Petroleum 1 (2015) 164–168

Contents lists available at ScienceDirect

Petroleum

journal homepage: www.keaipublishing.com/en/journals/petlm

Original article

Development and application of an innovative tool to automate the process of results extraction from the thermo-hydraulic simulator Olga

Francesco Carducci [a], Antonio Del Monaco [c], Giancarlo Giacchetta [a], Mariella Leporini [a], Barbara Marchetti [b,*]

[a] Dipartimento di Ingegneria Industriale e Scienze Matematiche (DIISM), Università Politecnica delle Marche, Via Brecce Bianche 12, Ancona, Italy
[b] Facoltà di Ingegneria, Università degli Studi eCampus, Via Isimbardi, 10, Novedrate, CO, Italy
[c] Tecnoconsult Engineering Construction SRL, Fano, Italy

A R T I C L E I N F O

Article history:
Received 28 April 2015
Received in revised form
5 June 2015
Accepted 8 June 2015

Keywords:
Thermo hydraulic simulation
Olga
Sensitivity analysis
Pipelines design
Pipelines opimization

A B S T R A C T

This paper presents the development and application of an innovative code to extract in an automated way data from the thermo-hydraulic simulator Olga. The results show that the tool can significantly reduce the time needed for the data extraction procedure and increase the reliability of results due to the fact that there is no more the need of the human operator. Moreover, during the data extraction phase, the Olga code is available for running different simulations allowing to optimize the use of this resource.

1. Introduction

The Flow Assurance engineer has to guarantee the correct production and transportation of oil, gas, and produced water products through pipelines facing issues and challenges such as erosion, wax, hydrates, asphaltenes, foam, corrosion, erosion, and sand.

A typical Flow Assurance analysis process is the sensitivity analysis which, from the thermodynamic analysis of multiphase flows, using Olga (the dynamic multiphase flow simulator), broads to the sizing of a gathering system. Using Olga to perform the analysis means that you first have to set up all the aspects of the scenario you want to simulate, lunch the simulation and finally extract the results.

Olga doesn't provide, as default, a way to automatically extract data from the analysis in a structured way. The result extraction is an operation that, at present, has to be carried out by the user "manually" using trend and profile plots from inside Olga. This "manual procedure" is slow, repetitive and requires a lot of time and effort.

In this paper the development, implementation and validation of a code (written using visual basic for application as a language) to extract results from Olga, called OtoEx is presented. The main characteristic of the code is that it automates the process of data extraction allowing a faster, more accurate and independent from Olga, recovering of the information.

2. Relevant literature

Several authors presented flow assurance studies performed by Olga code, there are a wide range of case studies in literature in which multiphase flow issues have been addressed by simulating the behavior of the systems.

* Corresponding author.
E-mail addresses: f.carducci@univpm.it (F. Carducci), Antonio.DelMonaco@tecnoconsult.it (A. Del Monaco), g.giacchetta@univpm.it (G. Giacchetta), m.leporini@univpm.it (M. Leporini), barbara.marchetti@uniecampus.it (B. Marchetti).

Peer review under responsibility of Southwest Petroleum University.

Production and Hosting by Elsevier on behalf of KeAi

http://dx.doi.org/10.1016/j.petlm.2015.06.003
2405-6561/

Ref. [1] used OLGA software to simulate pigging transient flow characteristic of a 79 km dual flowlines system of a deepwater gas field.

In many flow assurance designs for subsea production systems, a single assumed rock-layer thickness surrounding the subsea wellbore is used to simulate wellbore thermal performance over the well's entire projection life. This assumption may lead to significant errors in flowing wellhead temperature calculations and potential failure of the flow assurance thermal design.

Ref. [2], demonstrated a new generalized equivalent rock-layer thickness (ERT) model with a time-dependent impact zone of the formation rock-layer surrounding the wellbore. Various drill-stem-test (DST) data, field production data, and OLGA simulation results have verified the validity of the proposed model.

Ref. [3] presented a general Flow Assurance study mainly using OLGA software by performing a detailed flow and thermal analyses, using dedicated CFD simulations, to identify local cold or hot spot in a large offshore/subsea development. Hot spots could lead to an accelerated aging of some of the equipment materials, whereas cold spot could lead to a quicker cooldown time than required creating a local risk of wax or hydrate plug formation.

Ref. [4] have studied gas injection as an effective method to mitigate hydrodynamic slug using OLGA simulation.

Ref. [5] presented a new way to face flow assurance challenges developed by CD-adapco and SPT that have partnered to couple their industry leading analysis solutions – STAR-CCM+ and OLGA – to provide a multi-fidelity, multiphysics simulation tool for flow assurance applications.

Ref. [6], discussed the flow assurance design and operating strategies for the high pressure high temperature Blind Faith development located in deepwater Gulf of Mexico. An OLGA model based Flow Management Tool (FMT) was developed prior to field start-up to provide asset team engineers and operators with live information on calculated well production rates, steady state thermal performance of the flowlines with forward looking projections on cooldown times for hydrate management.

Ref. [7] in their paper described different operational scenarios where hydrate plugging might occur and how a hydrate plug formation prediction tool would be beneficial. They demonstrated the effectiveness of the implementation of an existing hydrate plug formation model, called CSMHyK (The Colorado School of Mines Hydrate Kinetic Model) that have been implemented in the transient multiphase flow simulator OLGA as a separate module.

Ref. [8], summarized some of the experiences from modeling and operation of gas/condensate pipelines based on analysis performed using the multiphase pipeline simulation tool OLGA.

Ref. [9] demonstrated how transient models such as OLGA are used to predict and alleviate the flow assurance problems associated with deepwater production of a gas condensate subsea system. The paper addresses the importance of flow modeling before and during production.

Despite the wide amount of papers dealing with the application of the thermohydraulic simulator Olga in flow assurance problems, there is no evidence in literature of codes developed for simplifying, speeding up and reducing errors of the data extraction process.

3. Material and methods

This chapter is structured in three parts. The first one is dedicated to the sensitivity analysis in flow assurance, describing why it is important and how it is performed using Olga as an analysis platform. Then two different data extraction procedures: the old "manual procedure" and the one that has been proposed through the development of OtoEx are described.

3.1. Sensitivity analysis in flow assurance

In flow assurance the sensitivity analysis approach is used to find the optimum condition for setting different parameters of a gathering system: the optimum pipeline's route that minimize the costs of the plant; the lowest number of pipes that allows to process safely the entire mass flow rate that comes from the wells; the diameter of the pipeline's system that allows the safe transportation of the mass flow. The best configuration is the one that allows costs minimization, to meet the required specification from the standards or the customer and to ensure the safety of the plant.

In order to successfully complete a sensitivity analysis, the first action to carry out is to perform a thermo-fluid dynamic simulation of the gathering system under analysis. Olga is a dynamic one-dimensional modified two fluid model, used to simulate two phase hydrocarbon flow in pipeline networks. It was first developed by IFE in 1983 for the Norwegian state oil company, Statoil. Since then has been improved thanks to the increasing of the experimental database and all the numerical testing in the oil companies involved. Olga can simulate pipeline networks with its full suite of equipments such as compressors, pumps, heat exchangers, separators, check valves, controllers and mass sources/sinks.

To simulate a flow scenario with Olga three major steps have to be carried out:

- Setup preparation
- Launch of the simulation
- Data extraction

This paper focus on the procedure and optimization related to data extraction.

3.2. Manual procedure for the extraction of data

At present, data extraction is carried out using a manual procedure which follows a simple algorithm:

1. Visualize the plot of a certain variable of interest with the trend/profile plot tool
2. Collect the information directly from the plot, activating an Olga's tool that reads the value of the function displayed at any specific selected point
3. Elaborate the information if needed
4. Process data

This procedure is time consuming and repetitive, and it can represent a significant issue when the number of scenario to analyze increases: it takes a lot of time and effort and could lead to errors due to the repetitive work. Moreover if Olga is fully dedicated to data analysis, it cannot be used efficiently to run other simulations.

3.3. Otoex software development

When one analysis is launched, Olga automatically produces a total of 6 files with different extensions (GENKEY, H5, TPL, PPL, RSW, OUT), inside each file are stored different kind of variables and parameters related to the scenario being simulated. The file of interest for the developed procedure are the .tpl and .ppl, which contain respectively the trend plot and the profile plot data. These are the very files used by Olga to store and plot the results of the analysis. The idea behind the developed code, consists in getting the needed information from those files, developing a routine able to recover the results and present them in a structured way, without having the necessity to run Olga.

The code Otoex was developed in visual basic for application, so that it can be as easy to use as an excel tool. The flowchart in Fig. 1 shows the architecture of the software. Otoex consists of three main macro-functions called "engines":

(1) An ingestion engine: loads the .ppl and .tpl files into excel
(2) An evaluation engine: seeks for the right set of data inside the text files
(3) A manipulation engine: elaborates the information and fills the tables

These tasks are accomplished through 20 different subroutines which are repeated n times, where n is the number of variables we want to extract.

As shown in Fig. 1, Olga's files represent the input of the algorithm, while a typical output is shown in Fig. 2: a table, or a series of tables, containing all the variables that have to be studied for the simulated scenario.

From the end user point of view, Otoex is available simply opening an excel file and enabling Activex controls. The interface is straightforward and consists of 2 pages:

(1) A "data input page" where the user must specify the characteristics of the simulation to analyze, such as the number of pipelines involved in the case study and their nominatives (shown in Fig. 3)
(2) A "tables page" which contains the results collected and elaborated from the code, structured in tables (shown in Fig. 2)

4. Otoex validation and results

Otoex's code was tested against a series of simulations that were previously analyzed with the conventional "manual procedure" of data extraction. In this chapter the case study that has been used to test the algorithm is described. Then, in the last section, the main differences between the manual procedure and OtoEx are discussed.

4.1. Case study description

The gathering system that has been analyzed is part of a larger plant, localized in the Mediterranean sea, which consists

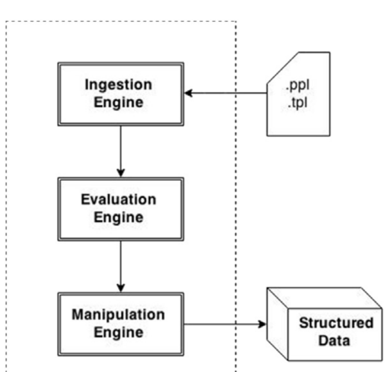

Fig. 1. Otoex code architecture.

of three different gathering centers that collect crude oil from more than fifteen wells. The aim of the study was to perform a sensitivity analysis over the nominal diameter of the pipelines, in order to find the optimum values which minimizes costs while assuring safety.

Fig. 4 helps to visualize the configuration of interest. It consists of one trunkline, two flowlines (F_A50, F_A51), a merge node (SG1), two wells node (A50, A51) and a collecting station (Central plant).

In Tables 1–3, the set of data needed to completely describe the gathering system and to correctly set up the analysis with Olga are listed:

(1) the basic information regarding the dimensions of the pipelines (Table 1);
(2) the environmental parameters (Table 2);
(3) the material properties (Table 3).

The wells operating conditions are always evaluated from the forecasts provided by the company that owns the gathering system. The analyzed forecasts showed that the wells of interests were basically producing just gas. It was decided to study the year of maximum GOR (Gas Oil Ratio), which happens to be the 2019 with a GOR value of 47,860. Another important parameter, related to the operating conditions, is the pressure difference between the central gathering station and the wells. For our case this value was determined to be 55 bara.

The fluid characterization is another key input for Olga's analysis. Olga needs a specific text file that has been generated using an external software named PVTsim. PVTsim is a versatile equation of state modeling software that allows the user to simulate fluid properties and experimental PVT (pressure, volume, temperature) data. It is based on a group of equations that simulate the behavior of fluids in different states, like the Peng Robinson and the Van der Waals relations. To accurately characterize the fluid with PVTsim, the molar percents of every element composing the gas and oil mixture of interest was introduced.

4.2. Data extraction

It has been run 14 different simulations, trying 7 different configurations, starting with a nominal diameter of 25 inches for the trunkline and 12¾ inches for the flowlines (Table 1). To perform the sensitivity analysis different key parameters able to describe the flow status inside the pipelines system have been taken into account: the gas and liquid velocity, the erosional velocity rate, the pressure and temperature level, the liquid accumulated and the holdup values. The results of the analysis, showed that the ideal configuration is a 10 inches trunkline and 8 inches flowlines.

After every simulation, the first step performed was the data extraction using the "manual procedure". Since there were 7 parameters to study and 14 different simulations to analyze, it was necessary to repeat the procedure 147 times. From experience, the estimated time required to extract data from this kind of simulation, stands between ten and fifteen minutes. At the end of this phase 14 tables (like the one in Fig. 2) were obtained.

Data extraction was repeated using Otoex and within two runs all the 14 simulations were analyzed. To obtain the same results and values of the "manual procedure" it took a total time of about 15 min. Further tests of the software have shown that, for this kind of simulations, it is possible to estimate a 1 min running time for every scenario simulated.

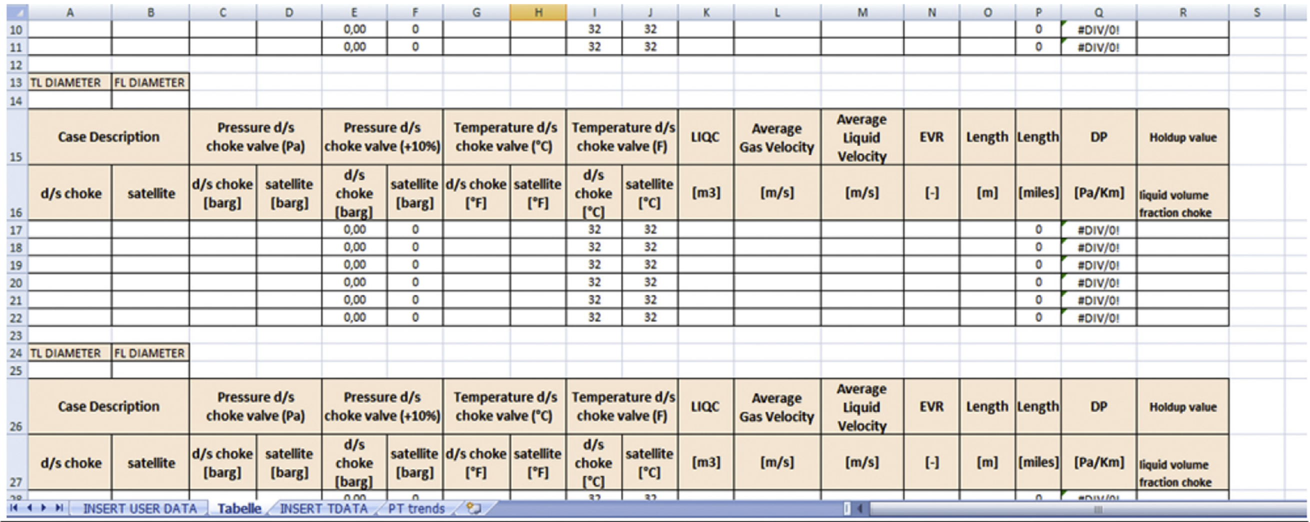

Fig. 2. Otoex output tables.

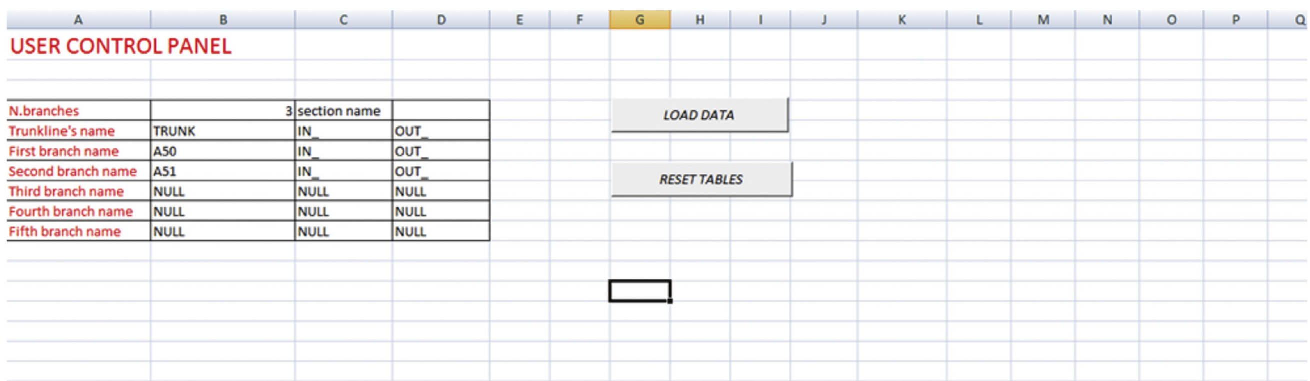

Fig. 3. Data input page.

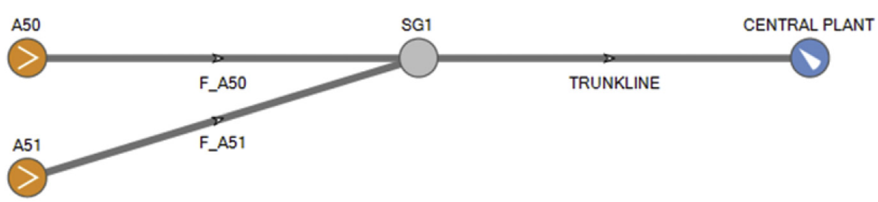

Fig. 4. Graphical representation of the case study.

Table 4 shows a comparison between the two procedures, based on the performed tests. The key aspects that is important to outline are:

(1) the time savings, from 10–15 min to 1 min required per simulation (up to 150%);
(2) the possibility to analyze up to 10 different scenario with a single run of the OtoEx;
(3) the possibility to perform the data extraction using a computer that doesn't even have Olga installed.

5. Conclusions and future developments

This code represents a simple tool for optimizing the use of a costly resource such as the Olga software. The results showed that it is possible to significantly reduce the time needed for

Table 1
Pipelines topography.

Inlet	Outlet	Pipeline type	Condition	ND [inch]	Length [m]
A50	SG1	Gas flowline	Underground	12¾	1197
A51	SG1	Gas flowline	Underground	12¾	1120
SG1	Central plant	Gas trunkline	Underground	24	29,111

Table 2
Environmental parameters.

Parameter	Value
Maximum soil temperature [°C]	34
Minimum soil temperature [°C]	9
Soil conductivity [W/m K]	4.6
Pipeline burial depth [m]	0.7

Table 3
Pipelines material properties.

Materials	Thermal conductivity [W/mK]	Roughness [μm]	Thickness [mm]
Carbon steel ×65	45	46	To evaluate
3LPP (insulator)	0.2	–	2.2

Table 4
Comparison between the manual procedure and OtoEx

	Manual procedure	OtoEx
Time required/simulation	10–15 min	1 min
Max number of simulation/run	1	10
Necessity of Olga	Required	Not required

extracting data, up to 150%, and that this operation can be performed with an higher level of accuracy due to the automatization of the procedure.

Since this is a first version, and even if it has demonstrated the ability to simplify and speeding up the simulation, the code need to be further developed to acquire a more structured and professional shape; moreover improvements have to be made in order to take into account different plants layout, and to make the operator able to specify the set of variables that he wants to analyze.

Along with the flexibility another aspect to improve is the efficiency of the software. At the actual stage, the code is rough, intricate, and needs to be refined. This aspect is crucial in order to enhance the usability of Otoex, reaching even higher performances.

The new release should then been tested against other simulations and possibly other extraction methodology.

Acknowledgments

The authors would like to acknowledge Tecnoconsult Engineering Construction srl for the support given to the development of this work.

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