Introduction to a New Approach to the Modeling of an Ethane Pipeline Profile

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Abstract

During initial design stages for new pipeline projects, significant emphasis is often supported on selecting the optimal choice of the new line route and also defining the operating envelope of the pipeline since these two points represent an important key in the future operations of the system. The work realized discuss the challenges involved in the design and predictive modeling of a proposed (810 Kilometer) liquid ethane pipeline using a new approach for pipeline profile modeling. For this raison, a study aiming at the homogenization of the pipeline shape was carried out. This was achieved by appealing to techniques of optimization, using the technique of the upscaling. Furthermore in an objective to simplify the pipeline profile while protecting the configuration of the flow and the main technological parameters.

The application of our approach is conducted on the feasibility study of the ethane transportation. The purpose is to determine an optimal configuration for the design of a pipeline transporting the ethane from the region of Hassi Messaoud (HMD) towards the region of Arzew, under the liquid phase.

Keywords: *Homogenization, optimization, simulation, ethane*

1. Introduction

The simulation of hydrocarbon flow in pipelines gives rise to numerous challenges to petroleum engineers; in particular, regarding how best to create a pipeline profile based on the data available. Very few works on the modeling of pipeline profiles has been presented in the literature [3]. In order to realize a simplified and efficient model which preserves, on the one hand, the overall geometry of the pipe and on the other hand the dynamic parameters, we propose in this work a new approach for the homogenization of the profile by a technique of upscaling. The application of our approach is carried out on the feasibility study of the transport of ethane. The objective is to determine an optimal configuration for the design of a pipeline transporting ethane from the Hassi Messaoud region (HMD) to the Arzew region in the liquid form.

2. How to handle the pipeline geometry?

When making pipeline models, the pipeline geometry is usually obtained either from survey data or from contour maps. Surveys would typically measure the depth every meter with a depth resolution of 1 cm, while a contour map would typically have equidistance in the order of 10 ft. This means that the amount of detail is vastly different, and different methods for making good pipeline simulation models are required.

The discretization of the profile of a pipeline carrying a multiphase system or a system able of changing phase during its transport must at least satisfy the following conditions:

1. The total length of the pipeline must be conserved.
2. The simplified geometry must have the same general shape (large and small scale undulations) to induce the same dynamic: loss of pressure, temperature evolution even acceleration of production, *etc.*
3. The total inclinations must be retained to predict the same overall liquid accumulation under the flow conditions of the system.
4. The angle distribution of the discretized profile must be as close as possible to the original distribution.

In the case of large length pipelines, discretization requires the compression of a large number of data points, typically several tens of thousands of coordinates at only a few thousand points. The transformation is therefore important and must be carried out with care since the consequences of a bad discretization are harmful particularly at the design stage of the development of a new field.

3. Theoretical model

Among the important elements in pipeline modeling is the best way to create a pipeline profile based on the available data, the importance of the flow model, the sensitivity of the holdup to the angle of inclination of the pipe, the flow and diameter of the pipe, and the importance of the boundary conditions.

Several studies have been carried out to investigate the Holdup profile and flow regime in pipelines [4], [5], [6], [8], nevertheless few or almost none of the models integrated the monophasic and diphasic flow into a single model. In practice the monophasic flow often changes in diphasic and it can again become monophasic during its flow in the pipeline and this is the case of the behavior of our effluent that will be studied. It is imperative, then, that a hydrodynamic model describes the ability of the phase change of our fluid in the pipeline. Indeed, a mono-diphasic model was developed by Niels H and Micheal Adewmni [7] or the latter couple the model of the phase behavior based on the equation of state Peng Robinson and the hydrodynamic model with two fluids.

During the transport of the fluid by pipeline, the interaction between the various dynamic parameters and kinematic is assured for this, we opted for a mechanistic model in order to model the evolution of these parameters while taking into account the interactions between the existing phases which consists in :

The equation of state of Peng Robinson:

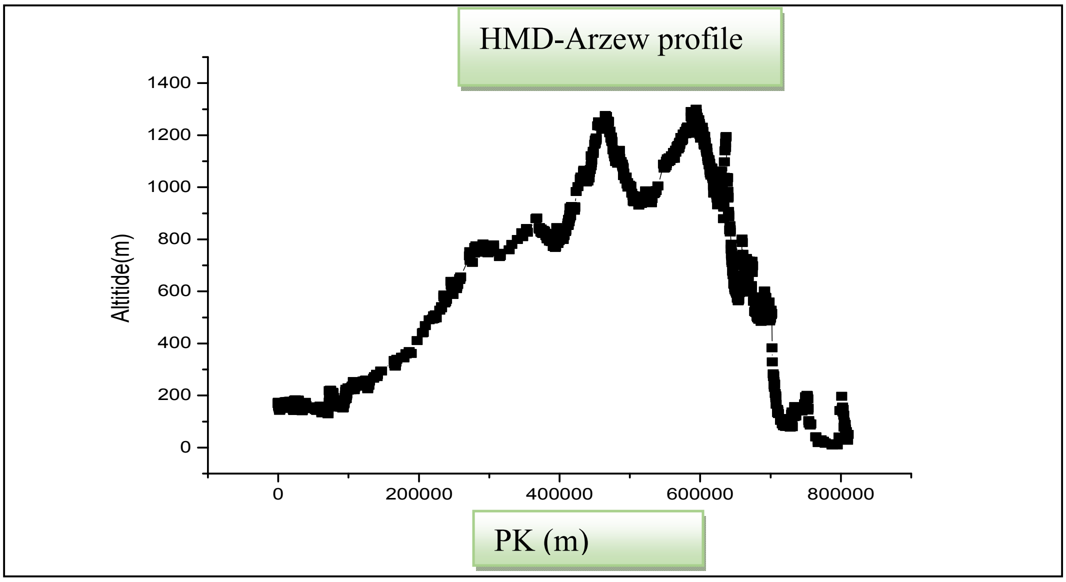
$$P = \frac{RT}{V-b} - \frac{a(t)}{V(V+b)+b(V-b)} \quad \text{…………..} \ (1)$$

The fluid model DFM (drift flux model):

$$\left.\frac{dP}{dL}\right)_{tot} = \left.\frac{dP}{dL}\right)_{acc} + \left.\frac{dP}{dL}\right)_{g} + \left.\frac{dP}{dL}\right)_{frot} \quad \text{…………} \ (2)$$

The profile of the line to be homogenized is of length (810) Km consisting of (1773) points distributed between the starting point HMD and the arrival terminal of Arzew shown in Figure (1). In this study, we are interested in finding a simple configuration of the line but representative of the relief of the pipeline layout. The proposed technique consists of minimizing the pressure and temperature deviation along the actual line and the model while preserving the physics of the flow (Holdup, temperature, pressure, *etc.*)

Figure 1 profile of the line HMD-Arzew



The homogenization of the profile is achieved by the upscaling technique, which is a new approach suggested for the homogenization of the profile.

In order to obtain an optimum profile of the pipeline with a reduced number of points for the simulation and respecting the flow configuration (dynamic pressure and temperature profile and the same holdup of the actual profile), we proceed from the following way:

Determine the altimetric height equivalent of the points of the homogenized line while minimizing the function:

$$\min\left(\sum_{i=1}^{n}\alpha\left(\frac{p_{real}-p_{hom}}{p_{real}}\right)^{2}+(1-\alpha)\left(\frac{T_{real}-T_{hom}}{T_{real}}\right)^{2}\right) \ldots\ldots (3)$$

$0 \prec \alpha \prec 1 \quad \alpha$

The decision variable is the height of the homogenized pipe to be adjusted. The major constraint for this upscaling operation is the holdup in any point of the actual and homogeneous section is the same.

$$H_L(x)_{real\,section}=H_L(x)_{homogeneous\,section} \ldots\ldots (4)$$

This approach has been adopted to the optimizer of the HYSYS ASPEN ONE.

Table 1: Subdivision of the HMD-ARZEW line into elementary sections

Starting Point	Arrival point	Number of point	Distance (Km)
HMD	OUARGLA	161	125,160
OUARGLA	GHARDAIA	90	97,67
GHARDAIA	H'RMEL	185	82,29
H'RMEL	LAGHOUAT	304	110,97
LAGHOUAT	TIARET	281	116,53
TIARET	PIK NADOR	145	51,96
PIK NADOR	PIK 640	130	49,34
PIK 640	PIK ZEMOURA	99	63,65
PIK ZEMOURA	ARZEW	378	113,09

Table 2: Characteristics of the real and homogenized section

characteristics	**Real section**	**Homogeneous section**
Total length (Km)	25,67	25,67
Upstream pressure (bar)	60,00	60,00
Downstream pressure (bar)	58 ,99	58 ,99
Upstream temperature (°C)	50 ,00	50,00
Downstream temperature (°C)	46,76	46,76
Hv (Vapor fraction)	0	0

The pressure profile, temperature and holdup of the two sections (real and homogeneous) are shown in the following figures:

Figure 2 Elevation profile

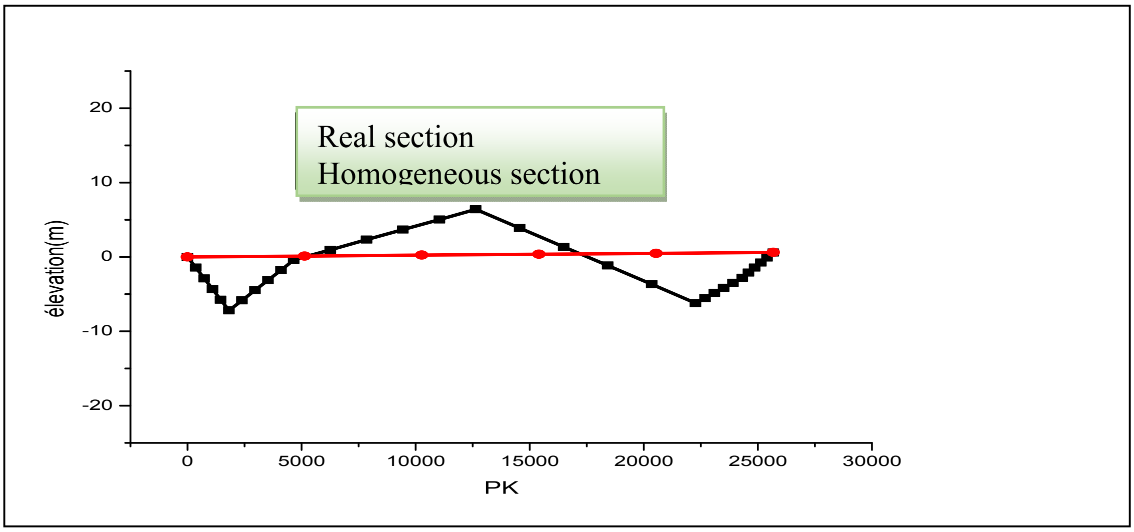


Figure 3 Pressure profile

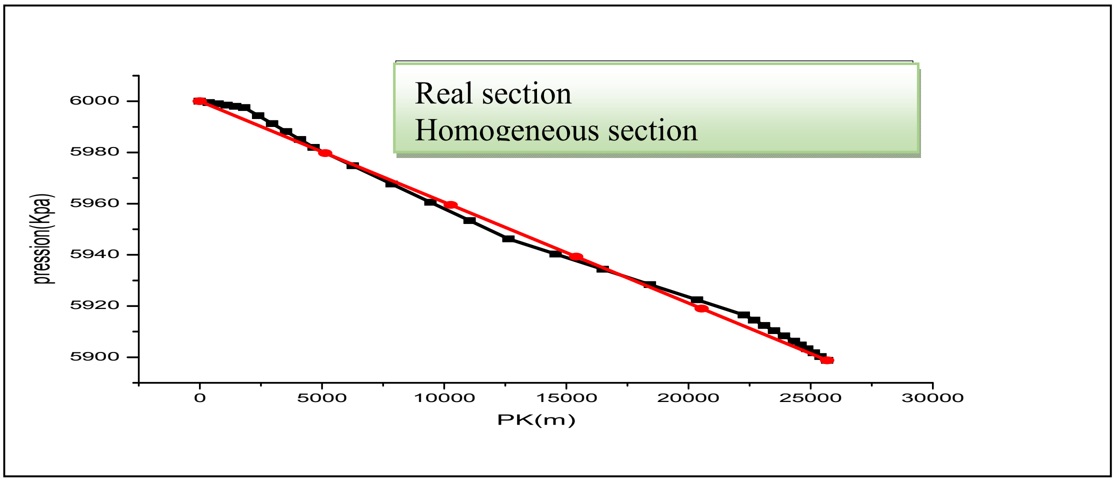


Figure 4 Temperature profile

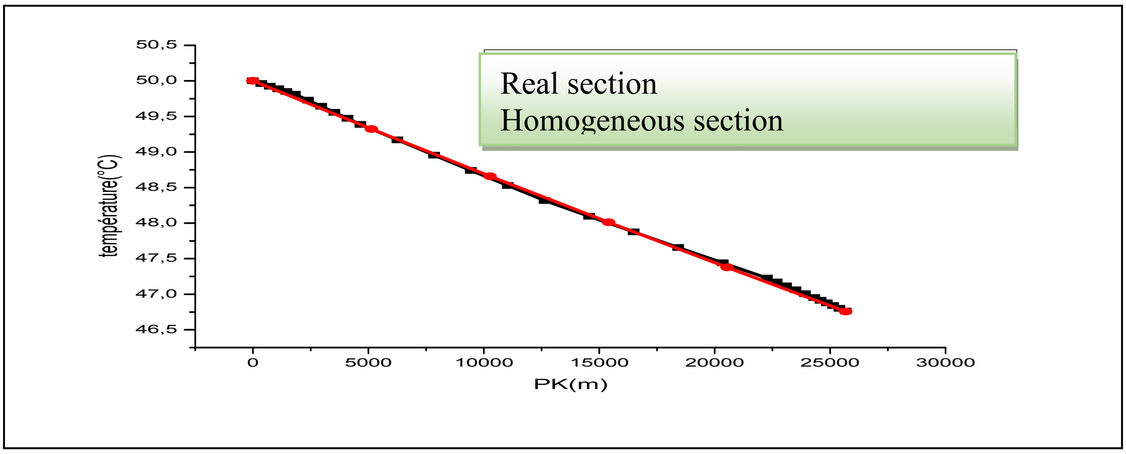
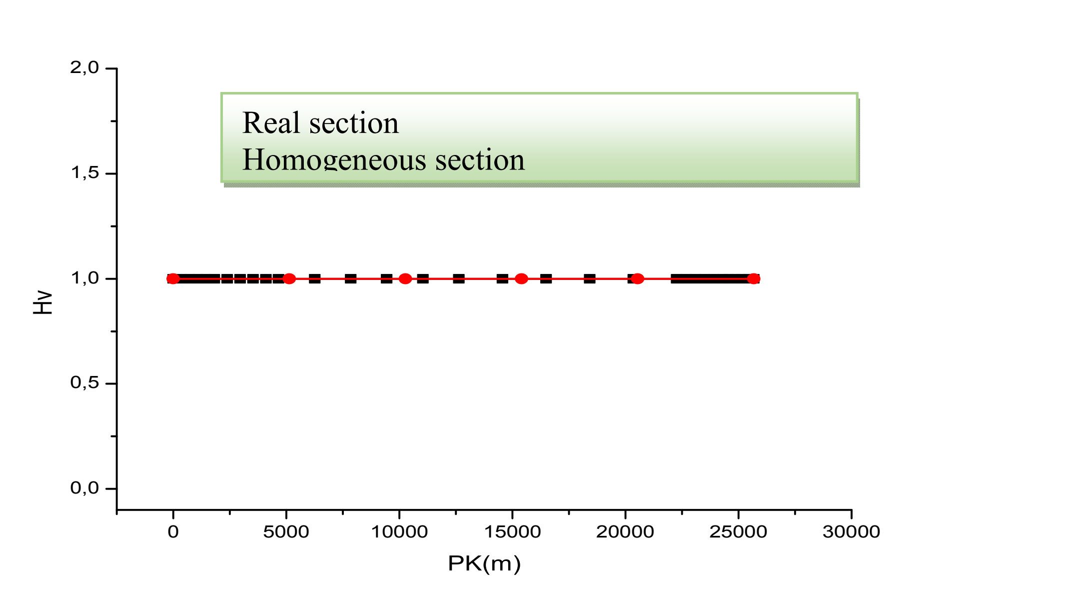


Figure 5 Holdup profile



The technical characteristics of the two sections (real and homogeneous) are summarized in the table below:

Table 3: The technical characteristics of the two sections (real and homogeneous)

	Real section	Homogeneous section
Heat transfer coefficient (Kj/h.m)	43,1320	43,7278
Flow regime	Single flow	Single flow
dp (friction) (Kpa/m)	3,92 E-03	3,92 E-03
Re (vapor)	7,38 E06	7,38 E06
speed (m/s)	2,48084	2,48070

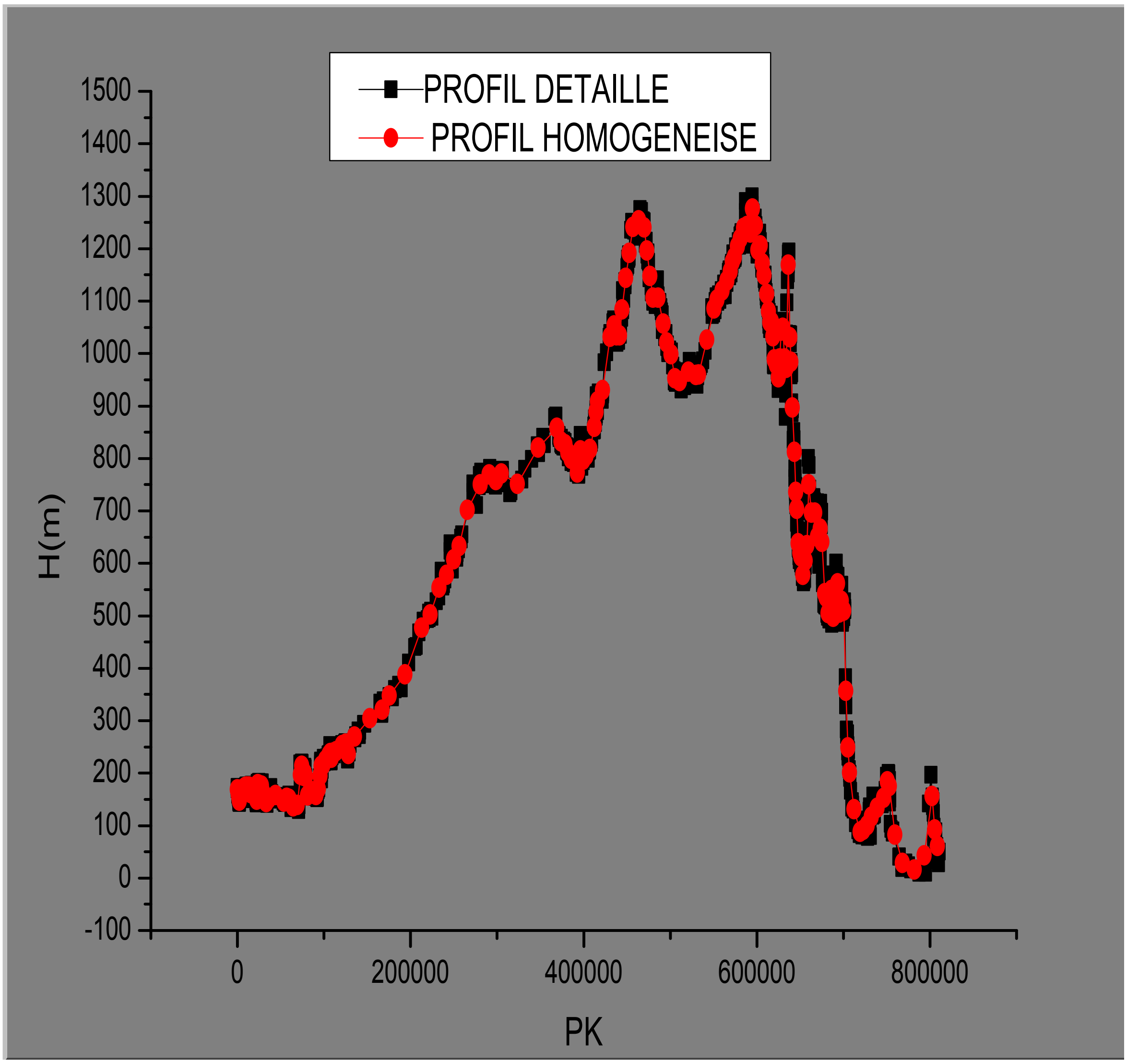
By respecting the same configuration of the flow without changing the main characteristics along the total pipeline that summarizes to the same value of the hold-up in the considered points. The results of the upscaling on the total profile are summarized in the table (4):

Table 4: Result of the Upscaling on all the profile

Starting point	Arrival point	Number of real points	Number of modeled points	Distance (Km)
HMD	OUARGLA	161	12	125,160
OUARGLA	GHARDAIA	90	7	97,67
GHARDAIA	H'RMEL	185	10	82,29
H'RMEL	LAGHOUAT	304	19	110,97
LAGHOUAT	TIARET	281	16	116,53
TIARET	PIK NADOR	145	6	51,96
PIK NADOR	PIK 640	130	17	49,34
PIK 640	PIK ZEMOURA	99	18	63,65
PIK ZEMOURA	ARZEW	378	13	113,09

The final model (homogenized by upscaling) consists of 118 points distributed between the starting terminal HMD and the arrival terminal ARZEW shown in the figure (6):

Figure 6 real and homogeneous profile



This approach allowed us to compress the number of points from 1773 to 118 points, so the chosen model is made up of 118 points that represent the same geometry. The essential characteristics of the detailed profile of the pipeline are conserved: Total pipe length,large scale ripples / small total rise and tilt pipe distribution. The comparative study confirmed the ability of the discretization methods to preserve the hydrodynamic behavior of the original profile, despite the compression of the significant data.

Conclusions

In the light of the obtained numerical results, it turns out that a too fine representation of the pipeline may lead to small instabilities of calculation and quite particularly in dynamic regime, as well as at the level of the connections of pipe segments. To remedy this problem i.e. the elimination of numerical instabilities, a study aiming at the homogenization of the pipeline shape was carried out. This was achieved by appealing to techniques of optimization, using the technique of the upscaling. Furthermore in an objective to simplify the pipeline profile while protecting the configuration of the flow and the main technical parameters. The results of the homogenization obtained are in a good agreement with a much more detailed model. Our work presents a contribution to the development of a treatment methodology of identical problems. The technique of homogenization proposed represents an effective tool for the simplification of lines. This approach is more rigorous than the stochastic methods based on mobile averages and other rough techniques.

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