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PROGRAM FOR MODELING OF GAS FLOW IN LANDFILLS

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Abstract

The contribution describes the LFS (Landfill Simulation) program for modeling of gas flow in landfill or other disintegrated material. This program is created in development environment of the Delphi program. The creation of the program based on the need of simulation of the gas exhaustion in landfills of garbage. On the basis of the parameters set (porosity, quantity of arising gas, material resistance against the gas flow, number of bore holes etc.) the program solves the pressures in single parts of landfill and also the quantity and concentration of methane in the gas being exhausted. The goal of the program is time simulation of physical values changes under the change of pressure conditions during the gas evolution or under change of pressure conditions arisen due to gas exhaustion or only due to venting of garbage landfill.

Keywords: landfill, garbage, methane, simulation, dynamic modeling

1 INTRODUCTION

The effect of a man on living environment is permanently increasing. The exhausting of power and raw materials resources is permanently more intensive and so the impairment of natural environment occurs. The result is contamination of water, atmosphere and soil, growth of wastes quantity including the dangerous wastes. It is necessary, for these reasons, to search permanently for new and more effective ways of sound living environment ensuring. The garbage incorrectly deposited in nature, e.g. the so called wild landfills, older landfills which do not already meet the existing standards etc. act very negatively on a man life. Especially, if this is a question of toxic and dangerous wastes. With the respect of this still greater necessity of our time to load the living environment with negative impacts as least as possible, it is necessary to pay an increased attention also to decking and disposing or alternative utilization of garbage on landfills. On landfills, due to biochemical process, the gas arises the substantial part of which is methane. That's why, the gas becomes an explosive mixture in certain concentration. That's why, it is necessary to lead away the gas from the landfill to prevent from possible explosions of the gas gathered but also to prevent from its smell spreading into the environs. With the respect of high methane calorific value this landfill gas can be purposefully combusted under certain conditions.

The quality of the gas exhausted from various parts of landfill is not always the same. However, it can be sorted in compression station. The gas of permanent quality can be used for electrical power generation under usage of washing equipment. The non-washed gas can be used for heating of near housing estates or gardener's objects. The rests after gas cleaning are combusted in landfill torches at temperatures of 1000°C up to 1200°C. The power usage of landfill gases is possible due to combustibility and relatively high calorific value of methane which makes 49 610 $kJ*kg^{-1}$.

The contribution is dealing with the simulation of the gas rise and its controlled exhaustion.

2 ANALYSIS OF THE PROBLEM

The goal of the program creation was to create an application which would enable the simulation of processes and exhaustion on landfills with the possibility to monitor the decomposition of landfill gas arising here, the effect of exhaustion on landfill gas leakage into atmosphere and effect of exhaustion duration on methane concentration in the gas being exhausted and its utilization.

For the purpose of this program I have created a model of landfill in the shape of right parallelepiped, in all three axes regularly distributed in such a way that the network of cells called "elements" arises (Fig. 1). Each element represents elementary spatial unit in the model. The gas arises in the element and the pressure increases in it. On the basis of various pressures between the neighboring elements there comes to gas exchange between them. The bore holes serving for gas exhaustion with the help of vacuum pump are located in this network. On the basis of the formulas (for linear model) and parameters set the program counts the quantity of gas flowing in single parts of landfill and quantity of gas being exhausted. The calculations of flows and pressures run always for short time period (second fragment) according to the simulation accuracy required. The shorter the time section the greater accuracy. In case of greater time sections the calculations tend more to destabilization.

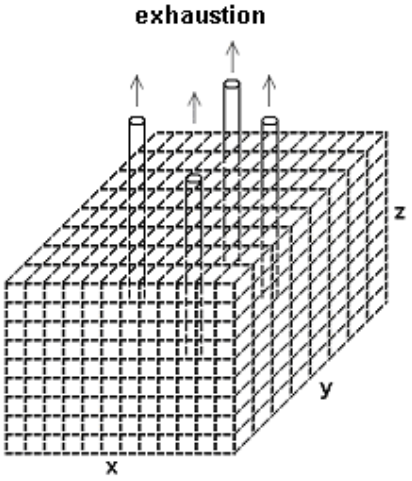

Figure 1 – Distribution of landfills on elements with the exhausting bore holes

3 MATHEMATICAL MODEL

An integral part of the model is the mathematical expression of relationships between the physical values which are described by the following equations:

- calculation of passing through quantity

$$Q = \frac{\Delta p}{R^n} \tag{1}$$

- resistance of waste material

$$R = \frac{R_m * L_1}{S} \tag{2}$$

- resistance of bore hole part

$$R = R_{mv} * L_2 \tag{3}$$

- quantity passing through the waste material

$$Q = \frac{\Delta p * S}{R_m * L_1} \tag{4}$$

- quantity passing through the bore hole

$$Q = \frac{\Delta p}{R_{mv} * L_2} \tag{5}$$

- calculation of pressure in elements

$$p = \frac{V * p_{atm}}{V_z} \tag{6}$$

where
- L_1 – length of the section [m]
- L_2 – length of a bore hole part [m]
- n – index of flow type, linear one in the program - value 1
- p – pressure in element [Pa = $kg.m^{-1}.s^{-2}$]
- p_{atm} – atmospheric pressure [Pa]
- Δp – pressure difference [Pa]
- Q – volume through-flow [$m^3.s^{-1}$]
- R – resistance of a section [$kg.m^{-4}.s^{-1}$]
- R_m – specific resistance [$kg.m^{-3}.s^{-1}$]
- R_{mv} – resistance of a bore hole of the length 1 m [$kg.m^{-5}.s^{-1}$]
- S – area through which the gas flows between elements [m^2]
- V – gas volume at the pressure p_{atm}
- V_z – free volume of the element (sum of air gaps in the element)

The relationship (4) arose by synthesis of the formula for passing through quantity (1) and formula for resistance of waste material (2). The relationship (5) arose by synthesis of formula for passing through quantity (1) and formula for resistance of the bore hole part (3). The relationship (6) is the expression of gas pressure as the linear dependence of gas quantity at stable volume.

4 CHARACTERISTICS OF THE LFS SIMULATION PROGRAM

The program counts the single changes of values in certain time step on the basis of formulas already mentioned above, the simulation run itself, however, is controlled by the user himself. For this, he has several keys for his disposal which are displayed only if they can be used in given moment.

The program counts with pre-set, read (from a file) and user's set parameters.

The information about simulation run are displayed according to the type either in text or graphical form (Fig. 2). In most cases, the parameters can be changed by clicking on given element whether the text or the graphical one.

Figure 2 – Presentation of the simulation run

The rectangle in the simulation presentation represents the landfill perimeter. The single points represent the elements in the model. The coloration is determined by the gas pressure in element. The lines between the elements represent the gas flow and are colored according to the quantity of flowing gas. The color range is displayed beside the quadrangle also with the values assigning. The first value is pressure, the second one the passing through quantity. This numerical assigning of values can be changed by clicking on given value in the course of simulation. The user has the possibility to scale up the presentation of the landfill according to his need, with utilization of all screen.

In given moment always only one layer of elements which are in the same height is displayed. The selection of the layer displayed is changed with the help of unrolling menu. The information about quantity of the gas being exhausted and methane concentration is displayed in the right upper corner.

The actual information concerning any element can be obtained by clicking on given element (Fig. 3).

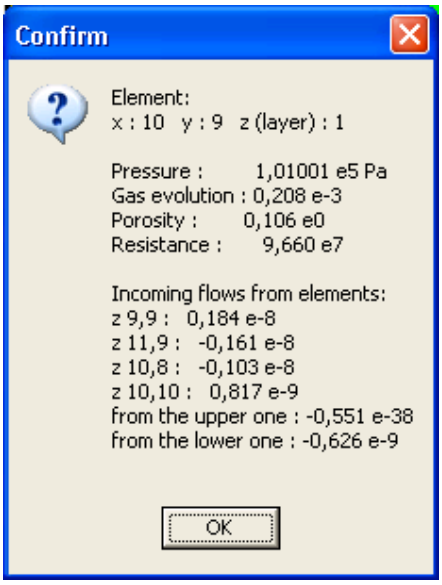

Figure 3 – Presentation of information about element

The pressures in single elements can be saved into the text file the course of simulation, same as the values of exhaustion.

5 EXAMPLE

The simulation can be carried out for concrete theoretical situation.

Dimensions of landfill: 160m x 160m x 20m.

Distribution on elements network: 16 x 16 x 4

Layout of bore holes: 4 x 4

Underpressure of vacuum pump: 4000 Pa

Characteristics of material:

average gas quantity from 1 m^3 of material per day: 0,045 m^3

porosity (per 1 m^2):0,1 m^2

resistance: 80.10^6 $kg.m^4.s^{-2}$

concentration in the range 45 – 60 %

Bore holes : 8 opened and 2 partially opened

We will start up the simulation and let it run till the pressures stabilization in all parts of landfill (Fig. 4).

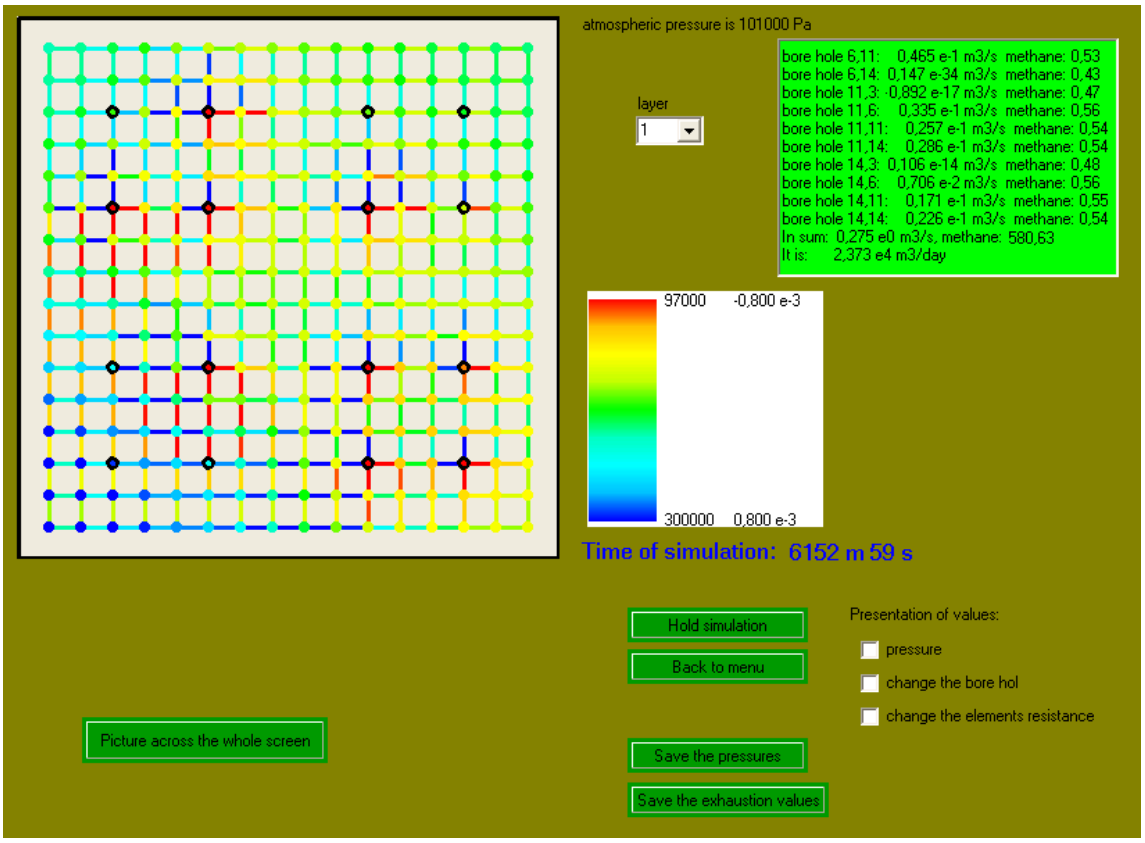

Figure 4 – Example

In the course of simulation we can monitor the quantity being exhausted from single bore holes as well as the total quantity and determine from which bore holes the gas will be exhausted (e.g. according to the methane concentration). After stabilization of pressures and gas flows we can read the total value of the quantity exhausted: 23730 m^3 per day (under constant quantity exhausted all the day long).

6 CONCLUSION

It can be said that the program mentioned has its benefit, advantages and disadvantages.

The benefit consists mainly in a new approach to solution of management problem and prediction in gas exhaustion from the landfill.

Advantages:

- the program enables to simulate the landfill reactions on changes in exhaustion and changes of methane quantity releasing from landfill material
- it enables to find out the possible parameters of the gas being exhausted in time and in dependence on quantity of gas already exhausted

Disadvantages:

- the dependence of results on selection of solution step
- the program does not solve the effect of humidity and temperature on parameters of the gas being exhausted

From disadvantages also the possibilities of further program development follow:

- effect of temperature, humidity and pressure on gas quantity releasing from material
- change of selection of the solution step, respectively the selection of other calculation method
- making the formulas for passing the gas through material more accurate, respectively the possibility of formula change by the user

possibility of program adjustment for monitoring of physical values state on factual landfill with the exhaustion control and with the possibility preliminary simulation of development.

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