Software Development for Real-time Drilling Data Analysis by Retrieving Data from a Remote Server

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ABSTRACT

A software has been developed to visualize the real-time drilling data by capturing data from a remote rig server using WITSML API functions. The WITSML is a set of data objects, defined in XML, to support drilling workflows. Using this software, the user can view the dynamic real-time data updated from the remote server, as well as, analyze the data dynamically using different modules for optimization and improve decision-making on ongoing drilling operations. Two real-time modules, pressure analysis and bit-wear estimation, are currently incorporated in the software to analyze the captured real-time data dynamically. The software has been successfully verified using a test server. The available test server provides the required data and parameters for the modules. For testing, a virtual 'well' has been created to verify the functionality of the modules. The software is currently ready for field testing.

Keywords: Real-time Data, WITSML API Function, Network Protocol, Data Analysis Module, Test Server.

1. INTRODUCTION

The increasing complexity of oil and gas drilling operations as well as increasing drilling costs has increased the efforts on research and development of gathering and analyzing real-time drilling data. Most current applications of real time analysis while drilling has been focused on the capture of real time data on the rig while drilling and remotely display the data at multiple location like onshore drilling centers or at the individual drilling engineers desktop. The objective of these newly developed real-time engineering tools is to utilize this data to improve the decision making in the complex drilling operation and thereby increase drilling efficiency and safety. To fulfill this goal a software was developed which provides a way for drilling engineers in an office environment to visualize drilling operational data in real-time and obtain real-time analyses based on the same data.

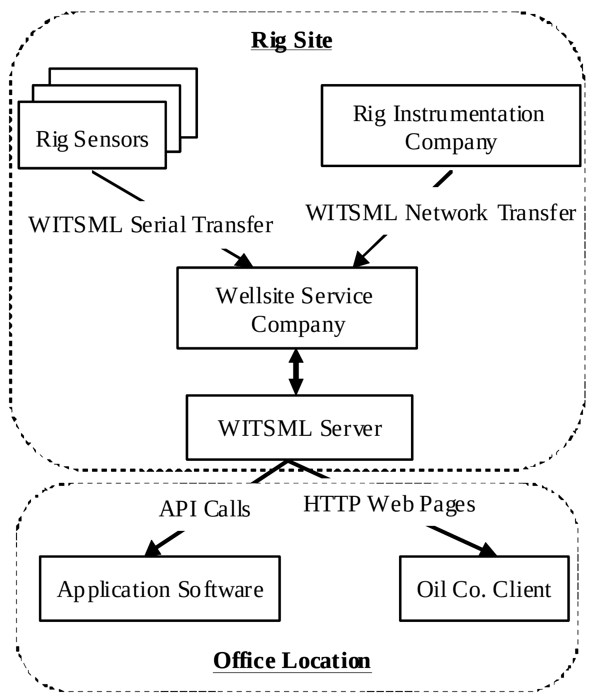

Fig. 1 Potential Scenarios between Rig Site and Clients

Figure 1 shows the potential scenarios [1] between rig site server and the clients in an office location. The data transformation network between server and client by API (Application Program Interface) calls has been used in the development of the new application software. In server/client mode, the Well site Information Transfer Standard Markup Language (WITSML) data objects are pulled on-demand by a client from a server. The client makes a request to the server, and the server responds with an acknowledgement or an error code. The client can add, update, delete and retrieve WITSML data objects on the server. The client/server uses the SOAP protocol to transport the requests/responses between client and server. The client/server API is also known as the STORE interface [2].

The software through WITSML STORE API functions retrieves well site information in XML document format from any well site data contributor, rig instrumentation, directional drilling company or mud-logger company. Using this software, the user can view the dynamic real time data updated from the remote server at user specific interval varying from seconds to hours. The software can then be used to analyze the data dynamically using different modules for optimization and improve decision-making to ongoing drilling operations. For the analysis, the user can choose one or more drilling evaluation modules.

2. MODULES FOR REAL-TIME DRILLING EVALUATION SOFTWARE

Currently two modules, pressure analysis and bit-wear estimation, are included in this real-time drilling evaluation software. The pressure analysis module dynamically calculates the individual and total frictional pressure losses (Standpipe Pressure) in the drilling circulating system using four different rheological models, generally used by drilling engineers, to troubleshoot operations, evaluate fluid behavior or to optimize the drilling hydraulics. The user can view both numerical and graphical results compared to the field measured values. The schematic diagram of a drilling circulating system is shown in Figure 2.

Mathematical Model of Pressure Analysis

The four rheological models [3], used in the software to calculate the drilling fluid pressure losses are, Newtonian model, Bingham Plastic model, Power Law model and API Power Law model. As an example, pressure loss calculations using API Power Law model is shown below:

Total frictional pressure loss or stand pipe pressure (*SPP*) is,

$$P_{Pump} = \Delta P_{DP} + \Delta P_{DP/Ann} + \Delta P_{DC} + \Delta P_{DC/Ann} + \Delta P_{Nozz} \quad (1)$$

Where:

ΔP_{DP}, Pressure drop in drill pipe

ΔP_{DC}, Pressure drop in drill collar

$\Delta P_{DP/Ann}$, Pressure drop in annulus between drill pipe and hole wall

$\Delta P_{DC/Ann}$, Pressure drop in annulus between drill collar and hole wall

ΔP_{Nozz}, Pressure drop across the bit nozzles

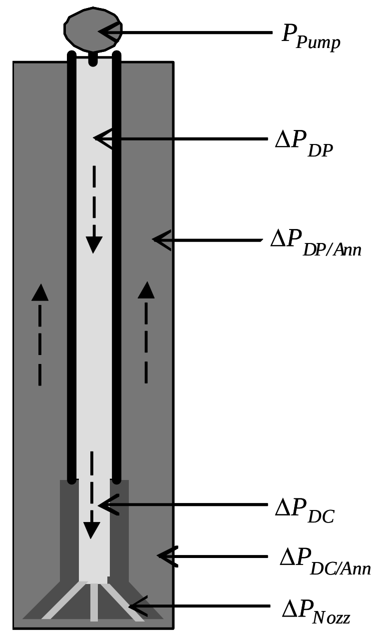

Fig. 2 Schematic Diagram of a Drilling Circulating System

Pressure drop in drill pipe: Average velocity in pipe is,

$$V_P = Q/\left(2.448\,D^2\right) \quad (2)$$

Where:

Q, Fluid flow rate

D, Inner diameter of pipe

Power law constant (n) is,

$$n_p = 3.32\log\left(R_{600}/R_{300}\right) \quad (3)$$

Where:

R_{600}, Rotational viscometer readings at 600 RPM

R_{300}, Rotational viscometer readings at 300 RPM

Fluid consistency index (K) is,

$$K_p = \frac{5.11\,R_{600}}{1022^{n_p}} \quad (4)$$

Effective viscosity in pipe (μ) is,

$$\mu_{ep} = 100\,K_p\left(\frac{96\,V_p}{D}\right)^{n_p-1}\left(\frac{3n_p+1}{4n_p}\right)^{n_p} \quad (5)$$

Reynolds number in pipe (N_{Re}) is,

$$N_{\mathrm{Re}\,p} = \left(928\,D\rho V_p\right)/\mu_{ep} \quad (6)$$

Friction pressure gradient in pipe is,

$$\left(dP/dL\right)_{dp} = \left(f_p V_P^2 \rho\right) / \left(25.8\, D\right) \quad (7)$$

Where:

f_p, Friction factor in pipe

Pressure drop in drill pipe is,

$$\Delta P_{DP} = \left(\frac{dP}{dL}\right)_{dP} \Delta L_{dP} \quad (8)$$

Where:

ΔL_{dP}, Length of drill pipe.

Pressure drop in drill collar: Average velocity (V_{dc}), Effective viscosity (μ_{edc}), Reynolds number (N_{Redc}) and Friction pressure gradient $\left(dP/dL\right)_{dc}$ in drill collars are calculated by using Eq. (2), Eq. (5), Eq. (6) and Eq. (7), respectively. Here, D is the inner diameter of drill collar.

Pressure drop in drill collar is,

$$\Delta P_{DC} = \left(\frac{dP}{dL}\right)_{dc} \Delta L_{dc} \quad (9)$$

Where:

ΔL_{dP}, Length of drill collar.

Pressure drop in drill pipe (DP)/Hole annulus: Average velocity in DP/Hole annulus (V_{dpa}) is,

$$V_{dpa} = \frac{Q}{2.448\left(D_2^2 - D_1^2\right)} \quad (10)$$

Where:

D_1, Outer diameter of drill pipe

D_2, Diameter of hole wall

Power law constant (n) is,

$$n_{dpa} = 0.657 \log\left(R_{100} / R_3\right) \quad (11)$$

Where:

R_{100}, Rotational viscometer readings at 100 RPM

R_3, Rotational viscometer readings at 3 RPM

Fluid consistency index (K) is,

$$K_{dpa} = \frac{5.11\, R_{100}}{170.2^{n_{dpa}}} \quad (12)$$

Effective viscosity (μ) is,

$$\mu_{edpa} = 100\, K_{dpa} \left(\frac{144\, V_{dpa}}{D_2 - D_1}\right)^{n_{dpa}-1} \left(\frac{2n_{dpa}+1}{3n_{dpa}}\right)^{n_p} \quad (13)$$

Reynolds number (N_{Re}) is,

$$N_{\mathrm{Re}\,dpa} = \frac{928\left(D_2 - D_1\right)\rho V_{dpa}}{\mu_{edpa}} \quad (14)$$

Friction pressure gradient is,

$$\left(dP/dL\right)_{dpa} = \left(f_{dpa} V_{dpa}^2 \rho\right) / \left(25.8\left(D_2 - D_1\right)\right) \quad (15)$$

Pressure drop in drill pipe/hole annulus,

$$\Delta P_{DP/Ann} = \left(\frac{dP}{dL}\right)_{dpa} \Delta L_{dP} \quad (16)$$

Where:

ΔL_{dP}, Length of drill pipe.

Pressure drop in drill collar (DC)/Hole annulus: Average velocity (V_{dca}),Effective viscosity (μ_{edca}), Reynolds number (N_{Redca}) and Friction pressure gradient $\left(dP/dL\right)_{dca}$ in drill collar/hole annulus are calculated by using Eq. (10), Eq. (13), Eq. (14) and Eq. (15), respectively. Here, D_1 is the outer diameter of drill collar.

Pressure drop in drill collar/hole annulus,

$$\Delta P_{DC/Ann} = \left(\frac{dP}{dL}\right)_{dca} \Delta L_{dc} \quad (17)$$

Where:

ΔL_{dc}, Length of drill collar.

Pressure drop across the bit nozzles: The expression is,

$$\Delta P_{Nozz} = \frac{156\, \rho\, Q^2}{\left(D_{Nn}^2\right)^2}; \quad n = 1, 2, 3, \ldots.. \quad (18)$$

Where:

D_{Nn}, Diameter of nozzles.

Similarly, another module dynamically updates and calculates the drill bit wear while the bit is still in the wellbore. A real-time bit wear optimization method [4], [5] has been used to estimate the real drill bit wear. Additional critical modules are under development to ensure a more successful optimization and safe drilling operation.

3. NETWORK PROTOCOL AND PROGRAM FLOW CHART

A test server has been used to verify the software. For testing, a virtual well has been created to verify the functionalities of the modules. The WITSML STORE API functions are used to store field data into the virtual well and then to retrieve the required data from the store server to analyze the drilling data in different modules using the SOAP protocol with call-type of Remote Procedure Call (RPC).

There are seven STORE interface functions to perform data transformation between Client and server. These functions are prefixed by ‘WMLS’ – a contraction of ‘WITSML Store’. The STORE API functions are:

WMLS_AddToStore – Add one new object to the server.

WMLS_DeleteFromStore – Delete one existing object from the server.

WMLS_GetBaseMsg - Get the fixed 'base' description of a return value.
WMLS_GetCap - Get the server's Capabilities object.
WMLS_GetFromStore - Get one or more objects from the server.
WMLS_GetVersion - Retrieves the data version(s) that are supported.
WMLS_UpdateInStore - Update one existing object on the server.

The basic network protocol, used in the software for the test server, is shown in Figure 3.

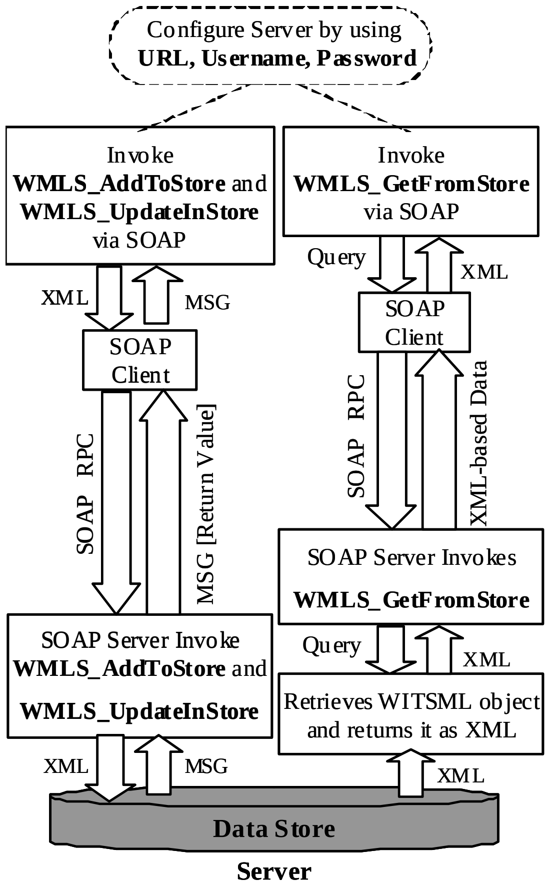

Fig. 3 Network Protocol for Test Server

According to Figure 3, XML-based data is stored in the test server using interface functions WMLS_AddToStore and WMLS_UpdateInStore and retrieves the data, in XML format, from the server using WMLS_GetFromStore interface function.

The program flow chart with the calculation routine of pressure analysis, as an example, is shown in figure 4.The steps inside the dotted area in Figure 4, are done repeatedly for calculating the pressure drop in drill pipe, drill collar, annulus between drill pipe and hole wall, annulus between drill collar and hole wall. Both Network Protocol (Figure 3) and Program Flow Chart (Figure 4) are used to retrieve and then analyze data for each module. The program flow chart of pressure analysis module is shown, as an example.

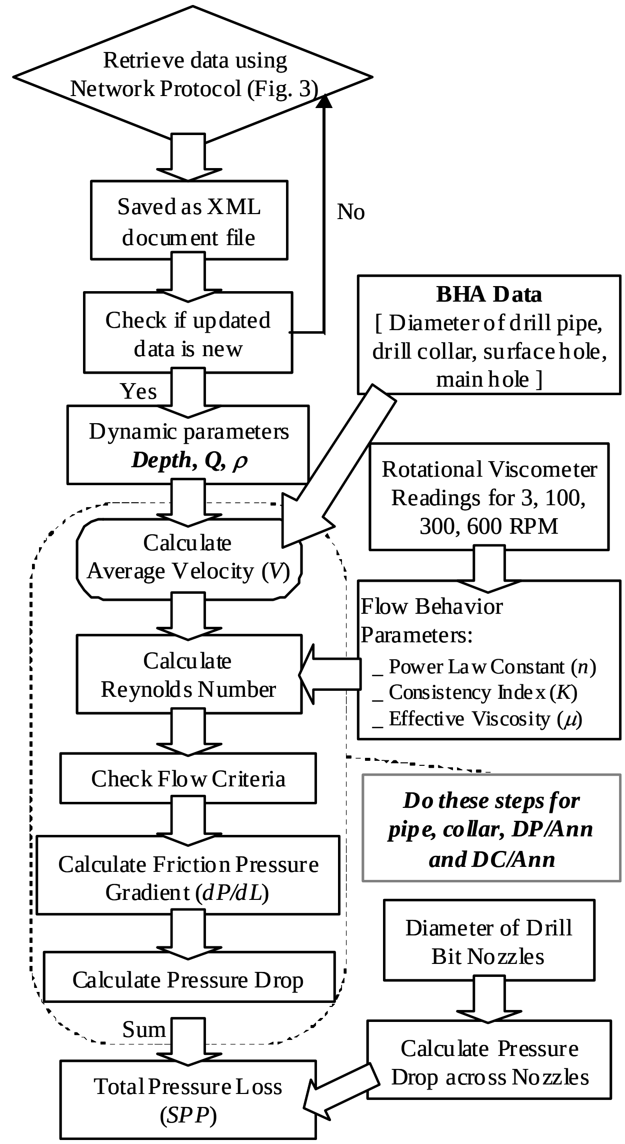

Fig. 4 Program Flow Chart with Calculation Routine

4. SYSTEM REQUIREMENTS

The basic system requirements for this software are as follows.

Supported Operating Systems
Windows 2000 Professional Edition
Windows Server 2003
Windows XP Home Edition, Professional Edition
Windows XP Service Pack 1, Service pack 2

Memory Requirements
PC with Pentium 400 MHz or faster processor. Pentium 800 MHz or faster is recommended.

96 MB of RAM. 256 or higher is recommended.

Other Requirements

Microsoft .NET Framework version 2.0 or later. Free download is available in Microsoft Download Center. The **Microsoft .NET Framework** is a software technology that is available with several Microsoft Windows operating systems such as, Windows XP, Windows Server 2003. It includes a large library of pre-coded solutions to common programming problems. The pre-coded solutions that form the framework's Base Class Library cover a large range of programming needs in a number of areas, including user interface, data access, database connectivity, web application development, numeric algorithms, and network communications.

Microsoft **WSE** (Web Service Enhancements) version 3.0. Free download is available in Microsoft Download Center. WSE 3.0 for Microsoft .NET is an add-on to Microsoft Visual Studio 2005 and the Microsoft .NET Framework 2.0 that enables developers to build secure Web services based on the latest Web services protocol specifications.

Microsoft Visual Studio 2005 or later (optional) is an **integrated development environment** (**IDE**). It is a software application that provides comprehensive facilities to computer programmers for software development. An IDE normally consists of a source code editor, a compiler, build automation tools, and (usually) a debugger.

5. RESULTS

The software has been tested with data from previously drilled wells. The data has been taken from an industry 'DataHub' for testing the pressure analysis module of the software. The industry data, in XML format, is used to compute the friction pressure loss (Stand Pipe Pressure - SPP) using the four rheological models following the network protocol and the flow chart, shown in Figure 3 and Figure 4, respectively. The software delivers the graphical and numerical representations of input data and the corresponding computed results, dynamically, in every user-defined time intervals.

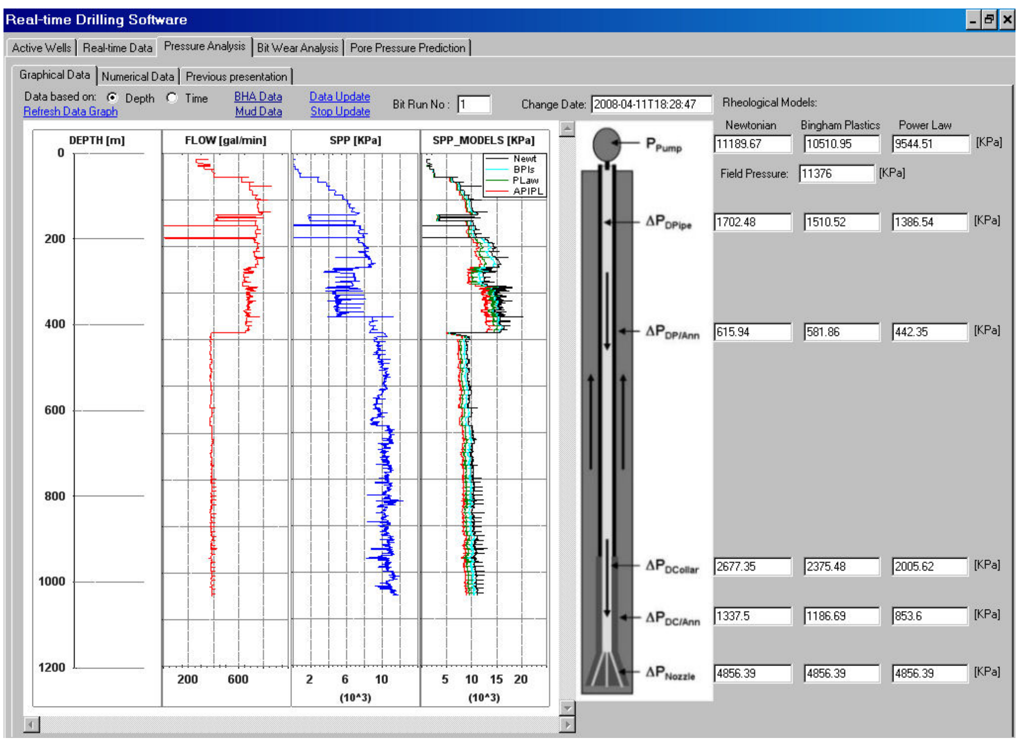

Fig. 5 Input and Output Data Presentations in Pressure Analysis Module

Figure 5 shows the graphical presentation of input data and computed output results of pressure analysis module using actual drilling data. Currently, the interface shows five tab pages at the top. Among them, the first tab page, named as 'Active Wells', shows the operational wells in the server from where the client can retrieve real-time data. The second tab page, named as 'Real-time Data' shows the updated real-time data of different variables, of the specified well, in each user-defined time interval. The third tab page is 'Pressure Analysis' module. The 'Graphical Data' of pressure analysis module is now displayed as shown in Figure 5. This figure shows the data, based on 'Depth'. The user can view the data based on 'Time' by selecting the 'Time' on the interface. There are four charts in this figure. The first three charts shows how the drilling data got from the remote server. The fourth chart shows the computed SPP in four rheological models that can be compared with field SPP data of chart three. Using this module, the drilling engineers will be able to compare the field SPP data with the corresponding analytical models and it will help them to troubleshoot operations or to optimize the drilling hydraulics. The 'Numerical Data' page of the present module shows the numeric values of all input data and also the corresponding output data.

Similarly, the fourth tab page, named as 'Bit Wear Analysis', displays the input data required to evaluate the estimated bit wear and the corresponding results dynamically.

6. CONCLUSIONS

This article presents a new real-time drilling data evaluation engineering tool or software to improve the decision making in the complex drilling operation and thereby increase drilling efficiency and safety. It dynamically retrieves data from the remote server by WITSML API functions via the SOAP XML-based protocol and at the same time analyzes the data in different modules using the retrieved real-time data.

The software has been successfully verified by using a test server. The available test server provides some required data and parameters for the modules. For testing, a virtual 'well' was created with actual well drilling data to verify the functionality of the modules. This software dynamically updates the critical parameters calculated by retrieving stored data from the virtual 'well' database using WITSML API calls. Furthermore, the verification of this software by retrieving and displaying the virtual 'well' updated log data has been successfully tested. The software is now ready for field testing.

7. REFERENCES

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