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FEATURES OF NONSTATIONARY LIQUID'S EFFLUENCE FROM SEVERAL TANK – WAGONS IN COMMON TERMINAL'S PIPNG SYSTEM

NESTACIONĀRAS ŠĶIDRUMA IZPLŪŠANAS ĪPATNĪBAS NO VAIRĀKĀM CISTERNĀM VIENOTĀ TERMINĀLA CAURUĻVADU SISTĒMĀ

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Introduction

Increase of economical efficiency of oil and oil products terminals significantly depends on optimization of hydraulic parameters and terminal's automatization level. That's why the task of nonstationary tanks filling or emptying processes optimization in oil terminals has a high importance.

In the work was made analysis of simultaneous emptying of several identical tank-wagons. All tank-wagons are connected to the effluent collector. Oil products from collector by means of centrifugal pump are pumped to the storage tank. It is expected that number of tank-wagons can be undefined and initial level of the product different. Generally starting of tank-wagons emptying is not simultaneously. Pipe connection point to the collector is defined in task's statement. Liquid's flow conditions during tank-wagons emptying process can change. Initially it can be turbulent, but later at lower liquid level it can became laminar. In special cases tank-wagons emptying process can undergo at the same conditions. For laminar process throughput rate **K** of Discharge valve is depending on Reynolds number can significantly change [1]. For turbulent process rate **K** reaching maximum value doesn't depend on Reynolds number (see Fig. 1). Hydraulic resistance coefficients in several sections of piping system can significantly change as well.

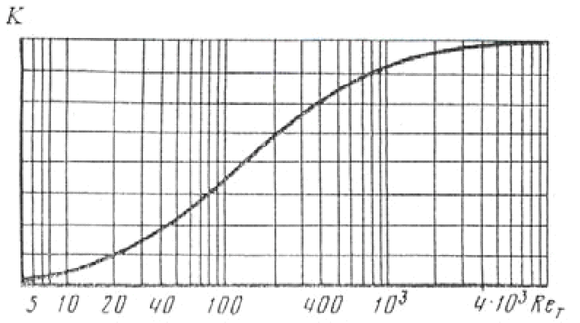


Fig. 1. Throughput rate **K** of Discharge valve depending on Reynolds number

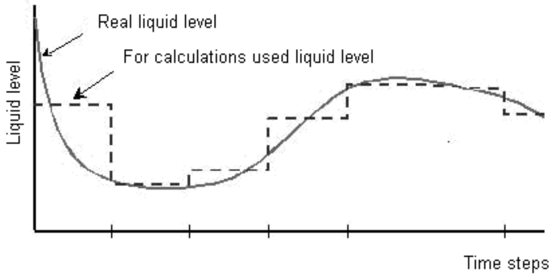


Fig 2. Real and for calculations used liquid level

Because volume of each tank-wagon is relatively big and oil product's level change is relatively slow, we can assume nonstationary emptying process as quasistationary – it means use a mechanical energy equilibrium equation for uniform flow taking in account liquid's level changes in time [2, 3]. During numerical calculation of quasistationary process full time has to be split in small time steps when pressure is assumed as constant and flow's conditions as stationary (see Fig 2). Accuracy of task's calculation depends on time step's parameters. For accurate calculations usually it is 0,05 – 0,1 seconds.

Goal of the work

Goal of this work was develop computer analysis methods for nonstationary tasks of pipeline transport, which are applicable for separate units of terminal.

Model of analyses

Analyzed model consists from three round cross section tank-wagons with total volume 68 m3. Variable section of liquid's surface during emptying process depends on liquid's high and is a given value. Tank-wagons in connection points are connected by a piping network with nominal diameter 150 mm. In the exit of system is defined permanent static pressure 0,9 bar modelling a pump's created vacuum (see Fig. 3).

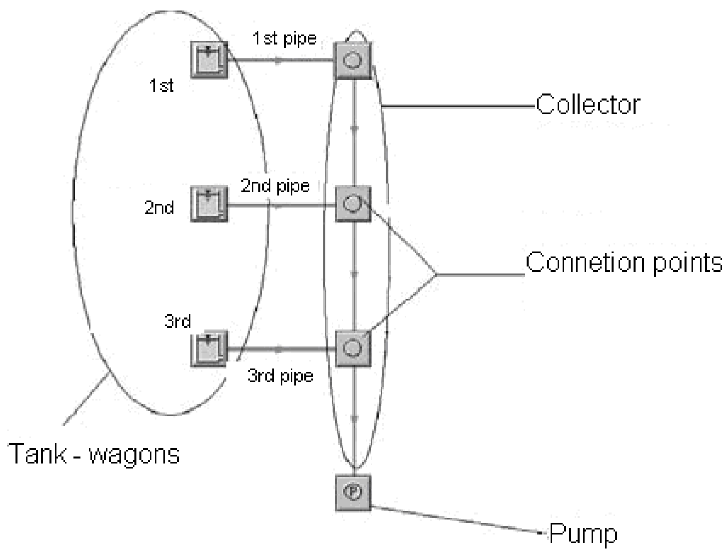


Fig. 3. Layout of the analyzed model

Analysis was made at the following system's parameters:

- Liquid – petrol
- Calculated temperature – + 20^0C
- Ambient pressure – atmospheric (101,325 kPa or 1,013 bar)
- Calculated time step – 0,1 second
- Defined accuracy (relative deviation) – 0,0001

At defined accuracy for calculation of pressure number of iterations is approximately 80000, but for calculation of flow rate approximately 30000.

Results of analyses

At equal initial fuel level **H** in the tank-wagons, faster is emptied closer to a pump located tank-wagon (No 3) (see Fig 4).

It is explicable with a lower hydraulic loses in piping, because distance from tank-wagon No 3 until the pump is shortest. Moreover liquid's level in nearest located tank-wagon generates backpressure in farther located tank-wagons.

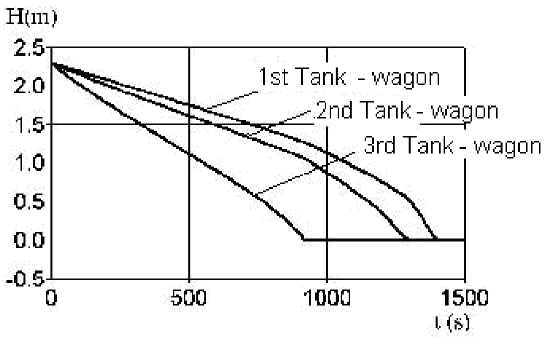


Fig. 4. Curves of Tank –wagons emptying dynamics

During calculations were found out regularities defining influence of pipes cross-sectional area on tank-wagons emptying time **t**. Increasing pipe diameter **D**, discharge capacity of pipe increases and emptying dynamics curves approximate each other (see Fig. 5, 6 and 7).

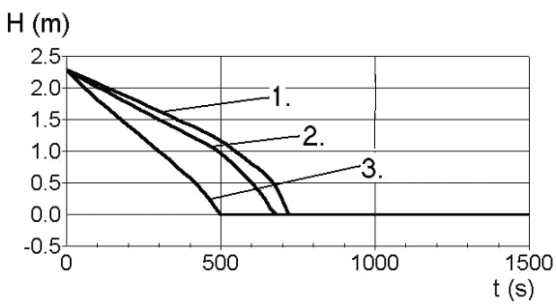


Fig. 5. Curves of Tank –wagons emptying dynamics using pipes with nominal diameter 200mm

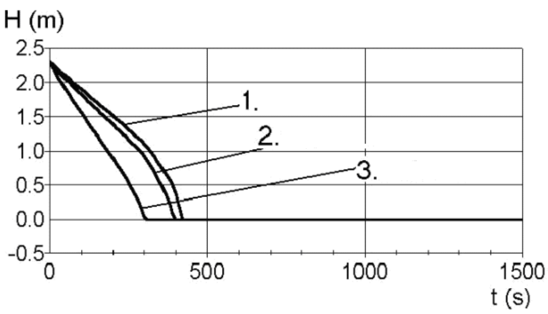
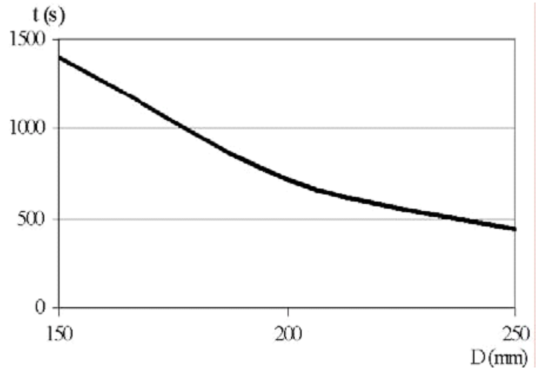


Fig. 6. Tank –wagons emptying dynamics curves using pipes with nominal diameter 250mm

During analysis was found out character of change of flow velocity **v** in connecting pipelines. In moments when flow from tank-wagons is stopped (tank-wagon is empty or disconnected) are specific velocity gradients (see Fig. 8).



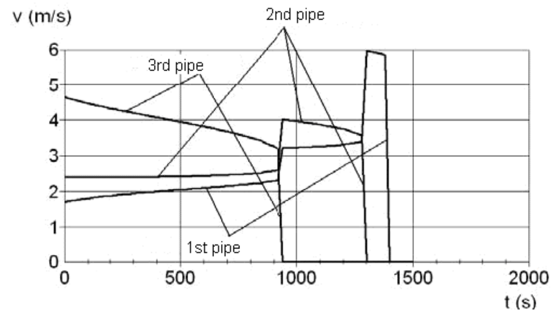


Fig. 7. Tank –wagons emptying dynamics depending on pipe diameter

Fig. 8. Dynamic of flow velocity changes

Emptying speed of closest to the pump located tank – wagon decreases almost lineary. Emptying speed of tank – wagon located in the middle changes insignificantly till the moment when closest tank – wagon is empty. The same time emptying speed of farther from the pump located tank – wagon almost lineary increases. Reason of this is pressure changes in tank – wagons. In the moment when emptying process in closest tank – wagon is stopped, happens rapid emptying speed jump in rest of tank – wagons. After speed jump emptying speed of in the middle located tank – wagon decreases, but in farthest – increases till the moment when middle tank – wagon is empty and happens one more speed jump in farthest tank – wagon. Consequently during emptying of several tank – wagons emptying speed changes lineary till the moment when one of tank – wagons is empty or emptying is stopped and happens rapid speed jump.

Because friction loses in piping are in proportion to flow rate velocities square, gradient of total loses **ΔH** is more rapid (see Fig. 9).

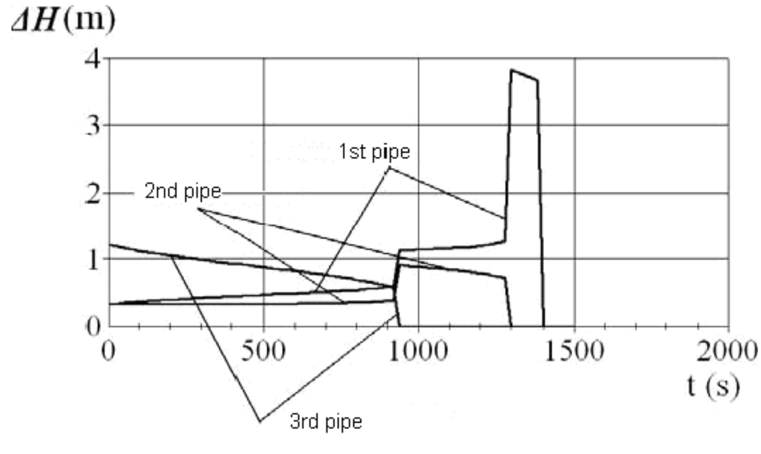


Fig. 9. Dynamic of pressure loses

In the work was made analysis of influence of piping system elements location and geometrical dimensions on its hydraulic parameters. Therefore was created symmetric system (see Fig. 10). It was found out that at equal rest system parameters, complete system's emptying time is approximately 7% less, what is not significant win. As system is symmetric, curves of first and third tank – wagons empting speed are coincident (see Fig. 11).

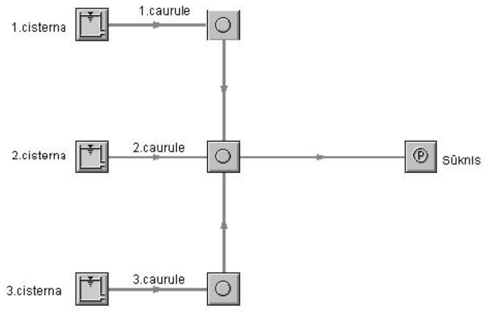


Fig. 10. Symmetric model of system

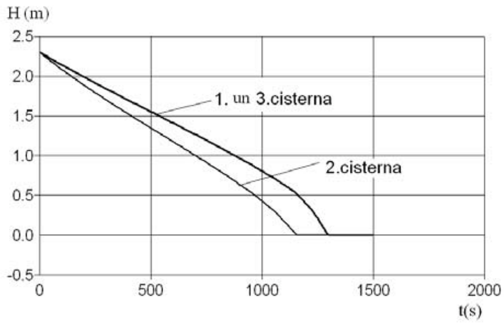


Fig. 11. Tank –wagons emptying dynamics curves for symmetric model

During the work was made piping diameter **D** changes influence analysis on emptying speed. So diameter of pipe connected to the first tank – wagon was defined 250mm, to the second tank – wagon – 200mm, but to the third tank – wagon and collector remain 150mm (version 1). From results of computer analysis we can conclude that dynamic of tank – wagons emptying in this case is insignificant (see Fig. 12), what can be explained with limited permeability of pump suction line. Than all pipes connected to the tank – wagons were defined equal – 150mm, but for pump suction line – 250mm (version 2). A result of analysis show that time of complete emptying of system is 520 seconds (see Fig. 13), what is approximately 60%less than result obtained in previous analysis (1300 seconds.

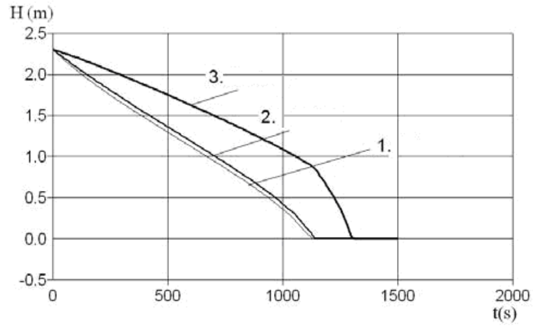


Fig. 12. Tank–wagons emptying dynamics curves for symmetric model (version 1)

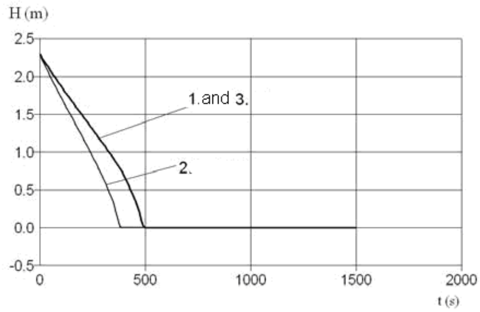


Fig. 13. Tank–wagons emptying dynamics curves for symmetric model (version 2)

In the case when inside the system is not vacuum created by the pump but backpressure, results are different. For calculation it was defined 1,2 bar absolute pressure (~ 0,2 bar gage pressure). It was defined that tank – wagons are not being effluent completely but until the level when pressure created by liquid becomes equal to pressure in the system's exit. Analyzing flow velocity in discharge pipelines, it was found out that initially highest velocity is in third tank – wagon's discharge pipe. It can be explained with lower hydraulic resistance. Decrease of liquids level decreases flow velocity in pipe. The same time velocities in discharge pipes of first and second tank – wagons increases till almost equalize and than uniform decreases (see Fig. 14).

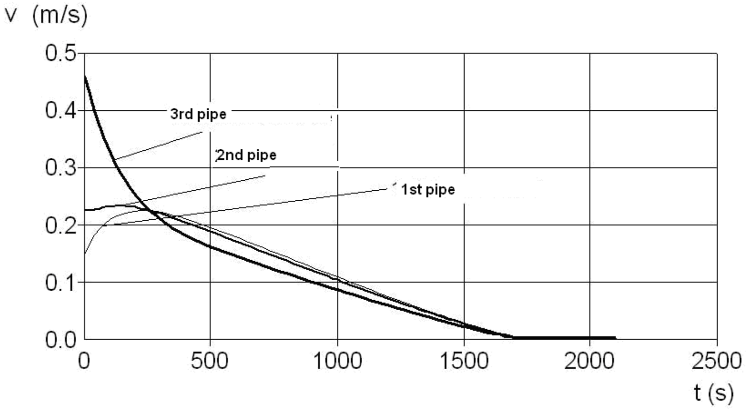


Fig. 14. Dynamic of flow velocity changes for system with back pressure

In reality beginning of tank – wagons emptying doesn't happens simultaneously but stepwise. That's why was made analysis of hydraulic parameters of model when beginning of emptying is with defined time offset. Model consists from two tank – wagons and valve (see Fig. 15). Opening of the valve initiate rapid pressure changes (hydraulic shock) caused by liquid inertia forces (see Fig. 17). Pressure changes have cyclic damped character (see Fig. 18).

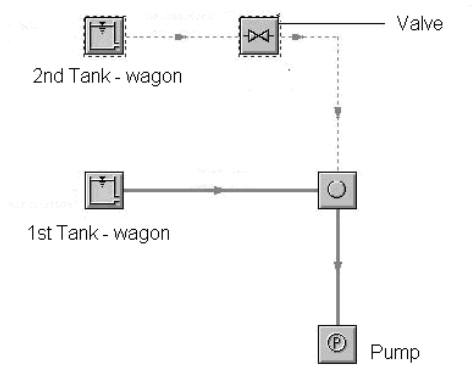


Fig. 15. Systems model with a valve

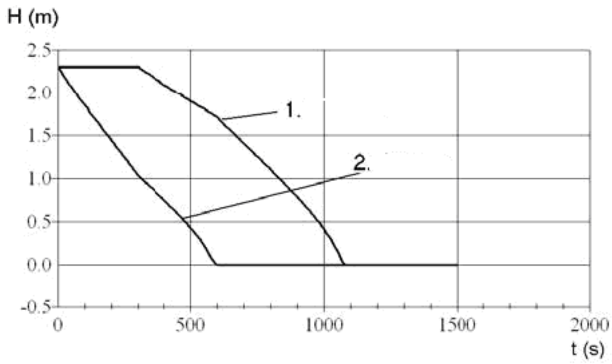


Fig. 16. Tank–wagons emptying dynamics curves for system with sequential Tank–wagons emptying start

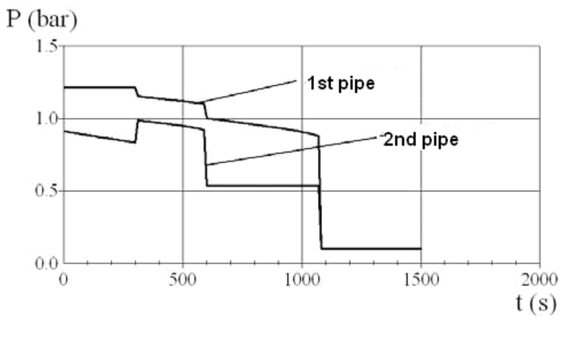


Fig. 17. Pressure changes in pipes for system with sequential Tank–wagons emptying start

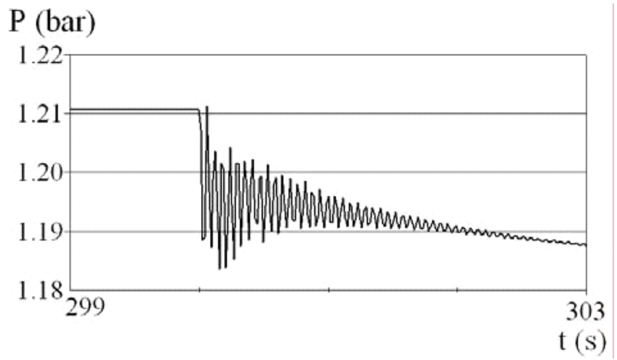


Fig. 18. Pressure fluctuations in pipe of first Tank–wagon after valve opening

Conclusions

In the work was created model of autonomous oil terminal's functional hydraulic system and method of computer analysis for quazistationary and nonstationary hydraulic parameters. Results of analysis show possibilities to use developed method for analysis of wide range hydraulic processes and complicated practical tasks. Quazistationary model allows analyzing specific features of emptying (filling up) processes. Acquired results can be used as initial parameters for analysis of rapid nonstationary hydraulic processes.

References

1. Едигаров С., Бобровский С. Проектирование и эксплуатация нефтебаз и газохранилищ. – М.: Недра, 1973 – 367 с.
2. Попов Д.Н., Панаиотти С.С., Рябинин М.В. Гидромеханика. – М.: Изд-во им. Н.Е. Баумана, 2002 – 383 с.
3. AFT Fathom User Guide.

Ušakovs V., Filipsons G. Nestacionāras šķidruma izplūšanas īpatnības no vairākām cisternām vienotā termināla cauruļvadu sistēmā

Darbā izveidots no vairākām dzelzceļa cisternām, sūkņa, noslēgvārstiem un cauruļvadu sistēmas sastāvoša naftas produktu termināla hidrauliskās sistēmas datormodelis. Ar dotā modeļa palīdzību veikta sistēmas hidraulisko parametru īpatnību analīze pie nestacionāriem darbības režīmiem. Noteiktas termināla elementu hidrauliskās mijiedarbības un ietekmes uz rezervuāru iztukšošanas laiku un šķidruma līmeņa izmaiņas raksturu likumsakarības. Datormodelis ļauj ņemt vērā plūsmas režīma izmaiņas cisternu iztukšošanas procesa laikā. Sākotnēji plūsmas režīms var būt turbulents, bet vēlāk pie zemāka šķidruma līmeņa tas kļūt laminārs. Darbā tika izpētīta cauruļvadu sistēmas elementu novietojuma un ģeometrisko izmēru ietekme uz sistēmas hidrauliskajiem parametriem. Tāpat tika apskatītas spiediena izmaiņu īpatnības sistēmā pie noliešanas vārsta atvēršanas. Īpaša vērība tika pievērsta speciālu apstākļu analīzei – uzpildes procesa uzsākšanai un pabeigšanai, noslēgvārstu atvēršanai un aizvēršanai, kad process kļūst nestacionārs. Tā kā šāda tipa uzdevumi ar analītiskām metodēm netiek risināti, to skaitliskajai analīzei nepieciešama tādu speciālu CAE datorprogrammu, kā, piemēram, AFT Fathom izmantošana.

Ushakov V., Filipsons G. Features of the non-stationary liquid's effluence from several Tank-wagons in common Terminal's pipeline system

In the work is created a computer model of hydraulic system of an oil terminal consisting from several Tank – wagons, pump, shot of valves and piping system. By means of created model it was investigated features of its hydraulic parameters in non – stationary operating conditions. Regularity governing the hydraulic interaction of terminal's elements on the time of emptying and the nature of a change in the liquid's level in the tanks are determined. Computer model allows taking in account change of flow conditions during tank-wagons emptying process. Initially it can be turbulent, but later at lower liquid level it can became laminar. In the work was investigated influence of piping system elements location and geometrical dimensions on hydraulic parameters of the system. Features of pressure changes in the system at drain valve's opening are also examined. Special interest was paid for analysis of special circumstances – starting and finishing of filling process, valves opening and closure when process becomes nonstationary. Because solution of such kind of tasks is impossible, for its numerical solution is necessary to use special CAE software like AFT Fathom.

Ушаков В., Филипсонс Г. Особенности нестационарного истечения жидкости из нескольких емкостей в трубопроводную систему терминала

В работе создана компьютерная модель гидравлической системы терминала нефтепродуктов состоящая из нескольких железнодорожных цистерн, насоса, запорных клапанов и трубопроводной системы. С помощью данной модели исследован характер изменения гидравлических параметров системы при нестационарных режимах работы. Определены особенносьти гидравлического взаимного влияния элементов терминала и изменения уровня топлива в емкостях в процессе опорожнения цистерн. Компьютерная модель позваляет учесть изменение режима течения жидкости в трубах в процессе опорожнения цистерн. Изначально режим может быть турбулентным, а затем с понижением уровня жидкости в цистерне течение может стать ламинарным. Исследовано влияние разположения элементов трубопроводной системы и их геометрических размеров на гидровлические параметры системы. Рассмотрены особенности изменения давления в системе при открытии и закрытии сливного клапана, когда процесс становится нестационарным. Так как аналитическими методами подобная задача не решается, для ее численного решения требуется использование специальных CAE программ типа AFT Fathom.