CONDITION BASED MAINTENANCE PROGRAM BASED ON LIFE-STRESS ACCELERATION MODEL AND TIME-VARYING STRESS MODEL

TECHNICAL FIELD

The present disclosure generally relates to maintenance of downhole tools and, more particularly, to condition based maintenance programs for downhole tools based on a life-stress acceleration model and a time-varying stress model.

BACKGROUND

Oil and gas wells produce oil, gas and/or byproducts from subterranean petroleum reservoirs. Various systems are utilized to drill and then extract these hydrocarbons from the wells. Since the environmental conditions within such wells are typically comparatively harsh, with high temperatures, high pressures and corrosive fluids, it is important to be able to accurate predict the effects of the environment on these systems, particularly when the systems may be subject to repetitive usage, in order to identify the appropriate maintenance schedule for a particular system before the system experiences any operational degradation. Condition Based Maintenance (CBM) methodologies are utilized to evaluate systems in light of the foregoing. Life-stress acceleration models are at the heart of Condition Based Maintenance (CBM) algorithm calculation. The life-stress acceleration models are well-established in the area of Accelerated Life Testing (ALT) and are able to relate life of systems, such as downhole tools or components thereof, consumed at different stress levels. ALT involves testing of components at very high stress levels and at a time-constant stress. However, it may not be practical to test downhole systems at those very higher stress levels since stress levels at downhole conditions are already very harsh. Furthermore, additional time-consuming and expensive lab tests are necessary for ALT, which may not fit within the parameters of a particular hydrocarbon drilling and recovery operation.

SUMMARY

According to a first aspect of the present invention, there is provided a computer-implemented method for performing condition based maintenance of an operating tool, the method comprising: determining a plurality of model parameters corresponding to stress variables associated with the tool; determining, for each step in a series of steps of an operational run of the tool, a life measure based on the plurality of model parameters and measured values of the corresponding stress variables for that step in the series of steps; calculating one or more failure parameters related to operation of the tool during the operational run based on the life measure determined for each step in the series of steps, a time duration of each step, and a life duration of the tool at reference levels of the stress variables; and performing maintenance of the tool based on the one or more failure

parameters, wherein the one or more failure parameters comprise a failure distribution during a step in the series of steps; and the failure distribution is computed based on the life measure associated with the step in accordance with the combined Weibull General Log Linear (GLL) model.

According to a second aspect of the present invention, there is provided a system for performing condition based maintenance of an operating tool, the system comprising: at least one processor; and a memory coupled to the processor having instructions stored therein, which when executed by the processor, cause the processor to perform functions, including functions to: obtain, from the memory, a plurality of model parameters corresponding to stress variables associated with the tool; determine, for each step in a series of steps of an operational run of the tool, a life measure based on the plurality of model parameters and measured values of the corresponding stress variables for that step in the series of steps; calculate one or more failure parameters related to operation of the tool during the operational run based on the life measure determined for each step in the series of steps, a time duration of each step, and a life duration of the tool at reference levels of the stress variables; and generate a maintenance order for performing maintenance of the tool based on the one or more failure parameters, wherein the one or more failure parameters comprise a failure distribution during a step in the series of steps; and the failure distribution is computed based on the life measure associated with the step in accordance with the combined Weibull General Log Linear (GLL) model.

According to a third aspect of the present invention, there is provided a computer-readable storage medium having instructions stored therein, which when executed by a computer cause the computer to perform a plurality of functions, including functions to: determine a plurality of model parameters corresponding to stress variables associated with the tool; determine, for each step in a series of steps of an operational run of the tool, a life measure based on the plurality of model parameters and measured values of the corresponding stress variables for that step in the series of steps; calculate one or more failure parameters related to operation of the tool during the operational run based on the life measure determined for each step in the series of steps, a time duration of each step, and a life duration of the tool at reference levels of the stress variables; and generate a maintenance order for performing maintenance of the tool based on the one or more failure parameters, wherein the one or more failure parameters comprise a failure distribution during a step in the series of steps; and the failure distribution is computed based on the life measure associated with the step in accordance with the combined Weibull General Log Linear (GLL) model.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the present disclosure will be understood more fully from the detailed description given below and from the accompanying drawings of various

CLAIMS

1. A computer-implemented method for performing condition based maintenance of an operating tool, the method comprising:

determining a plurality of model parameters corresponding to stress variables associated with the tool;

determining, for each step in a series of steps of an operational run of the tool, a life measure based on the plurality of model parameters and measured values of the corresponding stress variables for that step in the series of steps;

calculating one or more failure parameters related to operation of the tool during the operational run based on the life measure determined for each step in the series of steps, a time duration of each step, and a life duration of the tool at reference levels of the stress variables; and

performing maintenance of the tool based on the one or more failure parameters,

wherein the one or more failure parameters comprise a failure distribution during a step in the series of steps; and

the failure distribution is computed based on the life measure associated with the step in accordance with the combined Weibull General Log Linear (GLL) model.

2. The method of claim 1, wherein determining the plurality of model parameters comprises:

determining the plurality of model parameters based on data associated with failure times of the tool, suspension times of the tool, and levels of the stress variables throughout an operational life of the tool.

3. The method of claim 1, wherein determining the plurality of model parameters comprises:

determining values that maximize a log likelihood function of a probability density function (PDF) of a failure distribution, and wherein the failure distribution is computed based on levels of the stress variables within each step in the series of steps.

4. The method of claim 1, wherein determining the plurality of model parameters comprises:

estimating the plurality of model parameters based on at least one of domain knowledge of the tool, comparison with one or more other tools, or manufacturer's data associated with the tool.

5. The method of claim 1, further comprising:

adjusting the plurality of model parameters based on the one or more failure parameters, and failure rates of the tool.

6. The method of claim 1, wherein the life measure for each step in the series of steps of the operational run of the tool is determined using the General Log Linear (GLL) model comprising the plurality of model parameters and the measured values of the corresponding stress variables for that step.

7. The method of claim 1, wherein:

the one or more failure parameters comprise a remaining useful life (RUL) parameter associated with the tool; and

the RUL parameter is calculated based on the life duration of the tool at the reference levels of the stress variables and a proportion of life of the tool consumed over the operational run.

8. The method of claim 7, wherein:

the proportion of life of the tool consumed over the operational run is computed by summing, for all steps in the series of steps of the operational run, ratios of the time duration and the life measure for each step in the series of steps.

9. The method of claim 8, wherein the one or more failure parameters further comprise equivalent hours computed as a product of the life duration of the tool at the reference levels of the stress variables and the proportion of life of the tool consumed over the operational run.

10. A system for performing condition based maintenance of an operating tool, the system comprising:

at least one processor; and

a memory coupled to the processor having instructions stored therein, which when executed by the processor, cause the processor to perform functions, including functions to:

obtain, from the memory, a plurality of model parameters corresponding to stress variables associated with the tool;

determine, for each step in a series of steps of an operational run of the tool, a life measure based on the plurality of model parameters and measured values of the corresponding stress variables for that step in the series of steps;

calculate one or more failure parameters related to operation of the tool during the operational run based on the life measure determined for each step in the series of steps, a time duration of each step, and a life duration of the tool at reference levels of the stress variables; and

generate a maintenance order for performing maintenance of the tool based on the one or more failure parameters,

wherein the one or more failure parameters comprise a failure distribution during a step in the series of steps; and

the failure distribution is computed based on the life measure associated with the step in accordance with the combined Weibull General Log Linear (GLL) model.

11. The system of claim 10, wherein the functions performed by the processor include functions to:

obtain, from the memory, the plurality of model parameters determined based on data associated with failure times of the tool, suspension times of the tool, and levels of the stress variables throughout an operational life of the tool.

12. The system of claim 10, wherein the functions performed by the processor include functions to:

obtain, from the memory, the plurality of model parameters determined as values that maximize a log likelihood function of a probability density function (PDF) of a failure distribution, and wherein the failure distribution is computed based on levels of the stress variables within each step in the series of steps.

13. The system of claim 10, wherein the functions performed by the processor include functions to:

obtain, from the memory, the plurality of model parameters estimated based on at least one of domain knowledge of the tool, comparison with one or more other tools, or manufacturer's data associated with the tool.

14. The system of claim 10, wherein the functions performed by the processor include functions to:

adjust the plurality of model parameters based on the one or more failure parameters, and failure rates of the tool.

15. The system of claim 10, wherein the life measure for each step in the series of steps of the operational run of the tool is determined using the General Log Linear (GLL) model comprising the plurality of model parameters and the measured values of the corresponding stress variables for that step.

16. The system of claim 10, wherein:

the one or more failure parameters comprise a remaining useful life (RUL) parameter associated with the tool; and

the RUL parameter is calculated based on the life duration of the tool at the reference levels of the stress variables and a proportion of life of the tool consumed over the operational run.

17. The system of claim 16, wherein:

the proportion of life of the tool consumed over the operational run is computed by summing, for all steps in the series of steps of the operational run, ratios of the time duration and the life measure for each step in the series of steps.

18. The system of claim 17, wherein the one or more failure parameters further comprise equivalent hours computed as a product of the life duration of the tool at the reference levels of the stress variables and the proportion of life of the tool consumed over the operational run.

19. A computer-readable storage medium having instructions stored therein, which when executed by a computer cause the computer to perform a plurality of functions, including functions to:

determine a plurality of model parameters corresponding to stress variables associated with the tool;

determine, for each step in a series of steps of an operational run of the tool, a life measure based on the plurality of model parameters and measured values of the corresponding stress variables for that step in the series of steps;

calculate one or more failure parameters related to operation of the tool during the operational run based on the life measure determined for each step in the series of steps, a time duration of each step, and a life duration of the tool at reference levels of the stress variables; and

generate a maintenance order for performing maintenance of the tool based on the one or more failure parameters,

wherein the one or more failure parameters comprise a failure distribution during a step in the series of steps; and

the failure distribution is computed based on the life measure associated with the step in accordance with the combined Weibull General Log Linear (GLL) model.

20. The computer-readable storage medium of claim 19, wherein the instructions further perform functions to:

determine values that maximize a log likelihood function of a probability density function (PDF) of a failure distribution, and wherein the failure distribution is computed based on levels of the stress variables varying for each step in the series of steps.