

**SYSTEMS AND METHODS FOR OPTIMIZING EXISTING WELLS
AND DESIGNING NEW WELLS BASED ON THE DISTRIBUTION
OF AVERAGE EFFECTIVE FRACTURE LENGTHS**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] Not applicable.

FIELD OF THE INVENTION

[0003] The present invention generally relates to systems and methods for optimizing existing wells and designing new wells based on the distribution of average effective fracture lengths. More particularly, the present invention relates to optimizing existing wells and designing new wells based on the distribution of each average effective fracture length for a respective fracturing stage with respect to different reservoir properties.

BACKGROUND OF THE INVENTION

[0004] The history matching of well production profiles represents an important component in field development planning. In unconventional plays it is essential to history-match, on a reservoir well by well basis, the production decay curves of fluids using a single well simulator and to accurately estimate the improved permeability (k_{imp}) associated with the stimulated reservoir (drainage) volume (SRV) induced by the fracture system. It is important to note that improved permeability is not only associated with the permeability matrix, but also corresponds to the enhanced fluid-flow properties of the fracture system.

[0005] Traditionally, when micro-seismic monitoring data is not available, the history matching process assumes a simplistic model of the induced fracture system composed of several

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] The present invention therefore, overcomes one or more deficiencies in the prior art by providing systems and methods for optimizing existing wells and designing new wells based on the distribution of each average effective fracture length for a respective fracturing stage with respect to different reservoir properties.

[0020] In one embodiment, the present invention includes a method for optimizing well production in a stimulated reservoir volume, which comprises i) inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model; ii) determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties; iii) sampling an average effective fracture length from the distribution of average effective fracture lengths using a computer processor; and iv) optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

[0021] In another embodiment, the present invention includes a non-transitory program carrier device tangibly carrying computer executable instructions for optimizing well production in a stimulated reservoir volume, which comprises i) inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model; ii) determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties; iii) sampling an average effective fracture

length from the distribution of average effective fracture lengths; and iv) optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

[0022] In yet another embodiment, the present invention includes a non-transitory program carrier device tangibly carrying computer executable instructions for optimizing well production in a stimulated reservoir volume, which comprises i) inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model; ii) determining a distribution of average effective fracture lengths by: a) reading an effective fracture length for each fracture plane in each fracturing stage for each well; b) calculating an average effective fracture length for each fracturing stage using each effective fracture length for a respective fracturing stage; and c) building the distribution of average effective fracture lengths by correlating the average effective fracture length for each respective fracturing stage with each reservoir or well-log property; iii) sampling the average effective fracture length from the distribution of average effective fracture lengths; and iv) optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

[0023] The subject matter of the present invention is described with specificity, however, the description itself is not intended to limit the scope of the invention. The subject matter thus, might also be embodied in other ways, to include different steps or combinations of steps similar

CLAIMS

1. A method for optimizing well production in a stimulated reservoir volume, which comprises:

inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model;

determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties;

sampling an average effective fracture length from the distribution of average effective fracture lengths using a computer processor; and

optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

2. The method of claim 1, wherein the history matching is performed by a single well reservoir simulator.

3. The method of claim 1, wherein the distribution of average effective fracture lengths is determined by:

$$\hat{x}_{eff,s}^w = \frac{1}{F} \sum_{f=1}^F x_{eff,s,f}^w$$

7. The method of claim 3, wherein each reservoir or well-log property is a complex reservoir property.

8. The method of claim 3, wherein each fracturing stage for each well comprises a plurality of fracture planes, each fracture plane within a respective fracturing stage having a different effective fracture length.

9. A non-transitory program carrier device tangibly carrying computer executable instructions for optimizing well production in a stimulated reservoir volume, the instructions being executable to implement:

inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model;

determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties;

sampling an average effective fracture length from the distribution of average effective fracture lengths; and

$$\tilde{x}_{eff,s|p}^w = \text{Prob}(X_{eff} = \hat{x}_{eff,s}^w | P = p) = \frac{\text{Prob}_{P, X_{eff}}(p, \hat{x}_{eff,s}^w)}{\text{Prob}_P(p)}$$

13. The program carrier device of claim 11, wherein a longest axis of each fracture plane is read and designated as the effective fracture length for each respective fracture plane.

14. The program carrier device of claim 11, wherein the average effective fracture length for each fracturing stage is calculated by:

$$\hat{x}_{eff,s}^w = \frac{1}{F} \sum_{f=1}^F x_{eff,s,f}^w$$

15. The program carrier device of claim 11, wherein each reservoir or well-log property is a complex reservoir property.

16. The program carrier device of claim 11, wherein each fracturing stage for each well comprises a plurality of fracture planes, each fracture plane within a respective fracturing stage having a different effective fracture length.

17. A method for optimizing well production in a stimulated reservoir volume, which comprises:

inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model;

determining a distribution of average effective fracture lengths by:

reading an effective fracture length for each fracture plane in each fracturing stage for each well;

calculating an average effective fracture length for each fracturing stage using each effective fracture length for a respective fracturing stage; and

building the distribution of average effective fracture lengths by correlating the average effective fracture length for each respective fracturing stage with each reservoir or well-log property;

sampling the average effective fracture length from the distribution of average effective fracture lengths; and

optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

18. The method of claim 17, wherein the distribution of average effective fracture lengths is a discrete conditional distribution that is built by:

$$\tilde{x}_{eff,s|p}^w = \text{Prob}(X_{eff} = \hat{x}_{eff,s}^w | P = p) = \frac{\text{Prob}(P = p \cap X_{eff} = \hat{x}_{eff,s}^w)}{\text{Prob}(P = p)}$$

or a continuous conditional distribution that is built by:

$$\tilde{x}_{eff,s|p}^w = \text{Prob}(X_{eff} = \hat{x}_{eff,s}^w | P = p) = \frac{\text{Prob}_{P, X_{eff}}(p, \hat{x}_{eff,s}^w)}{\text{Prob}_P(p)}$$

**SYSTEMS AND METHODS FOR OPTIMIZING EXISTING WELLS
AND DESIGNING NEW WELLS BASED ON THE DISTRIBUTION
OF AVERAGE EFFECTIVE FRACTURE LENGTHS**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] Not applicable.

FIELD OF THE INVENTION

[0003] The present invention generally relates to systems and methods for optimizing existing wells and designing new wells based on the distribution of average effective fracture lengths. More particularly, the present invention relates to optimizing existing wells and designing new wells based on the distribution of each average effective fracture length for a respective fracturing stage with respect to different reservoir properties.

BACKGROUND OF THE INVENTION

[0004] The history matching of well production profiles represents an important component in field development planning. In unconventional plays it is essential to history-match, on a reservoir well by well basis, the production decay curves of fluids using a single well simulator and to accurately estimate the improved permeability (k_{imp}) associated with the simulated reservoir (drainage) volume (SRV) induced by the fracture system. It is important to note that improved permeability is not only associated with the permeability matrix, but also corresponds to the enhanced fluid-flow properties of the fracture system.

[0005] Traditionally, when micro-seismic monitoring data is not available, the history matching process assumes a simplistic model of the induced fracture system composed of several

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] The present invention therefore, overcomes one or more deficiencies in the prior art by providing systems and methods for optimizing existing wells and designing new wells based on the distribution of each average effective fracture length for a respective fracturing stage with respect to different reservoir properties.

[0020] In one embodiment, the present invention includes a method for optimizing well production in a simulated reservoir volume, which comprises i) inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model; ii) determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties; iii) sampling an average effective fracture length from the distribution of average effective fracture lengths using a computer processor; and iv) optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

[0021] In another embodiment, the present invention includes a non-transitory program carrier device tangibly carrying computer executable instructions for optimizing well production in a simulated reservoir volume, which comprises i) inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model; ii) determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties; iii) sampling an average effective fracture

length from the distribution of average effective fracture lengths; and iv) optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

[0022] In yet another embodiment, the present invention includes a non-transitory program carrier device tangibly carrying computer executable instructions for optimizing well production in a simulated reservoir volume, which comprises i) inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model; ii) determining a distribution of average effective fracture lengths by: a) reading an effective fracture length for each fracture plane in each fracturing stage for each well; b) calculating an average effective fracture length for each fracturing stage using each effective fracture length for a respective fracturing stage; and c) building the distribution of average effective fracture lengths by correlating the average effective fracture length for each respective fracturing stage with each reservoir or well-log property; iii) sampling the average effective fracture length from the distribution of average effective fracture lengths; and iv) optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

[0023] The subject matter of the present invention is described with specificity, however, the description itself is not intended to limit the scope of the invention. The subject matter thus, might also be embodied in other ways, to include different steps or combinations of steps similar

CLAIMS

1. A method for optimizing well production in a simulated reservoir volume, which comprises:

inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model;

determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties;

sampling an average effective fracture length from the distribution of average effective fracture lengths using a computer processor; and

optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length to improve permeability of the simulated reservoir volume.

2. The method of claim 1, wherein the history matching is performed by a single well reservoir simulator.

3. The method of claim 1, wherein the distribution of average effective fracture lengths is determined by:

$$\hat{x}_{eff,s}^w = \frac{1}{F} \sum_{f=1}^F x_{eff,s,f}^w$$

7. The method of claim 3, wherein each reservoir or well-log property is a complex reservoir property.

8. The method of claim 3, wherein each fracturing stage for each well comprises a plurality of fracture planes, each fracture plane within a respective fracturing stage having a different effective fracture length.

9. A non-transitory program carrier device tangibly carrying computer executable instructions for optimizing well production in a simulated reservoir volume, the instructions being executable to implement:

inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model;

determining a distribution of average effective fracture lengths based on the complex reservoir properties and the complex fracture network properties;

sampling an average effective fracture length from the distribution of average effective fracture lengths; and

$$\tilde{x}_{eff,s|p}^w = \text{Prob}(X_{eff} = \hat{x}_{eff,s}^w | P = p) = \frac{\text{Prob}_{P, X_{eff}}(p, \hat{x}_{eff,s}^w)}{\text{Prob}_p(p)}$$

13. The program carrier device of claim 11, wherein a longest axis of each fracture plane is read and designated as the effective fracture length for each respective fracture plane.

14. The program carrier device of claim 11, wherein the average effective fracture length for each fracturing stage is calculated by:

$$\hat{x}_{eff,s}^w = \frac{1}{F} \sum_{f=1}^F x_{eff,s,f}^w$$

15. The program carrier device of claim 11, wherein each reservoir or well-log property is a complex reservoir property.

16. The program carrier device of claim 11, wherein each fracturing stage for each well comprises a plurality of fracture planes, each fracture plane within a respective fracturing stage having a different effective fracture length.

17. A method for optimizing well production in a simulated reservoir volume, which comprises:

inputting one or more complex reservoir properties and one or more complex fracture network properties, the complex fracture network properties comprising data corresponding to clusters in a complex fracture network model;

determining a distribution of average effective fracture lengths by:

reading an effective fracture length for each fracture plane in each fracturing stage for each well;

calculating an average effective fracture length for each fracturing stage using each effective fracture length for a respective fracturing stage; and

building the distribution of average effective fracture lengths by correlating the average effective fracture length for each respective fracturing stage with each reservoir or well-log property;

sampling the average effective fracture length from the distribution of average effective fracture lengths; and

optimizing well production by history matching using the distribution of average effective fracture lengths and the sampled average effective fracture length.

18. The method of claim 17, wherein the distribution of average effective fracture lengths is a discrete conditional distribution that is built by:

$$\tilde{x}_{eff,s|p}^w = \text{Prob}(X_{eff} = \hat{x}_{eff,s}^w | P = p) = \frac{\text{Prob}(P = p \cap X_{eff} = \hat{x}_{eff,s}^w)}{\text{Prob}(P = p)}$$

or a continuous conditional distribution that is built by:

$$\tilde{x}_{eff,s|p}^w = \text{Prob}(X_{eff} = \hat{x}_{eff,s}^w | P = p) = \frac{\text{Prob}_{P, X_{eff}}(p, \hat{x}_{eff,s}^w)}{\text{Prob}_P(p)}$$