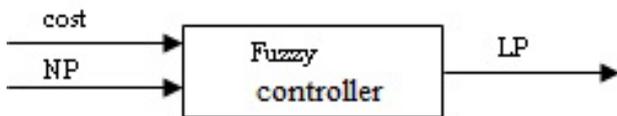


Fig.9 Block diagram of the production process control using a Fuzzy controller2

The rules for evaluation of possible financial costs of process were designed using the Fuzzy toolbox of Matlab such as new file. Such as inputs were used loss function and index of capability Cp which represents a non-conforming products. The follow figure displays these rules.

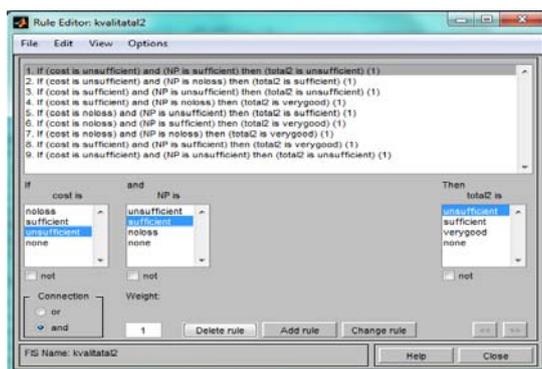


Fig. 10 Rules for loss of process

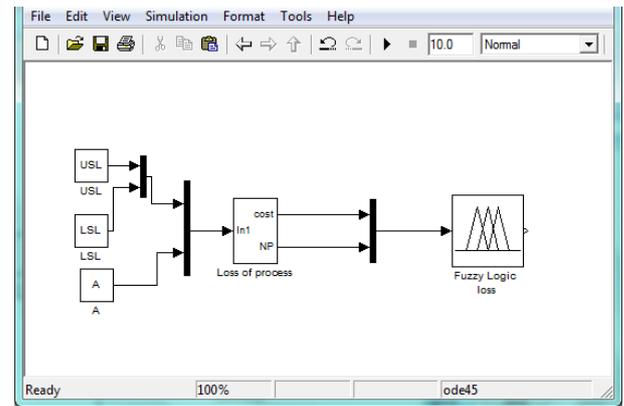


Fig. 11 Simulation scheme of evaluation loss of process

The total evaluation of achieved quality of the production process represents the block diagram shown in fig. 12.

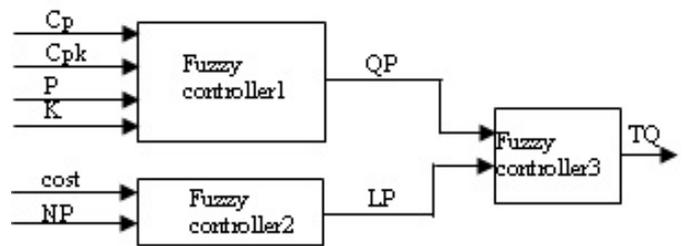


Fig.12 Block diagram of the total quality

IV. USING THE TOOLS OF MATLAB

To simulate the proposed evaluation model of the production process in terms of achieved quality were used tool of Matlab - Simulink, Fuzzy toolbox, possibility to creating graphical user interfaces - GUI and program tools.

Simulink is an interactive tool for modeling, simulating, and analyzing dynamic systems. It enables you to build graphical block diagrams, simulate dynamic systems, evaluate system performance, and refine your designs. Simulink integrates seamlessly with Matlab, providing you with immediate access to an extensive range of analysis and design tools.

The Fuzzy Logic Toolbox is a collection of functions built on the Matlab numeric computing environment. It is a tool for solving problems with fuzzy logic. The construction of fuzzy models can be accomplished in three ways: the first being through commands, the second through a graphical interface, and the third through block diagrams. The graphical interface provided is very intuitive, encouraging learning. The system allows export source code in C for embedded software projects. The tool also allows performing simulations of features which may be accompanied by visual form. The designer can configure the system so that the values corresponding to the inputs of fuzzy controller are obtained through an external interface. A strong point of the system is the simplicity in the construction of fuzzy systems [12].

There is considered a most common type of fuzzy system, which consists of a single rule base, whereby the associated

fuzzy model is described as a ‘grey box’ [13]. A single rule based system deals with all process inputs simultaneously while not taking into account the interactions and the structure of the system.

Guide - graphical user interface (GUI) is a graphical display in one or more windows containing controls, called components that enable user to perform interactive tasks. The types of components include graphical control (pushbuttons, edit boxes, lists, sliders, etc), static elements (frames and text strings), menus, and axes. Any GUI in Matlab is in essence a collection of objects. Every object in the GUI has a unique handle. Matlab is able to automatically generate a lot of code that is needed for GUI.

Most GUIs wait for their user to manipulate a control, and then respond to each action in turn. Each control, and the GUI itself, has one or more user-written routines (executable MATLAB code) known as callbacks, named for the fact that they “call back” to MATLAB to ask it to do things. The execution of each callback is triggered by a particular user action such as pressing a screen button, clicking a mouse button, selecting a menu item, typing a string or a numeric value, or passing the cursor over a component.

The GUI then responds to these events. You, as the creator of the GUI, provide callbacks which define what the components do to handle events. This kind of programming is often referred to as event-driven programming [14].

For this solution was designed follow user form.

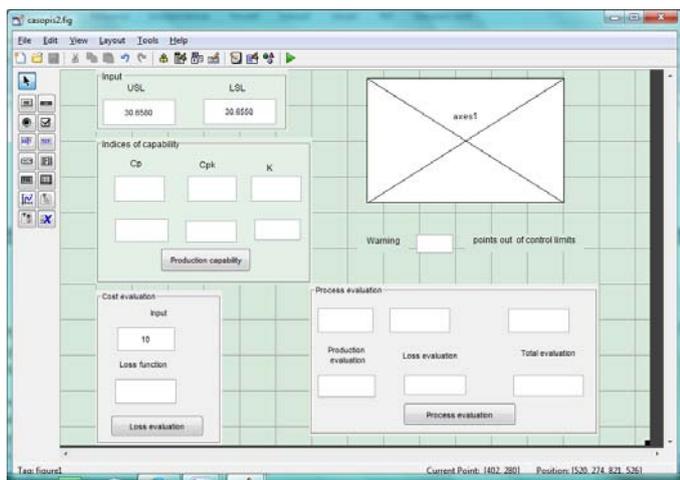


Fig.13 Design of the user interface

This form is divided into separate parts in order to vote monitored the process from different perspectives. Each required input values (USL and LSL) assign the user to the "Input" fields. Other fields are not accessible to the user. They are used to list the results calculated by a mathematical expression. The individual properties of objects have been set using the Property inspector.

A. Simulation of process

There is considered data which is retrieved from MS Excel, and individual necessary variables should be put into windows of user form. Given the fact that the proposal was also applicable to other data, it is necessary require of user input basic value of Upper and Lower specification limit and the estimated cost of repairing the loss assessment process. After entering the required inputs the process is visualized in parts. On the basis of the achieved level of visualization process we can assume a level of achieved quality of process. Visualization recourse was described in more detail in [15].

Within the individual subsystems in a simulation scheme are used the user functions which calculate the necessary values. These values are input to the fuzzy block, which they subsequently processed by established rules.

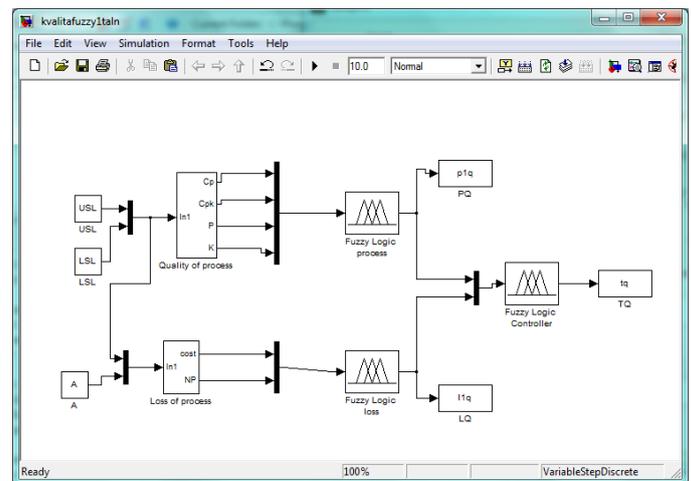


Fig. 14 Simulation scheme of selected process

This proposal is based on the requirements in order to assess the quality reached in terms of process and in view of the possible economic losses. To better assess the actual process values are key indicators Cp and K shown separately.

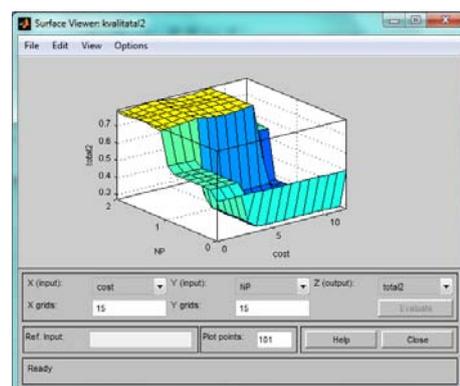


Fig. 15 Surface viewer for a loss of process

After running the main script, the individual display units in the diagram show the numeric values that represent the level of quality of evaluation process.

B. Using designed user form to evaluate the process

The graphical user interface design is based on the following requirements:

- 1) Show the numerical values of the production process capability indices.
- 2) Graphical display of the observed process with regard to the possibility of exceeding the upper, respectively lower control limits.
- 3) The evaluation of process for possible economic losses using the loss function and non-conforming products.
- 4) Evaluation of total quality of production process using linguistic terms according to used fuzzy principles.

The user writes the name of main M-file to the command line of workspace. After confirming this command is displayed an empty environment and waiting for the required inputs. The evaluation of process is split, but for the total evaluation is necessary to have evaluated both parts of the process.

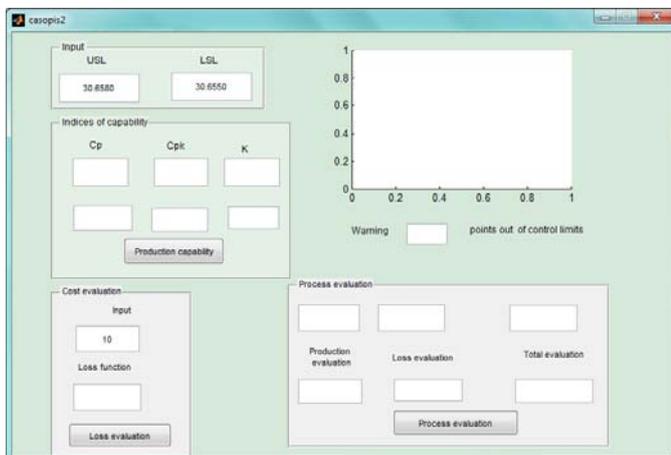


Fig. 16 Graphical interface for evaluate the process

The user inserts the values of upper and lower specification limits into the box USL and LSL, which are known of technical documentation. After pressing the pushbutton "Production capability", capability indexes are written into the windows and is displayed the graphical interpretation of the observed process. The program determines the number of values that are outside the upper or lower control limits as well and prints the number into the settings. The statistical evaluation of the achieved level of competence in the production process are the techniques that assess not only the number of these values, but also their arrangement. It is a fact that these values were due to random effects, or indicate any cause.

Because the process is evaluated using the fuzzy toolbox and Simulink, it is necessary to insert the necessary variables to the basic workspace of Matlab. There was used *assignin* command.

This command is particularly useful for these tasks:

- Exporting data from a function to the Matlab workspace.
- Within a function, changing the value of a variable that is defined in the workspace of the caller function (such as a variable in the function argument list)

```
y1=get(handles.USL,'userdata');
assignin('base','USL',y1)
```

The pushbutton "Loss evaluation" evaluates the process in terms of possible financial losses. User input is required for the evaluation of the loss function according to mathematical expression (6) - A , where A -represents costs for repair.

The pushbutton "Process evaluation" runs the simulation according the simulation scheme (Fig.14). For correct running of simulation it is necessary to put into workspace of Matlab variables from fuzzy blocks. The numeric values of these variables are written into the graphical interface.

According to the used rules are shown the linguistic explanation of numeric expressions. To evaluate the total quality was proposed distribution in Table I.

TABLE I. RANGE OF TOTAL QUALITY

Total quality	
Range	Quality
0–0,5	Insufficient
0,5–0,75	Sufficient
0,75–1	Very Good



Fig. 17 Evaluation of observed production process

V. CONCLUSION

The aim of such an approach is to highlight the possibility of creating a helpful system that would fulfill the role of intelligent advisor for the issue based on composed knowledge base and implement the knowledge of experts in this field. Knowledge and awareness of the importance of such an

assessment of the production process gives companies a competitive edge in attracting and keeping the production of its plan.

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REFERENCES

- [1] A. Vagaska. "Statistical quality optimization of milled surface". In: *Process Control Pardubice*, pp.C154a-1-C154a-5, 2008 ISBN 9788073950774.
- [2] M. Terek, E. Hrnčiarová. "Statistical process control" EKONOMIA Bratislava, 2004, ISBN 80-89047-7-1.
- [3] S. Hrehova, A. Vagaska. "Application of fuzzy principles in evaluating quality of manufacturing process". *WSEAS Transaction on Power Systems*. Volume 7, Issue 2, pages 50-59, 2012 ISSN 1790-5060.
- [4] D.C. Montgomery "Introducing to statistical process control", Sixth edition, 2009, John Wiley & Sons, Inc, ISBN 978-0-470-16992-6.
- [5] M. Amitava. "Fundamentals of Quality Control and Improvement". Wiley, 2008, ISBN 978-0-470-22653-7, http://www.google.sk/books?hl=cs&lr=&id=BYvDPdSerZUC&oi=fnd&pg=PR3&dq=manufaturing+quality+control&ots=QFSU64WSmk&sig=i4Vx3USALefmR-D4Z4ySh9UfIUk&redir_esc=y#v=onepage&q=267&f=false.
- [6] G.Vijaya, S.Arumbagam. "Monitoring the Stability of the Processes in Defined Level Software". *WSEAS Transactions on information science and applications*, Issue 9, Volume 7, p. 1200-1209, 2010, ISSN: 1790-0832.
- [7] M. Benkova, E. Florekova, G. Bogdanovska. "The variability of quality parameters and loss function". In *Acta Montanistica Slovaca*, 2005 Volume 10, No 1, p. 57-61, ISSN 1335-1788.
- [8] M. Terek, E. Hrnčiarová. "Process capability indices and percentage non-conforming products". *Quality innovation prosperity*, Vol. IV, No 1. 2000 ISSN 1335-1745.
- [9] A.M. Spiridonica, M. Pislaru, R.C. Ciobanu. "A Fuzzy Approach Regarding the Optimization of Statistical process Control through Shewhart Control Charts". In: 10th International Conference on Development and application systems, 2010, Suceava, Romania, May 27-29. <http://www.dasconference.ro/cd2010/data/papers/A51.pdf>
- [10] V. Kavasnicka. "Nonclassical logics III. Fuzzy logics, logical connectives and Mamdani regulator". <http://www2.fkit.stuba.sk/~kvasnicka/Logika/Lecture09/9.kapitola.pdf>
- [11] eMathTeacher: "Mamdani's Fuzzy Inference Method." http://www.dma.fi.upm.es/java/fuzzy/fuzzyinf/funpert_en.htm.
- [12] L.F.R.E. Silva, R. Frozza, R.F. Molz. "Qualitative Study of Software for Fuzzy Systems Simulation and Development". Proceedings of the 11th WSEAS international conference on neural networks and 11th WSEAS international conference on evolutionary computing and 11th WSEAS international conference on Fuzzy systems, pp. 285-292, World Scientific and Engineering Academy and Society (WSEAS), 2010 ISBN: 978-960-474-195-3.
- [13] A. Gegov, N. Petrov., B. Vatchova, D. Sanders. "Advanced Modelling of Complex Processes by Fuzzy Networks". *WSEAS Transactions on circuits and systems*, Issue 10, Volume 10, October 2011, pp.319-330, ISSN: 1109-2734.
- [14] http://www.mathworks.com/help/pdf_doc/matlab/buildgui.pdf.
- [15] S. Hrehova "Visualisation of input data using tools of Matlab", *Automatization and control in theory and practise ARTEP* 2013, 2013, Stara Lesna, Slovak republic, ISBN 978-80-553-1330-6.

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