INTRODUCTION

Every petroleum production system must have a source from which the production fluid comes from. This source refers to the well completion, which is the interface between the system and the reservoir. A detailed explanation about completions, reservoirs and inflow performance is out of the scope of this report, however, the idea is to introduce the concept of inflow performance relationship or IPR.

The IPR is a mathematical expression relating the average reservoir pressure, the well bottom hole pressure and its inflow hydrocarbon flowrate from the reservoir to the flowing bottomhole for a given depletion state. The pressure difference between the reservoir and the bottom hole is the driving force to transport hydrocarbons out of the well location within a reservoir and up to the surface.

As defined above, the IPR is a pseudo-steady state expression, since it depends on the evolution of the pressure difference between the reservoir and the well bottom hole pressure, also known as drawdown. The average reservoir pressure depends on the amount of wells, and production rate, and the flowing bottomhole pressure is related to the well infrastructure and surface network. Since the reservoir depletion is given in terms of weeks or months, production engineers approximate the drawdown behavior with the IPR. In this way, they are capable of scheduling production and even prepare forecast about it.

This class supports the following IPR models

- Vogel equation
- Jones equation
- Fetkovich equation
- Back pressure equation
- Productivity index model

DOCUMENT OBJECTIVE

Describing the main features, algorithms and calculations perform by the VertCompletionObj class.

DOCUMENT SCOPE

Describe all properties, methods and events included in the VertCompletionObj class, in its version 01. Additional to this, provide a detailed explanation on the major algorithms applied to solve the object depending on the variable configurations.

Class developed in MATLAB R2015a.

PRELIMINARIES

In the following sections there are shown all inflow performance relationships (IPR) included in the model. The unit system is not set, therefore, for obtaining a particular variable in a preferred system, the remaining variables in the equation have to be consistent. For more information about IPR, review (Beggs, 2003), or any other reference book or source about petroleum production engineering.

As a remark, the symbol P_{ws} was used to refer to the average reservoir pressure. However, in some books this symbol may be used to design other locations in the production system.

VOGEL EQUATION

$$\frac{q_{sc}}{q_{sc,max}} = 1 - 0{,}2 \cdot \frac{P_{wf}}{P_{ws}} - 0{,}8 \cdot (\frac{P_{wf}}{P_{ws}})^2 \qquad \text{(eq. 01)}$$

where:

q_{sc}	Inflow flowrate corresponding to wellbore flowing pressure
$q_{sc,max}$	Inflow rate corresponding to zero wellbore flowing pressure
P_{wf}	Wellbore flowing pressure
P_{ws}	Average reservoir pressure at a given depletion state

JONES EQUATION

$$P_{ws} - P_{wf} = A \cdot q_{sc} + B \cdot q_{sc}^2 \qquad \text{(eq. 02a)}$$

$$P_{ws}^2 - P_{wf}^2 = A \cdot q_{sc} + B \cdot q_{sc}^2 \qquad \text{(eq. 02b)}$$

where:

A	Jones' model laminar flow constant
B	Jones' model turbulent flow constant

FETKOVICH EQUATION

$$\frac{q_{sc}}{q_{sc,max}} = ({P_{ws}}^2 - {P_{wf}}^2)^n \qquad \text{(eq. 03)}$$

where:

n	Exponent depending on well characteristics, typically ranging from 0,568 to 1,000

BACK PRESSURE EQUATION

$$q_{sc} = C \cdot ({P_{ws}}^2 - {P_{wf}}^2)^n \qquad \text{(eq. 04)}$$

where:

C	Flow coefficient
n	Exponent depending on well characteristics

WELL PRODUCTIVITY INDEX MODEL

$$q_{sc} = J_o \cdot (P_{ws} - P_{wf}) \qquad \text{(eq. 05a)}$$

$$q_{sc} = J_g \cdot ({P_{ws}}^2 - {P_{wf}}^2) \qquad \text{(eq. 05b)}$$

where:

J_o	Oil productivity index
J_g	Gas productivity index

PROPERTIES

An attribute table describes each property. This table is a simplified version of the property attributes available in MATLAB, and it purpose is for any user or programmer with no previous experience in MATLAB have a better understanding of the property functionality.

For information, the attribute descriptions are as follows:

Property attribute	Description	Values
Access	Property accessibility once a class instance is created. · Public: unrestricted access · Protected: access from classes and subclasses · Private: access from class member only	{public | protected | private}

Property attribute	Description	Values
Dependent	Property auto-calculated by class instance, once all dependencies have been set. When true, the property does not store any value, and it is calculated in every callback.	{true | false}
Hidden	Property visibility for a class instance. When true, the property is not listed in the available class instance's properties.	{true | false}
Set access	Property ability to be written by the user in a class instance. · Public: unrestricted access · Protected: access from classes and subclasses · Private: access from class member only · Immutable: access from class constructor only	{public | protected | private | immutable}
Get access	Property ability to be read by the user in a class instance. · Public: unrestricted access · Protected: access from classes and subclasses · Private: access from class member only	{public | protected | private}

One important remark about this class is that the user has to select one of the available type of IPR and provide all the required information (constants, maximum inflow rate and exponents). IPR models can be used one at a time, and their properties are unrelated to other models.

IPRTYPE

<table>
<tr><td>Description</td><td colspan="5">Inflow performance relationship type
String defining the type of inflow performance relationship (IPR) to be used to calculate the well inflow production. The class supports most of the traditional IPR equations, including: well productivity index (for oil and gas reservoirs), Vogel equation, Fetkovich equation, Jones equation (for gas and oil reservoirs) and the backpressure equation.
This string can be one of the following:
· <code>'Well PI'</code>
· <code>'Vogel'</code>
· <code>'Fetkovich'</code>
· <code>'Jones'</code>
· <code>'Backpressure equation'</code>
Value by default = <code>'well pi'</code></td></tr>
<tr><td>Access</td><td>Public</td><td>Dependent</td><td>False</td><td>Set access</td><td>Public</td></tr>
<tr><td>Hidden</td><td>False</td><td>Class</td><td>String</td><td>Get access</td><td>Public</td></tr>
</table>

QSC

Description	*Reservoir production, standard conditions* Reservoir production given in Sm^3/d. Standard conditions refer to 1 atm (101,33 kPa) and 15,56 C.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

PWS

Description	*Reservoir pressure* Reservoir pressure given in kPa.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

PWF

Description	*Bottom hole pressure* Well bottom hole pressure given in kPa.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

TWF

Description	*Bottom hole temperature* Well bottom hole temperature given in C.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

JONESA

Description	*Jones equation constant, laminar flow* Jones equation constant related to the laminar flow. The property `IPRType` must be set to `'Jones'`, and the following properties need to be defined as well: `JonesType` and `JonesB`				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

JONESB

Description	*Jones equation constant, turbulent flow* Jones equation constant related to the turbulent flow. The property `IPRType` must be set to `'Jones'`, and the following properties need to be defined as well: `JonesType` and `JonesA`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

JONESTYPE

Description	*Jones equation formulation* String specifying the type of reservoir, hence IPR formulation. This string can be one of the following: · `'Gas'` · `'Oil'` The property `IPRType` must be set to `'Jones'`, and the following properties need to be defined as well: `JonesB` and `JonesA`. Value by default = `'oil'`				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	String	**Get access**	Public

WELLPIJ

Description	*Well productivity index* Well productivity index value, suggested in Sm3/d.kPa The property `IPRType` must be set to `'Well PI'`, and the following properties need to be defined as well: `WellPIType`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

WELLPITYPE

Description	*Well productivity index equation formulation* String specifying the type of reservoir, hence IPR formulation. This string can be one of the following: · `'Gas'` · `'Oil'` The property `IPRType` must be set to `'Well PI'`, and the following properties need to be defined as well: `WellPIJ`. Value by default = `'oil'`				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	String	**Get access**	Public

VOGELQMAX

Description	*Jones equation parameters, maximum flowrate* Maximum flowrate, as required by Jones IPR equation suggested in Sm3/d. The property `IPRType` must be set to `'Vogel'`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

FETKOVICHQMAX

Description	*Fetkovich equation parameters, maximum flowrate* Maximum flowrate, as required by Jones IPR equation suggested in Sm3/d. The property `IPRType` must be set to `'Fetkovich'`, and the following properties need to be defined as well: `FetkovichN`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

FETCHOVITCHN

Description	*Fetkovich equation parameters, exponent* Exponent depending on well characteristics, typically ranging from 0,568 to 1,000. The property `IPRType` must be set to `'Fetkovich'`, and the following properties need to be defined as well: `FetkovichQmax`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

BACKPRESSUREC

Description	*Back pressure equation parameters, coefficient* The property `IPRType` must be set to `'Backpressure equation'`, and the following properties need to be defined as well: `BackPressureN`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

BACKPRESSUREN

Description	*Back pressure equation parameters, exponent* The property `IPRType` must be set to `'Backpressure equation'`, and the following properties need to be defined as well: `BackPressureC`.				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

CALCULATIONTYPE

Description	*Type of IPR formulation* Type of formulation for the IPR equation, either to calculate flowing bottomhole pressure or inflow flowrate. The two possible strings for this property are as follows: · `'pwf'` · `'q'`				
Access	Public	**Dependent**	False	**Set access**	Public
Hidden	False	**Class**	String	**Get access**	Public

AOFP

Description	*Absolute open flow potential* Maximum inflow rate from a well. This value corresponds to a well bottom hole pressure equal to 0 kPa.				
Access	Public	**Dependent**	True	**Set access**	Public
Hidden	False	**Class**	Double	**Get access**	Public

METHODS

An attribute table describes each method. This table is a simplified version of the method attributes available in MATLAB, and it purpose is for any user or programmer with no previous experience in MATLAB have a better understanding of the method functionality.

For information, the attribute descriptions are as follows:

Method attribute	Description	Values
Access	Method accessibility once a class instance is created. · Public: unrestricted access · Protected: access from classes and subclasses · Private: access from class member only	{public | protected | private}
Hidden	Method visibility for a class instance. When true, the property is not listed in the available class instance's methods.	{true | false}
Static	Method independency on a class object. Relative to methods inherent to the class code, such as error/exception handling. When true, the method is only available inside the class code only and does not require arguments related to the class instance.	{true | false}

SOLVECOMPLETION

Description	*Solve vertical completion* This method solves the IPR model selected by the user, calculating either the flowing bottomhole pressure (P_{wf}) or the inflow flowrate ($q_{o,sc}$). The user must be consistent with the unit system used to defined the IPR variables, since the method does not apply any error control regarding this. Advisable units: kPa for pressure, and m3/d for inflow flowrate.				
Access	Public	**Hidden**	False	**Static**	False

CALCULATEPWF

Description	*Calculate flowing bottomhole pressure* This method solve the IPR model selected by the user, using the flowing bottomhole formulation of the equation. This is an auxiliary method used by the `SolveCompletion` method.				
Access	Public	**Hidden**	False	**Static**	False

CALCULATEQ

Description	*Calculate inflow flowrate* This method solve the IPR model selected by the user, using the inflow flowrate formulation of the equation. This is an auxiliary method used by the `SolveCompletion` method.				
Access	Public	**Hidden**	False	**Static**	False

PWFBACKPRESSURE

Description	*Flowing bottomhole pressure calculation, back pressure equation* This method solves the back pressure equation (IPR model), to calculate the flowing bottomhole pressure. This is an auxiliary method used by the `CalculatePwf` method.				
Access	Protected	**Hidden**	True	**Static**	False

PWFFETKOVICH

Description	*Flowing bottomhole pressure calculation, Fetkovich equation* This method solves the Fetkovich equation (IPR model), to calculate the flowing bottomhole pressure. This is an auxiliary method used by the `CalculatePwf` method.				
Access	Protected	**Hidden**	True	**Static**	False

PWFJONES

Description	*Flowing bottomhole pressure calculation, Jones equation* This method solves the Jones equation (IPR model), to calculate the flowing bottomhole pressure. This is an auxiliary method used by the `CalculatePwf` method.				
Access	Protected	**Hidden**	True	**Static**	False

PWFVOGEL

Description	*Flowing bottomhole pressure calculation, Vogel equation* This method solves the Vogel equation (IPR model), to calculate the flowing bottomhole pressure. This is an auxiliary method used by the `CalculatePwf` method.				
Access	Protected	**Hidden**	True	**Static**	False

PWFWELLPI

Description	*Flowing bottomhole pressure calculation, well productivity index* This method solves the well productivity index formulation (IPR model), to calculate the flowing bottomhole pressure. This is an auxiliary method used by the `CalculatePwf` method.				
Access	Protected	**Hidden**	True	**Static**	False

QBACKPRESSURE

Description	*Inflow flowrate calculation, back pressure equation* This method solves the back pressure equation (IPR model), to calculate the inflow flowrate. This is an auxiliary method used by the `CalculateQ` method.				
Access	Protected	**Hidden**	True	**Static**	False

QFETKOVICH

Description	*Inflow flowrate calculation, Fetkovich equation* This method solves the Fetkovich equation (IPR model), to calculate the inflow flowrate. This is an auxiliary method used by the `CalculateQ` method.				
Access	Protected	**Hidden**	True	**Static**	False

QJONES

Description	*Inflow flowrate calculation, Jones equation* This method solves the Jones equation (IPR model), to calculate the inflow flowrate. This is an auxiliary method used by the `CalculateQ` method.				
Access	Protected	**Hidden**	True	**Static**	False

QVOGEL

Description	*Inflow flowrate calculation, Vogel equation* This method solves the Vogel equation (IPR model), to calculate the inflow flowrate. This is an auxiliary method used by the `CalculateQ` method.				
Access	Protected	**Hidden**	True	**Static**	False

QWELLPI

Description	*Inflow flowrate calculation, well productivity index* This method solves the well productivity index formulation (IPR model), to calculate the inflow flowrate. This is an auxiliary method used by the `CalculateQ` method.				
Access	Protected	**Hidden**	True	**Static**	False

STRUCTURE BRIEFING

In the following table, there is a list of all public properties included in every object created from this class.

Property	**Name**	**Remarks**
IPRType	Inflow performance relationship type	Required. Default value = `'well PI'`
Qsc	Reservoir production, standard conditions	Required.
Pws	Reservoir pressure	Required.
Pwf	Well down hole pressure	Required.
Twf	Well down hole temperature	Required.
JonesA	Jones equation constant, laminar flow	Required (*).
JonesB	Jones equation constant, turbulent flow	Required (*).
JonesType	Jones equation formulation	Required (*). Default value = `'oil'`
WellPIJ	Well productivity index	Required (*).
WellPIType	Well productivity index equation formulation	Required (*). Default value = `'oil'`
VogelQmax	Vogel equation, maximum inflow rate	Required (*).
FetkovichQmax	Fetkovich equation, maximum inflow rate	Required (*).
FetkovichN	Fetkovich equation, exponent	Required (*).
BackPressureC	Back pressure equation, coefficient	Required (*).
BackPressureN	Back pressure equation, exponent	Required (*).
CalculationType	Production system calculation type	Required. Default value = `'pwf'`
AOFP	Absolute open flow potential	Dependent.

(*) For using one IPR equation, all parameters related to it must be defined. Only one IPR can be use at a time.

APPLICATION

In the next blocks of code, some applications of the class are shown

EXAMPLE 1: DEFINING AN OBJECT

```
VC = VertCompletionObj;
VC.Pws = 2e4;
VC.Twf = 45;
VC.IPRType = 'Well PI';
VC.WellPIType = 'oil';
VC.WellPIJ = 30/100;
```

REFERENCES

Beggs, H. (2003). *Production Optimization using Nodal Analysis* (II ed.). Tulsa, Oklahoma, USA: OGCI and Petroskills Publications.