CASING WEAR ESTIMATION

BACKGROUND

[0001] In the drilling of wellbores for hydrocarbon exploration and production, a portion of the wellbore will be drilled and cased with a casing, and thereafter the length of wellbore will be extended by further drilling. During the further drilling, the drill string extends through and contacts the casing, which contact by the drill string may cause casing wear. Casing wear may be particularly pronounced in deviated portions of the wellbore (*i.e.*, those portions of the wellbore that are not vertically orientated). Although some casing wear is expected, excess casing wear can adversely affect both structural integrity of a wellbore as well as the casing's ability to withstand exposure to high pressures within the casing (*e.g.*, during hydraulic fracturing, and formation pressure).

[0002] As the length and geometrical complexity of wellbores increase with improved drilling technology, existing casing wear models cannot accurately predict casing wear.

SUMMARY

[0002a] According to a first aspect of the present invention, there is provided a method of determining a value indicative of aggregate casing wear in a drilling operation, the determining comprising: calculating a value indicative of static casing wear of the drilling operation, the static casing wear caused by interaction of a drill string against an inside diameter of a casing; calculating a value indicative of impact casing wear of the drilling operation, the impact casing wear caused by interaction of the drill string against the inside diameter of the casing; and combining the value indicative of static casing wear and the value indicative of impact casing wear to determine the value indicative of aggregate casing wear, wherein calculating the value indicative of impact casing wear comprises: selecting a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and calculating the value indicative of impact casing wear based on the selected model.

[0002b] According to a second aspect of the present invention, there is provided a system comprising: a processor; a memory coupled to the processor; the memory storing a program that, when executed by the processor, causes the processor to: calculate a value indicative of static casing wear for an interval of casing of a drilling operation, the static casing wear based on interaction of a drill string against an inside diameter of the interval of casing; calculate a value indicative of impact casing wear for

the interval of casing of the drilling operation, the impact casing wear based on interaction of the drill string against the inside diameter of the interval of casing; and combine the value indicative of static casing wear and the value indicative of impact casing wear to determine a value indicative of aggregate casing wear for the interval of casing, wherein when the program calculates the value indicative of impact casing wear, the program further causes the processor to: select a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and calculate the value indicative of impact casing wear based on the selected model.

[0002c] According to a third aspect of the present invention, there is provided a non-transitory computer-readable medium storing a program that, when executed by a processor, causes the processor to calculate a value indicative of static casing wear of a drilling operation, the static casing wear based on interaction of a drill string against an inside diameter of a casing; calculate a value indicative of impact casing wear of the drilling operation, the impact casing wear based on interaction of the drill string against the inside diameter of the casing; and combine the value indicative of static casing wear and the value indicative of impact casing wear to determine a value indicative of aggregate casing wear, wherein when the program calculates the value indicative of impact casing wear, the program further causes the processor to: select a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and calculate the value indicative of impact casing wear based on the selected model.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] For a detailed description of exemplary embodiments, reference will now be made to the accompanying drawings in which:

[0004] Figure 1 is a side elevation, partial cross-sectional, view that shows an operational environment in accordance with at least some embodiments;

[0005] Figure 2 is a side elevation, partial cross-sectional, view that shows another operational environment in accordance with at least some embodiments;

[0006] Figure 3A is a side elevation, partial cross-sectional, view that shows a view of drill string within a wellbore;

[0007] Figure 3B is a side elevation, partial cross-sectional, view that shows a view of drill string within a wellbore;

[0008] Figure 4 is a cross-sectional end elevation view of a wellbore that shows example static casing wear in accordance with at least some embodiments;

[0009] Figure 5 is a cross-sectional end elevation view of a wellbore that shows example parabolic casing wear in accordance with at least some embodiments;

CLAIMS

~~What is claimed is:~~

1. A method of determining a value indicative of aggregate casing wear in a drilling operation, the determining comprising:

calculating a value indicative of static casing wear of the drilling operation, the static casing wear caused by interaction of a drill string against an inside diameter of a casing;

calculating a value indicative of impact casing wear of the drilling operation, the impact casing wear caused by interaction of the drill string against the inside diameter of the casing; and

combining the value indicative of static casing wear and the value indicative of impact casing wear to determine the value indicative of aggregate casing wear,

wherein calculating the value indicative of impact casing wear comprises:

selecting a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and

calculating the value indicative of impact casing wear based on the selected model.

~~2. The method of claim 1 wherein calculating the value indicative of impact casing wear further comprises:~~

~~selecting a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and~~

~~calculating the value indicative of impact casing wear based on the selected model.~~

~~3~~2. The method of claim ~~2~~1 wherein selecting the model further comprises:

selecting a first model for use with respect to a first portion of the casing;

selecting a second model for use with respect to a second portion of the casing, the second model distinct from the first model, and the second portion of the casing at a different depth that the first portion of the casing.

~~4~~3. The method of claim ~~2~~1 wherein selecting the model further comprises:

selecting a first model which creates a first value; and

selecting a second model which creates a second value, the second model distinct from the first model;

wherein calculating the value indicative of impact casing wear further comprises combining the first and second values.

~~54~~. The method of claim ~~21~~ wherein selecting a model from the plurality of models further comprises selecting at least one from the group consisting of: a model based on a parabolic cross-sectional wear pattern; a model based on an elliptical cross-sectional wear pattern; a model based on a sinusoidal cross-sectional wear pattern; a model based on a pattern where a single wear peak is offset radially from a static wear peak.

~~65~~. The method of claim 1 ~~or 2~~ wherein calculating the value indicative of impact casing wear further comprises:

sensing vibration of a portion of the drill string based on sensors disposed within the drill string;

wherein calculating the value indicative of impact casing wear further comprises calculating the value indicative of impact casing wear based on the vibration sensed by the sensors.

~~76~~. The method of claim ~~65~~ wherein calculating the value indicative of impact casing wear further comprises at least one selected from the group consisting of: calculating based on an impact force sensed by the sensors; calculating a non-zero value indicative of impact casing wear in locations along the drill string where vibration is sensed; and calculating a zero value indicative of impact casing wear in locations along the drill string where no vibration is sensed.

~~87~~. The method of claims 1, ~~2,~~ or ~~65~~ further comprising changing a drilling parameter responsive to the value indicative of aggregate casing wear.

~~98~~. The method of claim ~~87~~ wherein changing the drilling parameter further comprises changing at least one selected from the group consisting of: weight-on-bit; rotational speed of the drill string; and a component of a bottomhole assembly.

~~10~~9. The method of claim 1, ~~2,~~ ~~6~~5, or ~~8~~7 further comprising:

removing the drill string from the casing;

measuring wall thickness of the casing using a wireline logging tool; and

adjusting a model used to calculate the value indicative of impact casing wear, the adjusting based on the wall thickness of the casing.

~~11~~10. The method of claim 1 ~~or 2~~ wherein calculating the values indicative of static casing wear and impact casing wear further comprises at least one selected from the group consisting of: calculating during planning of a wellbore prior to the drilling operation; and calculating during the drilling operation.

~~12~~11. A system comprising:

a processor;

a memory coupled to the processor;

the memory storing a program that, when executed by the processor, causes the processor to:

calculate a value indicative of static casing wear for an interval of casing of a drilling operation, the static casing wear based on interaction of a drill string against an inside diameter of the interval of casing;

calculate a value indicative of impact casing wear for the interval of casing of the drilling operation, the impact casing wear based on interaction of the drill string against the inside diameter of the interval of casing; and

combine the value indicative of static casing wear and the value indicative of impact casing wear to determine a value indicative of aggregate casing wear for the interval of casing,

wherein when the program calculates the value indicative of impact casing wear, the program further causes the processor to:

select a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and

calculate the value indicative of impact casing wear based on the selected model.

~~13~~12. The system of claim ~~12~~11 ~~further comprising~~:

wherein when the processor calculates the value indicative of static casing wear, the program causes the processor to calculate a plurality of values indicative static casing wear, each value at a respective ~~for the~~ interval of casing;

wherein when the processor calculates the value indicative of impact casing wear, the program causes the processor to calculate a plurality of values indicative impact casing wear, each value at a respective ~~for the~~ interval of casing; and

wherein when the processor combines, the program causes the processor to combine the values at respective for the interval of casing to generate a plurality of values indicative of aggregate casing wear, each value of aggregate casing wear at a respective ~~for the~~ interval of casing.

~~14. The system of claim 12 or 13 wherein when the program calculates the value indicative of impact casing wear, the program further causes the processor to:~~

~~select a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and~~

~~calculate the value indicative of impact casing wear based on the selected model.~~

~~15~~13. The system of claim ~~14~~12 wherein when the processor selects the model, the program further causes the processor to:

select a first model for use with respect to a first interval of casing;

select a second model for use with respect to a second interval of casing, the second model distinct from the first model, the second interval of casing at a different distance along the wellbore than the first interval of casing.

~~16~~14. The system of claim ~~14~~12 wherein when the processor selects the model, the program causes the processor to:

select a first model which creates a first value; and

select a second model which creates a second value, the second model distinct from the first model;

calculate the value indicative of impact casing wear further based on a combination of the first and second values.

~~17~~15. The system of claim ~~14~~12 wherein when the processor selects the model, the program causes the processor to select at least one from the group consisting of: a model based on a parabolic cross-sectional wear pattern; a model based on an elliptical cross-sectional wear pattern; a model based on a sinusoidal cross-sectional wear pattern; a model based on a pattern where a single wear peak is offset radially from a static wear peak.

~~18~~16. The system of any of claims ~~12-17~~11 to 15:

wherein when the processor calculates the value indicative of impact casing wear, the program further causes the processor to receive an indication of vibration of a portion of the drill string, the indication of vibration based on sensors disposed within the drill string; and

wherein when the processor calculates the value indicative of impact casing wear the program causes the processor to calculate the value indicative of impact casing wear based on the vibration sensed by the sensors.

~~19~~17. The system of any of claims ~~12-17~~11 to 15 wherein the program further causes the processor to perform at least one action selected from the group consisting of: change a drilling parameter during drilling, the change responsive to the value indicative of aggregate casing wear; change a parameter associated with a planned wellbore based on the value indicative of aggregate casing wear; and display on a display device during drilling the value indicative of aggregate casing wear.

~~20~~18. The system of any of claims ~~12-17~~11 to 15 wherein the program further causes the processor to:

receive an indication of casing wall thickness measured by a wireline logging tool; and

adjust a model used to calculate the value indicative of impact casing wear, the adjusting based on the wall thickness of the casing.

~~21~~19. The system of any of claims ~~12-17~~11 to 15 wherein when the processor calculates the values indicative of static casing wear and impact casing wear, the program causes the processor to at least one selected from the group consisting of:

calculate during planning of a wellbore prior to the drilling operation; and calculate during the drilling operation.

~~22~~20. A non-transitory computer-readable medium storing a program that, when executed by a processor, causes the processor to

calculate a value indicative of static casing wear of a drilling operation, the static casing wear based on interaction of a drill string against an inside diameter of a casing;

calculate a value indicative of impact casing wear of the drilling operation, the impact casing wear based on interaction of the drill string against the inside diameter of the casing; and

combine the value indicative of static casing wear and the value indicative of impact casing wear to determine a value indicative of aggregate casing wear,

wherein when the program calculates the value indicative of impact casing wear, the program further causes the processor to:

select a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and

calculate the value indicative of impact casing wear based on the selected model.

~~23~~21. The non-transitory computer-readable medium of claim ~~22~~20 further comprising:

wherein when the processor calculates the value indicative of static casing wear, the program causes the processor to calculate a plurality of values indicative static casing wear, each value at a respective distance along wellbore;

wherein when the processor calculates the value indicative of impact casing wear, the program causes the processor to calculate a plurality of values indicative impact casing wear, each value at a respective distance along wellbore; and

wherein when the processor combines, the program causes the processor to combine the values at respective distances along the wellbore to generate a plurality of values indicative of aggregate casing wear, each value of aggregate casing wear at a respective distance along the wellbore.

~~24. The non-transitory computer-readable medium of claim 22 or 23 wherein when the program calculates the value indicative of impact casing wear, the program further causes the processor to:~~

~~select a model from a plurality of models, each model based on a respective cross-sectional wear pattern, the selecting creates a selected model; and~~

~~calculate the value indicative of impact casing wear based on the selected model.~~

~~25~~22. The non-transitory computer-readable medium of claim ~~24~~20 wherein when the processor selects the model, the program further causes the processor to:

select a first model for use with respect to a first portion of the casing;

select a second model for use with respect to a second portion of the casing, the second model distinct from the first model, the second portion of the casing at a different distance along the wellbore than the first portion of the casing.

~~26~~23. The non-transitory computer-readable medium of claim ~~24~~20 wherein when the processor selects the model, the program causes the processor to:

select a first model which creates a first value; and

select a second model which creates a second value, the second model distinct from the first model;

calculate the value indicative of impact casing wear further based on a combination of the first and second values.

~~27~~24. The non-transitory computer-readable medium of claim ~~24~~20 wherein when the processor selects the model, the program causes the processor to select at least one from the group consisting of: a model based on a parabolic cross-sectional wear pattern; a model based on an elliptical cross-sectional wear pattern; a model based on a sinusoidal cross-sectional wear pattern; a model based on a pattern where a single wear peak is offset radially from a static wear peak.

~~28~~25. The non-transitory computer-readable medium of any of claims claim ~~22-27~~ 20 to 24:

wherein when the processor calculates the value indicative of impact casing wear, the program further causes the processor to receive an indication of vibration of

a portion of the drill string, the indication of vibration based on sensors disposed within the drill string; and

wherein when the processor calculates the value indicative of impact casing wear the program causes the processor to calculate the value indicative of impact casing wear based on the vibration sensed by the sensors.

~~29~~26. The non-transitory computer-readable medium of any of claims ~~22-28~~20 to 25 wherein the program further causes the processor to perform at least one action selected from the group consisting of: change a drilling parameter during drilling, the change responsive to the value indicative of aggregate casing wear; change a parameter associated with a planned wellbore based on the value indicative of aggregate casing wear; and display on a display device during drilling the value indicative of aggregate casing wear.

~~30~~27. The non-transitory computer-readable medium of any of claims ~~22-29~~20 to 26 wherein the program further causes the processor to:

receive an indication of casing wall thickness measured by a wireline logging tool; and

adjust a model used to calculate the value indicative of impact casing wear, the adjusting based on the wall thickness of the casing.

~~31~~28. The non-transitory computer-readable medium of any of claims ~~22-27~~20 to 24 wherein when the processor calculates the values indicative of static casing wear and impact casing wear, the program causes the processor to select at least one ~~selected~~ from the group consisting of: calculate during planning of a wellbore prior to the drilling operation; and calculate during the drilling operation.