InSite® for Well Intervention Coiled Tubing Job Design and Data Acquisition

Enables Coiled Tubing job design, data acquisition, and remote viewing of real-time data

**Introduction**

Halliburton has recently expanded its software suite to carry out Coiled Tubing design and real-time data acquisition calculations. InSite® for Well Intervention software system has been designed, using Halliburton's own Coiled Tubing experience and testing to produce a tool superior to any available commercially for this application.

Since this new software is built upon the InSite platform used throughout the different Halliburton product lines, Halliburton can make full use of the InSite Anywhere® system for remote viewing of the real-time data gathered during higher profile operations. This data can then be viewed from any Internet-connected device, including some smart phones to enable key personnel to watch and make decisions in real-time without actually being on location.

**Coiled Tubing Job Design using InSite® for Well Intervention**

With wells becoming deeper, more highly deviated, and overall more complex, the need for accurate Coiled Tubing design and analysis is becoming more critical. Hydraulics and mechanical forces can now be analyzed in greater detail prior to any operation to help ensure the likelihood of a successful job.

**Forces and Stresses**

The InSite® for Well Intervention Design Forces Module is used to model Coiled Tubing deployment, with or without tools, into and out of a well, using an accurate representation of the wellbore.

The program analyzes the cumulative forces acting at a particular stage of the job and determines whether the target depth can be reached, specified tasks performed, and equipment retrieved to surface. This module can be used to simulate any Coiled Tubing operation such as:

- Logging (open-hole and cased-hole)
- Perforating
- Fishing
- Drilling
- Extended-reach applications
- High-pressure applications
The following screenshots show example outputs that can be obtained very quickly to enable analysis of the forces present during a Coiled Tubing operation.

**Multiple Case Comparisons**

An advanced feature of the InSite® for Well Intervention design analysis is the ability to compare several different cases easily during a single design. For instance, to find out which Coiled Tubing string is most suitable for a particular application, the types of tubing can be compared on the one output graph, enabling decisions to be made quickly and easily. These comparisons can be made based on any input parameter. The following screenshots show an example of different string comparisons for a single well.

**Coiled Tubing and Well Hydraulics**

InSite® for Well Intervention has the capability of accurately modeling fluid hydraulics in the Coiled Tubing and wellbore. Fluid flow is influenced by several conditions (including string and wellbore geometry, fluid properties, pump rate, measured depth, choke pressure, and reservoir properties), and slight changes may have minimal or dramatic impacts on the potential success of a job.

The hydraulics simulations in InSite® for Well Intervention use the Halliburton Material Library database and calculations, which are based on empirical data gathered from Halliburton's great wealth of drilling fluids, cementing, stimulation, and fracturing experience. Extensive testing, using fluids and proppants in Coiled Tubing, have also been done to complement this experience.

Advanced energy-balancing calculations in the model includes frictional heating due to fluid flow, heat transfer between formation and wellbore, heat transfer between annulus and tubing, and heat transfer within the tubing and annulus along the direction of flow. Fluids are tracked as they move through the system with pressures and temperature being calculated and displayed throughout the wellbore.
The InSite® for Well Intervention hydraulics design module combines hydraulic calculations with a powerful graphical interface to enable the user to predict flow rates and pressures at any stage of a Coiled Tubing job. As with the forces model, comparisons can be made, using different parameters (e.g., different pump rates or Coiled Tubing strings) in a single job to enable quick and clear decisions to be made.

The following screenshot shows an example of some of the hydraulics output that can be obtained quickly with a single mouse click.

The output parameters can also be expressed in a Depth Based plot to observe the downhole parameters during the proposed operation as shown below.

Stage Table Design

Another advanced feature of the InSite® for Well Intervention design software is the ability to add the dimension of time. This feature enables hydraulics and mechanics for a complete job to be calculated simultaneously with any parameter charted against time. Using the feature, you can see maximum Coiled Tubing stresses (on surface and downhole) during the entire operation. This can be done more accurately as the hydraulics change throughout the job as defined by the user inputs. Pressures can be predicted at any location (such as the choke or well reservoir) throughout the job and input data adjusted to optimize the job performance. Volumes and times for different operations are calculated automatically to aid job planning.
Real-Time Data Acquisition and Calculations

One of the most important features of any Coiled Tubing data acquisition software is the ability to track fatigue and monitor stresses in the Coiled Tubing during an actual job. This feature is important to help ensure that no failures occur during an operation.

Fatigue Prediction and Monitoring

Halliburton has developed a comprehensive String Management System. This system incorporates software and real-time Data Acquisition for fatigue monitoring and Life Prediction. In addition, the String Management System includes processes for keeping track of the remaining life of each string, inspection and spooling processes, and procedures for storing Coiled Tubing strings.

Halliburton’s InSite® for Well Intervention software package uses our proprietary fatigue model developed from extensive empirical data compiled by Vladimir Avakov. The Design Module of InSite® for Well Intervention can be used as a modeling tool to predict fatigue for Coiled Tubing string design. The simulator features an Analyzer to compare multiple cases and optimize the material, diameter, and wall thickness(es) of the string. To calculate the fatigue, the job is run in the Stage Table, and then pre- and post-job fatigue can be compared. The program can accept various inputs in the Stage Table without permanently altering critical fatigue data. When used in real-time, fatigue accumulation is calculated as the job progresses.

Features of the Fatigue Calculator/Simulator include:

- Calculates which segments along the string undergo bending events.
- Calculates the changes to the bending radius at the reel as the Coiled Tubing is run into and out of the well.
- Displays the used life along the string as it accumulates.
- Creates a permanent and ongoing record of fatigue damage to a CT string.

Using the InSite® for Well Intervention fatigue-analysis software, the remaining life of the string and welds can be predicted. Prejob simulations of the planned work including contingencies can be simulated and life-used peaks predicted.

The following graphic shows the output from the real-time InSite® for Well Intervention Fatigue Viewer. Note that the fatigue accumulated during the current operation is clearly visible (in red) against the previous fatigue.

The previous graphic shows the percentage of used life. The upper display gives a graphical interpretation of the string itself, where the taper occurs noted as a change in ID and where welds occur, indicated by different colored lines to represent the different types of welds.

Extensive testing and field evaluations have proven the consistency and reliability of Halliburton's fatigue life model. Halliburton takes a conservative approach to tubing life and retire our strings before ovality becomes a concern. Whereby others in the industry utilize tubing ovality as a major factor in their string retirement criteria, Halliburton’s fatigue life model takes into account several more factors. These include job exposure type (acid, H₂S, CO₂, etc.), internal and external pressures, and the number of cycles.

For more information on how Halliburton calculates fatigue, refer to the following papers:

- OTC 7325 - Coiled Tubing Life Prediction (1993)
- SPE 38407 - Large Coiled Tubing Fatigue Life (1997)
Real-Time Calculations
Throughout any Coiled Tubing operation, stresses can be calculated and monitored at multiple positions to help ensure different types, and locations of failure can be predicted and, therefore, possibly avoided.

Surface Stresses
Using measured values of pressures and loads on the surface, stresses are calculated at four key locations of the Coiled Tubing surface setup. These values are shown in real-time on a chart to give the operator a visual warning of when high stresses are being encountered. The following graphic shows an example of the graphical means of tracking surface stresses in the Coiled Tubing during an operation.

Downhole Calculations
As well as calculating surface stresses in the Coiled Tubing, InSite® for Well Intervention also can calculate downhole stresses along with various other parameters, which can be graphed in real-time as the job progresses. These calculations are made by using known values of pressure and depth combined with given variables such as fluid weights and volumes to provide the operator with a greater knowledge of well activity. This enhanced knowledge can help the operator make job changes.

The following charts show some of the downhole calculation possibilities and also demonstrates the real-time fluid-tracking ability (represented by different colors) in the wellbore.

For more information on how Halliburton calculates tubing limits and stresses, refer to the following papers:
- SPE 46004 - Collapse Data Analysis and Coiled Tubing Limits (1998)
Operator Display

To simplify all available data for the Coiled Tubing operator, Halliburton has developed a very powerful operator display that summarizes all important data onto one easy-to-read graphical interface, as shown in the following screenshot. This display is completely customizable.

The main features that have been developed for the operator display include the following:

- Fully dynamic limits bands on the edges of the gauges. Note the red and green bands on the gauges, which provides notification to the operator to keep the parameters within the green areas to help ensure no risk of failures.

- An advanced warning screen. Warnings appear for the following scenarios:
  - If stresses on the Coiled Tubing string (on surface or downhole) are approaching limits
  - When welds or high fatigue areas are approaching the level wind or injector
  - As the BHA approaches the surface or any changes in downhole wellbore geometry
  - Fluid totalizers are customizable to handle multiple fluids.

Advanced Design Calculations

Halliburton is currently developing InSite® for Well Intervention to have the ability of carrying out job design calculations for common job types such as sand cleanout and nitrogen lifting.

This new feature will also incorporate Halliburton’s proprietary CoilSweep™ and Hydra-Blast™ specialist tools. The following example shows a safe operational envelope that has been calculated to assist the engineer and operator while performing a sand cleanout with Coiled Tubing.

Friction Matching

To optimize future operations, we can learn a lot from previous operations. When a job is designed, certain parameters must be estimated. One significant parameter, particularly in deviated wellbores, is the friction coefficient between the Coiled Tubing and the wall of the wellbore. This value has the most influence on how far we can push Coiled Tubing along an extended reach well. Factors such as condition of the wellbore tubulars, type of wellbore section (open hole, slotted liners, etc.), fluid type in the well, etc. affect this number and can make significant differences to a job design.

When working on a series of similar wells, we can look back at previous operations to verify the validity of all the assumptions made on past operations by fine tuning the design until they closely match the actual job field data. These calculated values of friction can then be applied to any subsequent operations helping ensure that our job designs have the best chance of success and the most suitable equipment to carry them out is on location from the start.
The following graph is an example of post job friction matching; the software also has the capability of calculating friction matching in real-time while the operation is being carried out.

ACE™ Equipment on FLECS™ Control System

The ACE™ (Automatic Controlled Equipment) operating system installed on the FLECS™ (Flexible Electronic Control System) hardware gives the operator a control system with built-in safety features and Ethernet connectivity. The ACE operating system is the same platform used to control other Halliburton equipment such as pumps and blenders, giving uniform functionality on location.

All of the critical Coiled Tubing operational information is on display at the same time, which can be configured and set using keyboard, mouse, or a touchscreen interface.

The safety features included with this control system are as follows:

- **Basic Controls**
  - Stops injector, based on tag, overpull, weight or speed limits

- **Advanced Controls**
  - Improved limit system
    - “Soft” stop ramps down injector speed at higher speeds, avoiding equipment damage
  - Automatic chain lube system
  - Tubing slip detection
  - Chain life (stretch) indication system

For more information, contact your Halliburton representative or email us at production-solutions@halliburton.com.

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