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STATE VALUE OF PIPELINE TRANSPORT SYSTEMS IF THERE IS INJURY FROM EXTERNAL INFLUENCE

Summary. In the article considered questions about selection of criteria for state value of pipeline systems if there is damage from external influences. The algorithm is formulated and the computer program to calculate the survivability of transport systems is compiled. The program allows to establish the extent of damage of the system by given scenario of damage.

ОЦЕНКА СОСТОЯНИЯ ТРУБОПРОВОДНЫХ ТРАНСПОРТНЫХ СИСТЕМ ПРИ НАЛИЧИИ ПОВРЕЖДЕНИЙ ОТ ВНЕШНИХ ВОЗДЕЙСТВИЙ

Аннотация. В статье рассмотрены вопросы выбора критериев для оценки состояния трубопроводных систем при наличии повреждений от внешних воздействий. Сформулирован алгоритм и составлена компьютерная программа для расчета живучести транспортных систем. Программа позволяет установить степень повреждения системы для заданного сценария повреждения.

1. INTRODUCTION

Pipeline transportation systems are potentially dangerous objects, which can cause damage on environment and on human health when there is a failure. Damage of pipelines caused by such phenomena as earthquakes, landslides, mass movement, fires are known and generally regarded as emergency situations requiring the operative measures. Feature possibilities of damaged systems may be reduced significantly and it takes time and material costs for their recovery The research of piping systems behavior in case of their damage is complicated by the fact that such events are unpredictable, its difficult to establish the probability. The system attribute to operate under damage is usually associated with survivability [1-5].

In the sequel survivability means attribute of the damaged system to realize functional purpose completely or partially.

The description of systems behavior under these conditions requires using of criteria, which allows to estimate the changes in the structure adequately and the consequences that entail these changes. At the same time, in literature about systems of pipeline transportation such criteria are not provided and the methods, allowing to estimate survivability of the systems, are not available.

2. THE PURPOSE AND THE METHOD OF RESEARCH

The purpose of this research is to formulate the state value evaluating criteria and functionality of pipeline systems if there is damage from external influence.

Let's consider the example of the transport system, which is shown schematically in Fig. 1.

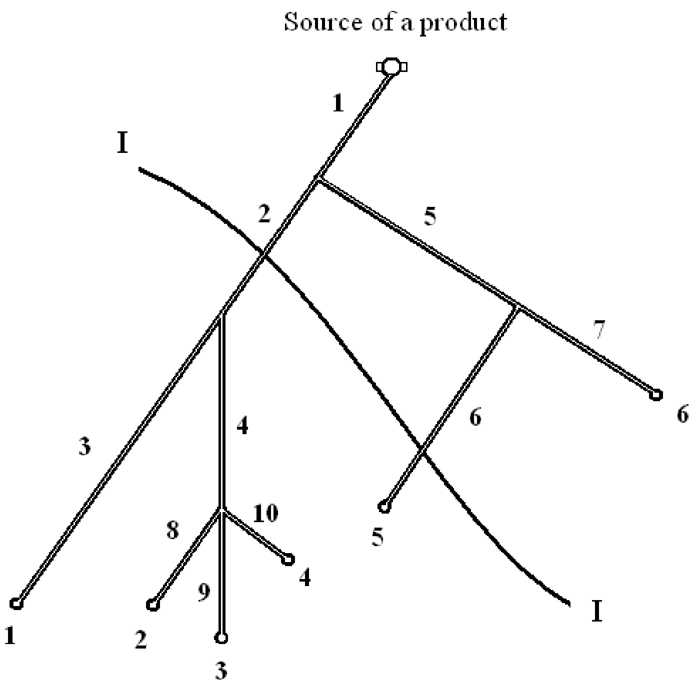

Fig. 1. The scheme of pipeline and the position of soil displacement line I-I
Рис. 1. Схема трубопровода и положение линии сдвига грунта I-I

The system consists of source, six consumer and ten product pipelines. Interaction with environment is defined by the formulated script, associated with the external damaging influences.

Let's represent the potential damage in the form of underground pipes rupture as a result of the shift of soil along the line I-I (Fig. 1). In this case, there are two damaged pipelines (numbers 2 and 6), and there are five disabled consumers (numbers 1,2,3,4 and 5).

These characteristics indicate the level and the result of the system damage. For estimating the damage degree the dimensionless quantity k_P should be used, which is equal to the quantity of damaged pipelines to their total quantity. If considered the result of damage, it can be also described in relative performances, such as the proportion of disabled users of their total quantity k_0, or the proportion of a product that cannot be delivered to the consumer because of structural damage of k_F.

It is convenient to consider the behavior of the system if there is damage in rectangular coordinates with abscissa k_0 (or k_F) and ordinate k_P. Scope of possible scenarios Λ is determined by inequality system (Fig. 2):

$$\begin{cases} 0 \le k_0 \le 1 \\ 0 \le k_P \le 1 \end{cases} \quad (1)$$

It should be considered scenarios related to the implementation of various damage schemes exactly in Λ.

If the scenario allows possibility for one-time act (failure of one or more pipelines), the event is visible in single point of Λ (eg A, with a gap along the line I-I in Fig. 1).

If, in accordance with analyzed scenario the sequence of developing failures is estimated, then it appears in the Λ area as a system of points, which describes the development of a process and its implications in time (for example, points B, C, D, E in Fig. 2).

Let's suppose that at the initial time all the elements of system are fixed and consumers get the desired product in gross capacity. When all the customers are disconnected, the state of the system will be characterized by a point on the segment AB (Fig. 3). It means that within the limits of damage accumulation, the state of the system will be characterized by a number of points, which will gradually shift from origin of coordinates to direction of the segment AB.

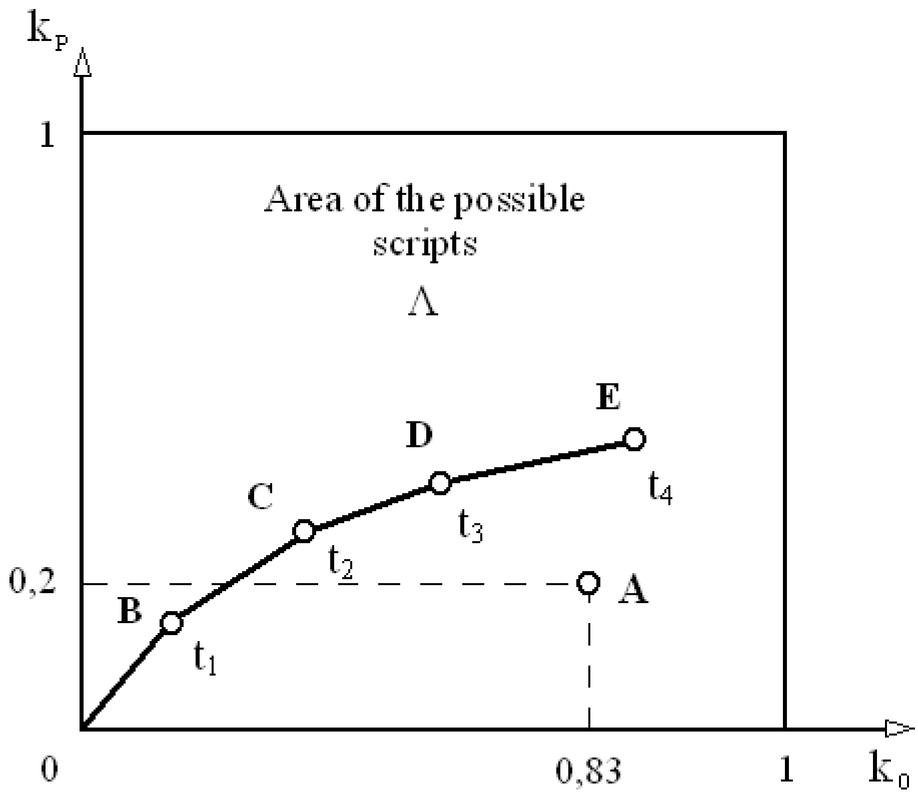

Fig. 2. The scope of systems damaging process development
Рис. 2. Область развития процесса повреждения системы

The evaluation of the process results development, depending on the system destination can be realized by using the criteria k_0 or k_F (Fig. 3).

Two characteristics usually considered as comparable if they differ in size by no more than twice. Coefficients k_P and k_0 are comparable within the zone Ω_1 (Fig. 3), which position due to this approach is determined by a system of inequalities:

$$\begin{cases} k_P < 2k_0 \\ k_P > 0{,}5k_0 \end{cases} \quad (2)$$

In case of using the coefficient k_F the zone Ω_1 can be estimated by the same way:

$$\begin{cases} k_P < 2k_F \\ k_P > 0{,}5k_F \end{cases} \quad (3)$$

Then, if the damage occurs in accordance with the scenario 1, and the mapping of this process occurs within a zone Ω_1 (Fig. 3), then we should assume that the result of the damage is roughly comparable (proportional) to the degree of the damage system.

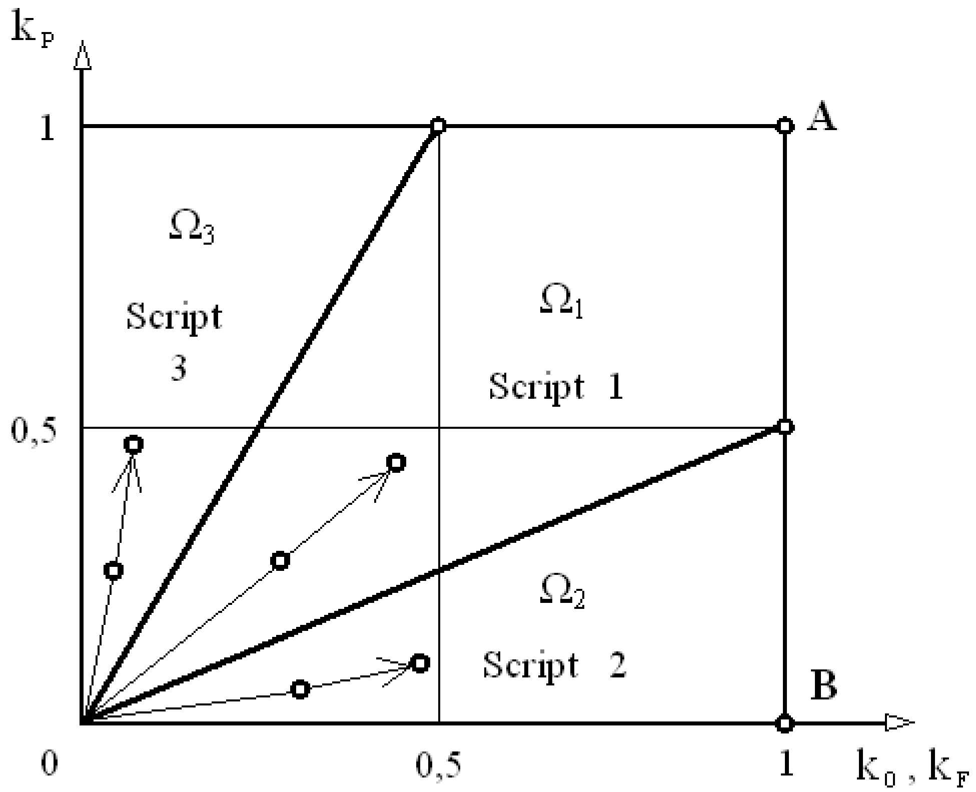

Fig. 3. A graphical representation of some variants of damage
Рис. 3. Графическое представление некоторых вариантов развития повреждений

Let's consider a situation when the damage occurs in accordance with the scenario 2 and the representation of this process occurs within a Ω_2 zone (Fig. 3). It means that relatively little damage to the system with serious consequences related to restriction of its functionality.

Under these conditions the system will be characterized by low survivability with the potential of a quick recovery because of the relatively small number of damaged pipelines.

In case, if scenario 3 is implemented (Fig. 3) and displayed events are within Ω_3 zone, then the survivability of the system is regarded as high, because the observed multiple injuries are assessed as negligible effect on its functioning. However, in this case the required time on restoring the system can be significant because of large number of damaged pipelines.

3. ESTIMATED ALGORITHM

So far as industrial transport systems can be highly developed with a large number of pipelines, the analysis of implications of possible damage should be done using the estimated algorithm and relevant computer program.

Let's consider the pipeline system that is schematically depicted in Fig. 4. The system consists of a source, six product consumers and nine pipelines, which are considered as interconnected structural elements. The connection between individual elements of a system can be described by the tabular form of connections, which is shown in Table 1.

When filling the table you should mark with (+) in *i*-column all the pipelines that you see moving throughout the design diagram (Fig. 4) from i - user to the source of the product. For example, when filling the first column, the pluses should be placed in the lines of the pipeline 7, 2 and 1, for the second column in the lines 8, 2 and 1, etc.

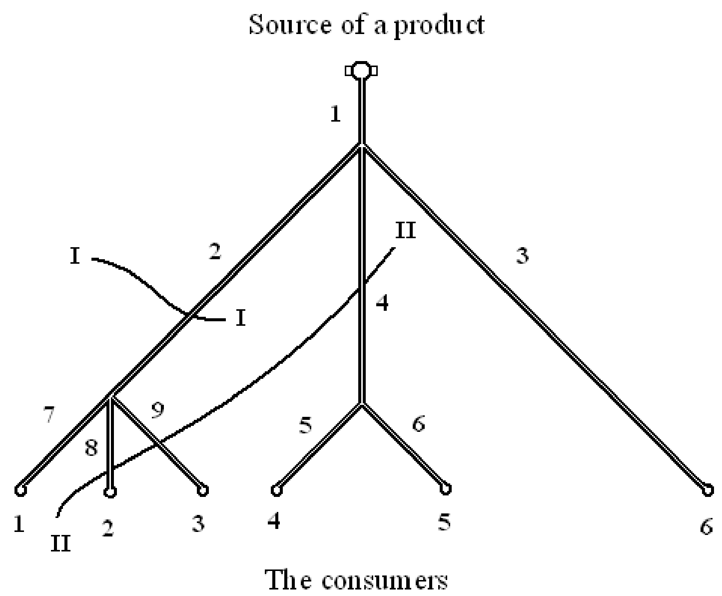

Fig. 4. Design diagram of pipeline transport system
Рис. 4. Расчетная схема трубопроводной транспортной системы

Table 1

The connection between the structural elements of the transport system

Number of pipeline	Number of product consumer					
	1	2	3	4	5	6
1	+	+	+	+	+	+
2	+	+	+			
3						+
4				+	+	
5				+		
6					+	
7	+					
8		+				
9			+			

The state value of damaged system is performed by using the program SCENARY. You should enter the initial data, which is describing the state of intact system.

For this purpose in computer complex MathCAD [6] you should set:

1. The number of pipelines (N = 9);
2. The number of product consumers (n = 6);
3. Column vector $\| \Phi \|$ with the elements, values of which match the proportion of delivered products to each consumer in the nominal operation mode.

So if 10%, 20%, 30%, 5%, 5%, 30% of product is delivering to consumers 1-6, then the matrix $\| \Phi \|$ is defined this way:

$$\| \Phi \| = \begin{Vmatrix} 0{,}1 \\ 0{,}2 \\ 0{,}3 \\ 0{,}05 \\ 0{,}05 \\ 0{,}3 \end{Vmatrix} . \qquad (4)$$

At the next stage the matrixes of coupling between the elements of the system $\| S1 \|$, $\| S2 \|$, ... $\| S9 \|$ are forming, which are constructed with using the lines of connection table. Each row of the table will be written as row vector. The element of vector is equating to 1 if it was set (+) in the relationships table or 0 if the (+) was missing.

The fragment of a program with the initial data and corresponding row vectors for the considered system is shown in Fig. 5.

The scenario of a possible damage should be provided in the program further. For this purpose, the calculating part should indicate the number of damaged pipelines nd and set a matrix $\| SUM \|$ which describes the nature of the damage.

Let's suppose that pipeline 2 is damaged in the system (cutset I-I in Fig. 1). Then it should be specified in the calculation part of the program: nd=1 and $\| SUM \| = \| S2 \|$.

A fragment of the calculation part of the program with the given data is shown in Fig. 6. As a result of calculations the program determines the values of the coefficients k_P, k_0, k_F and builds graphical dependency allowing to judge the degree of damage impact for the system functionality. The results of calculations for the given scenario are shown in Fig. 7.

If the script of damage is changed, the calculation of the program will be changed only. For example, if there is a damage of pipelines 4, 8 and 9 (section II-II in Fig. 4) in the new scenario, then the number of damaged pipelines (nd = 3) should be indicated in the program and set a description of the final damage as the sum of: $\| SUM \| = \| S4 \| + \| S8 \| + \| S9 \|$. The program fragment with a given scenario is shown in Fig. 8. The results of these calculations are shown in Fig. 9.

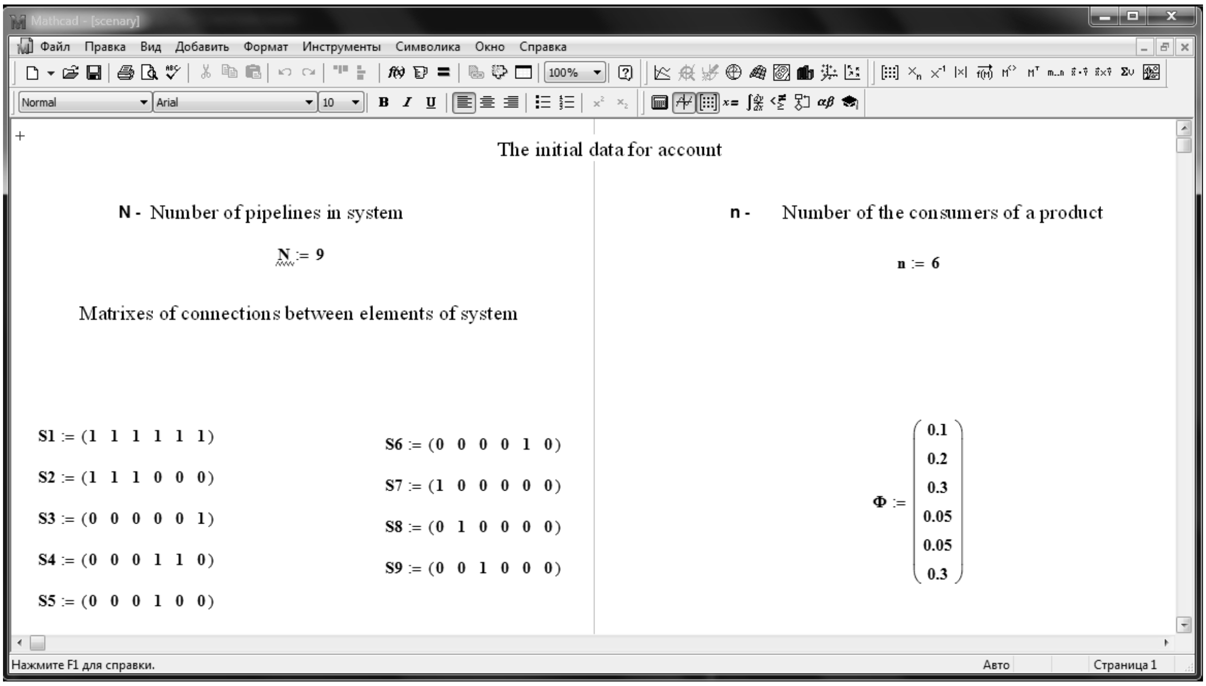

Fig. 5. Program listing with initial data
Рис. 5. Листинг программы с исходными данными

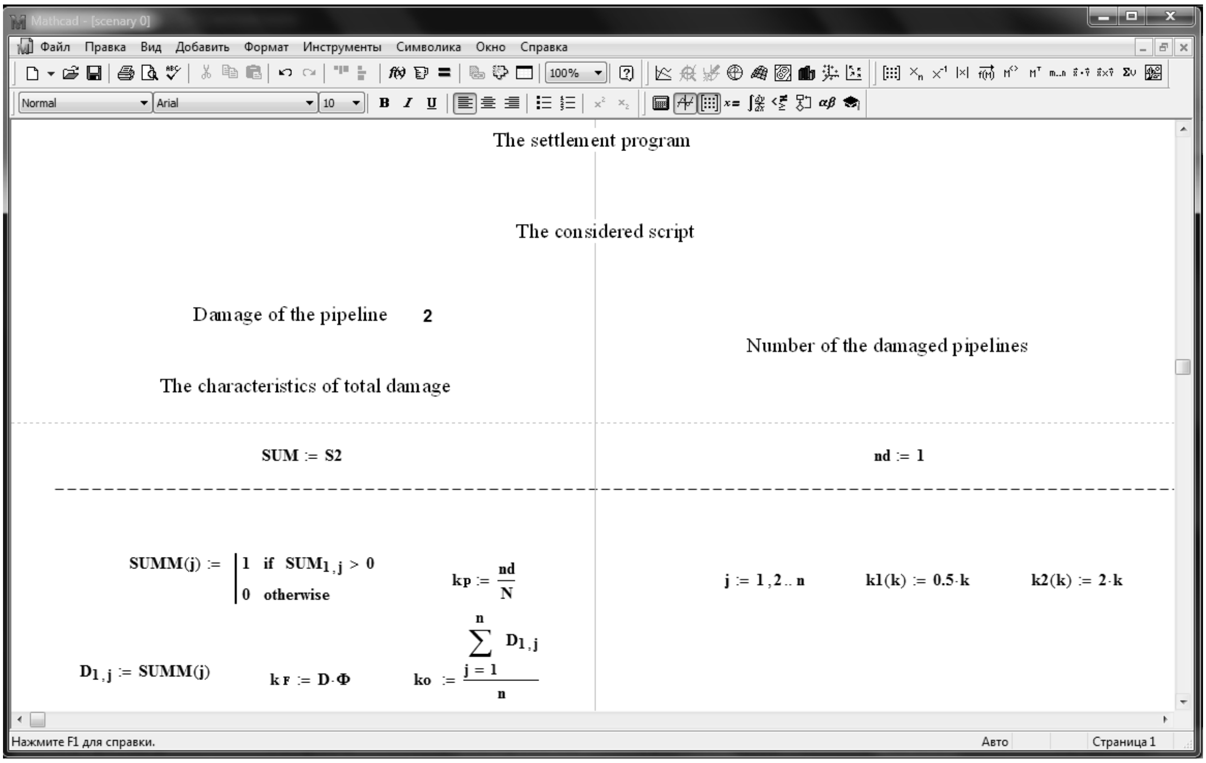

Fig. 6. Listing of calculation part of the program
Рис. 6. Листинг расчетной части программы

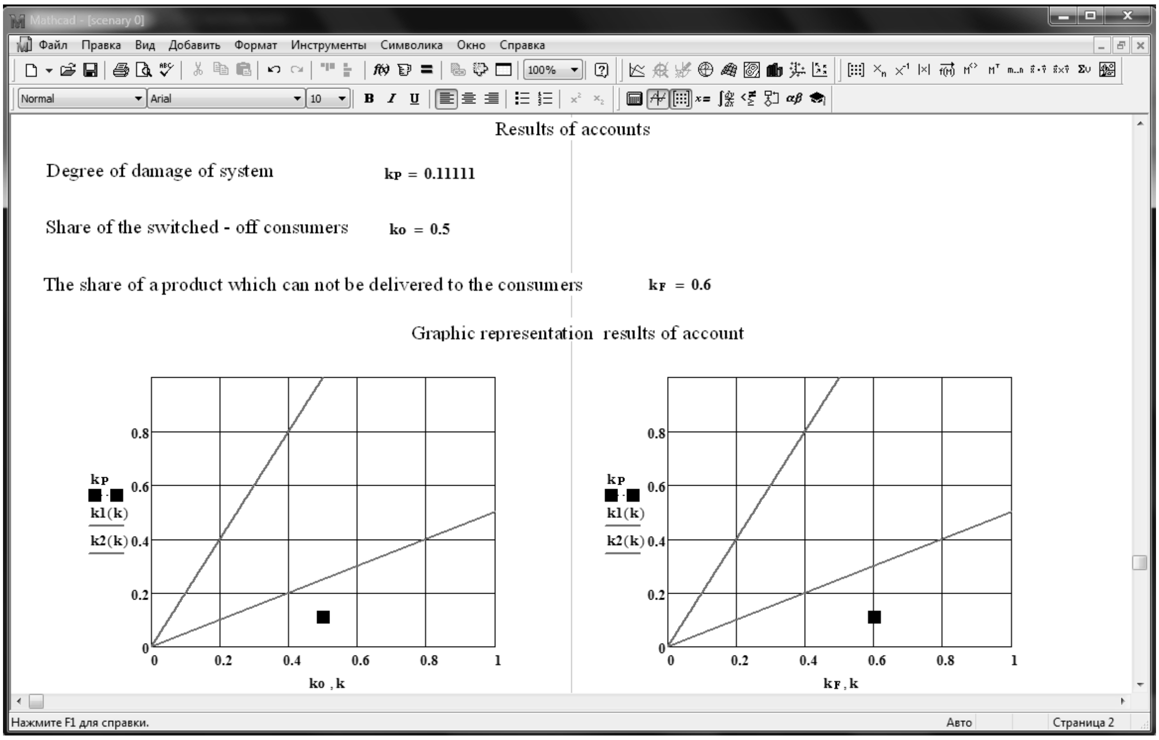

Fig. 7. Program listing with the calculation results
Рис. 7. Листинг программы с результатами расчетов

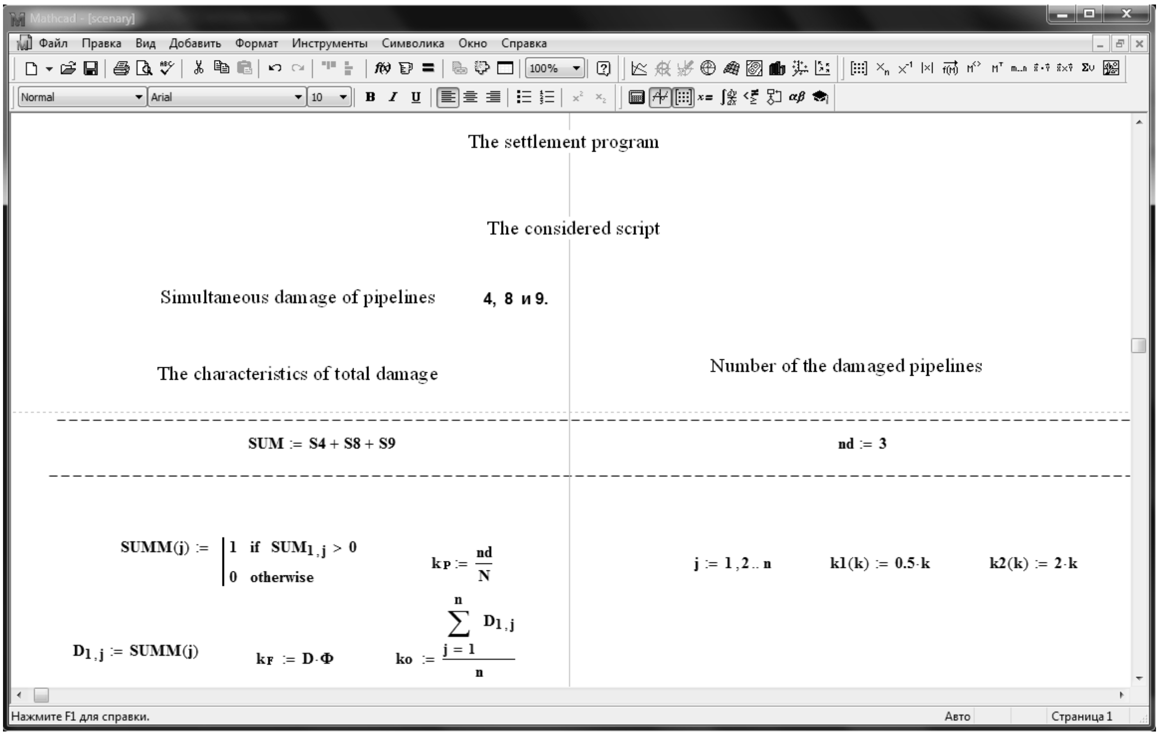

Fig. 8. Program listing with a given scenario of damage
Рис. 8. Листинг программы с заданным сценарием повреждения

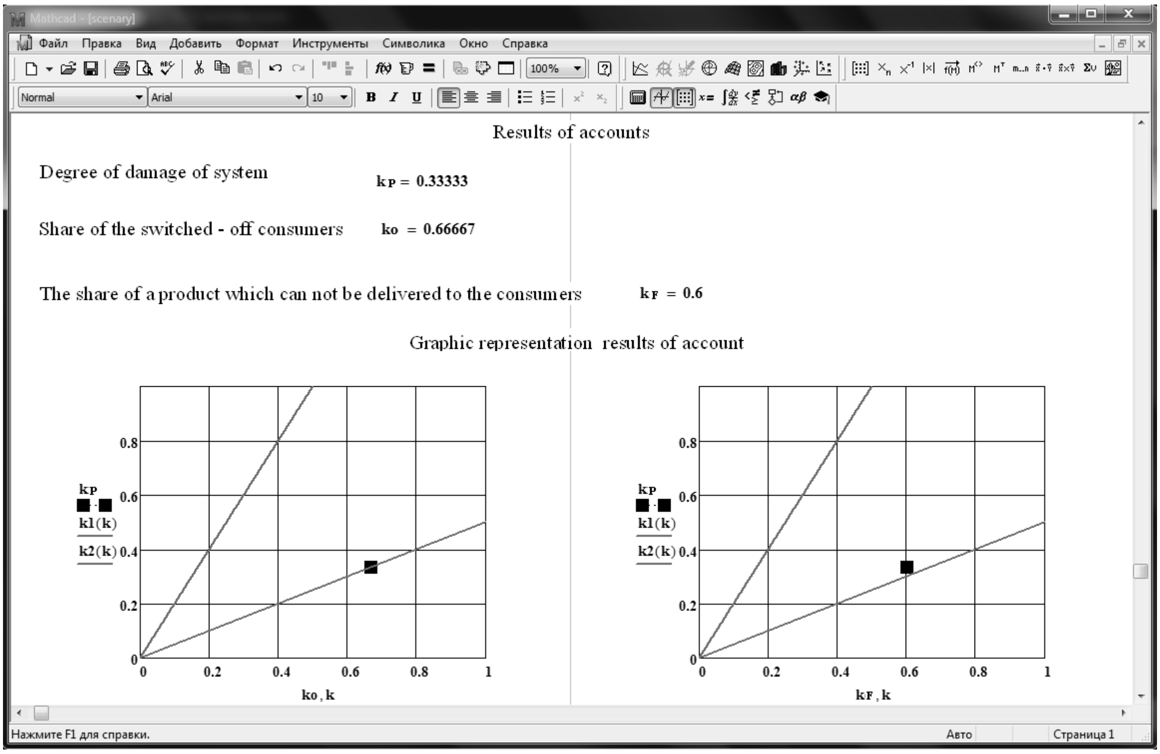

Fig. 9. The results of calculations using the program
Рис. 9. Результаты расчетов с использованием программы

Any of damage scenarios can be set and described just the same.

4. CONCLUSIONS

1. The extent of pipeline system damage from outside influences should be evaluated by relative number of damaged elements.
2. Depending on the system purpose the damage result can be assessed both by the relative number of disabled customers and the relative decrease in the proportion of deliverables.
3. A visual representation of the damage process in the area of possible Λ scenarios leads to the conclusion of the test pipeline system tenacity.
4. The computer program allows to:
   - evaluate the results of pipeline transport system damage for different scenarios connected with damage to one or more pipelines;
   - monitor the dynamics of the damage, if it is a multistage and evolves over time;
   - to obtain a clear graphical representation of system damage.

Bibliography

1. Мартынюк В.Ф., Суворова В.В.: *Основные виды аварий в газораспределительных системах*. Управление качеством в нефтегазовом комплексе, №2, 2006, с. 37-40.
2. Павлов С.В., Гвоздев В.Е., Митакович С.А., Ефремова О.А., Плеханов С.В.: *Моделирование аварийных разливов нефти и нефтепродуктов для планирования действий в условиях ЧС*. ArcReview №3 (26), DATA+, Москва 2003, с. 15-16.

3. Красных Б.А., Мартынюк В.Ф., Сергиенко Т.С., Сорокин А.А., Феоктистов А.А., Нечаев А.С.: *Анализ аварий и несчастных случаев на объектах газового надзора*. Анализ опасностей, Москва 2003.
4. Атнабаев А.Ф., Бахтизин Р.Н., Нагаев Р.З., Ефремова О.А., Павлов С.В., Сайфутдинова Г.М.: *ГИС - модели для анализа последствий аварийных разливов нефти*. ArcReview №1 (32), DATA+, Москва 2005, с. 18-19.
5. Громов Ю.Ю., Драчев В.О., Набатов К.А., Иванова О.Г.: *Синтез и анализ живучести сетевых систем:* Монография. Издательство машиностроение - 1, Москва 2007.
6. Дьяконов В.: *MathCAD 2000: Учебный курс*. Питер, Санкт-Петербург 2000.

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