RESERVOIR SIMULATOR, METHOD AND COMPUTER PROGRAM PRODUCT

FIELD OF THE INVENTION

The present invention relates generally to hydrocarbon reservoir analysis and, more specifically, to a reservoir simulator which models proppant damage effects on reservoir production.

BACKGROUND

In hydrocarbon exploration, accurately understanding the economic projections of a reservoir is vitally important. Conventional approaches include the use of reservoir simulators which predict production behavior and, hence, cashflow from a well. In addition to the reservoir simulators, however, geomechanical calculations are also required to account for the reduction in proppant permeability (i.e., proppant damage) over time – which directly effects production. In conventional reservoir simulators, to model this effect engineers utilize compaction tables, so called because they were developed to model compaction effects consisting of pressure versus transmissibility and pore volume relationships.

In conventional thought, laboratory tests and physical theory suggest that permeability in proppant packs is a function of closure stress and pore pressure. The disadvantage to this approach is that calculating closure stress and analyzing the laboratory-determined relationships between fracture permeability and closure stress directly would be too computationally demanding on the reservoir simulator, and would require more data than typically available. Therefore, it would be much more practical to develop a reservoir simulator which somehow utilizes the fracture permeability versus closure stress relationship in a computationally efficient manner. To date, however, no solution has been presented to the industry.

In view of the foregoing, there is a need in the art for a reservoir simulator that converts the fracture permeability versus closure stress relationship to a fracture permeability verses pore pressure relationship, and vice versa, in order to predict proppant damage on production, to thereby provide a more accurate economic projection of the reservoir.

SUMMARY

According to a first aspect of the present invention, there is provided a computer-implemented method to model proppant damage effects on a wellbore fracture using a reservoir simulator, the method comprising: uploading proppant damage behavior data into the reservoir simulator, the proppant damage behavior data comprising data reflecting a fracture closure stress versus fracture permeability relationship for a defined proppant type; using the reservoir simulator to: transform the fracture closure stress versus fracture permeability relationship into a pore pressure versus fracture permeability relationship; and calculate a fracture permeability reduction factor using the pore pressure versus fracture permeability relationship; modeling growth of the wellbore fracture using a fracture simulator, thereby generating fracture characteristic data; communicating the fracture characteristic data to the reservoir simulator; and modeling production of the wellbore using the reservoir simulator, the production model being based upon the fracture permeability reduction factor and the fracture characteristic data, thereby modeling the proppant damage effects on the wellbore.

According to a second aspect of the present invention, there is provided a system comprising processing circuitry to implement the above method.

According to a third aspect of the present invention, there is provided a computer program product comprising instructions which, when executed by at least one processor, causes the processor to perform the above method.

According to a fourth aspect of the present invention, there is provided a computer-implemented method to model proppant damage effects on a wellbore fracture using a reservoir simulator, the method comprising: calculating closure stress data on the wellbore fracture; transforming the closure stress data into pore pressure data; and calculating a reduction in permeability of the wellbore fracture as a function of the pore pressure, thereby modeling the proppant damage effects on the wellbore.

According to a fifth aspect of the present invention, there is provided a method of completing a well by modeling proppant damage effects on a wellbore fracture using a reservoir simulator, the method comprising: uploading proppant damage behavior data into the reservoir simulator, the proppant damage behavior data comprising data reflecting a fracture closure stress versus fracture permeability relationship for a defined proppant type; using the reservoir simulator to: transform the fracture closure stress versus fracture permeability relationship into a pore pressure versus fracture permeability relationship; andcalculate a fracture permeability reduction factor using the pore pressure versus fracture permeability relationship; modeling growth of the wellbore fracture using a fracture simulator, thereby generating fracture characteristic data; communicating the fracture characteristic data to the reservoir simulator; modeling production of the wellbore using the reservoir simulator, the production model being based upon the fracture permeability reduction factor and the fracture characteristic data, thereby modeling the proppant damage effects on the wellbore; and utilizing the modeled proppant damage effects on the wellbore to select a proppant for use in the well completion and for designing a fracture treatment plan for the well.

According to a sixth aspect of the present invention, there is provided a method of developing a hydrocarbon field by modeling proppant damage effects on a wellbore fracture using a reservoir simulator, the method comprising: uploading proppant damage behavior data into the reservoir simulator, the proppant damage behavior data comprising data reflecting a fracture closure stress versus fracture permeability relationship for a defined proppant type; using the reservoir simulator to: transform the fracture closure stress versus fracture permeability relationship into a pore pressure versus fracture permeability relationship; and calculate a fracture permeability reduction factor using the pore pressure versus fracture permeability relationship; modeling growth of the wellbore fracture using a fracture simulator, thereby generating fracture characteristic data; communicating the fracture characteristic data to the reservoir simulator; modeling production of the wellbore using the reservoir simulator, the production model being based upon the fracture permeability reduction factor and the fracture characteristic data, thereby modeling the proppant damage effects on the wellbore; and utilizing the modeled proppant damage effects on the wellbore to select proppants for use in the field development and for designing fracture treatment plans for the wells drilled within the field development.