

UM – Drillstring Analysis Software

Getting started

Edition 1

2021

Powered By



Getting Started Using UM Drillstring Analysis Software: simulation of drill string behavior in well

This manual leads you through the process of UM Drillstring Analysis installation and basics of describing the models, running and analyzing results of three types of analysis:

- **Static Analysis:** Evaluation of the equilibrium position of the Bottom Hole Assembly for the defined bit location in the borehole. The analysis provides an accurate representation of the deformed shape of the assembly in the hole, forces acting on the assembly, as well as internal force factors and stresses in the assembly units.
- **Torque & Drag Analysis:** Estimation of resistance torque and axial drag forces acting on drillstring in wellbore for standard set of technical operations: rotary and slide drilling, rotation off bottom, pick up and slack off, back reaming, reaming and fishing. Distributions of axial forces and torques, internal force factors and stresses, as well deformations an assembly are estimated.
 - + **Soft-string** analysis is the fast solution based on assumption of positioning of assembly along the well trajectory.
 - + **Stiff-string** analysis is the detailed analysis considering local deformations and lateral displacements of assembly units in the borehole; application of Static Analysis approach for the whole drillstring analysis.
- **Time Domain Analysis:** Simulation of drillstring motion in borehole with account of side contact with wellbore walls, bit-rock interaction, and any set of harmonic excitations; determination of dangerous dynamic effects having place in the assembly, estimation of stress load of drillstring components, optimization of drilling loots characteristics and operational settings.

Getting Started **D**S **A**UM

UM Drillstring Analysis

We will consider Static and Time Domain Analysis of bottom hole assembly on the single test model - Rotary BHA. Support of assemblies equipped by mud motors and steering tools will be added in the next release of the software. Torque&Drag Analysis will be demonstrated for the single assembly.

It assumes that you go through the manual step by step sequentially. Information that is given in one section might be further given shortly or even omit.

Compatibility

	32-bit	64-bit
Windows XP	1	√
Windows Vista	1	√
Windows 7	1	√
Windows 8	✓	√
Windows 10	1	✓

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Installing UM Drillstring Analysis Software

This section contains the description of processes necessary to install UM Drillstring Analysis Software.

Drillstring Analysis Software Structure

UM Drillstring Analysis Software (here and below - DSA) consists of general GUI and number of executable files and DLL's using for analysis and results output.

DSA software installation

Start the installation file and follow the steps.

Important! Installation can be started by Administrator only.



Атим

Installation proposes to install application in C:\Program Files\ Drillstring Analysis\1 folder for Windows XP and C:\Program Files (x86)\UM Software Lab\Drillstring Analysis\1 folder for Windows 7/8/10 by default. Executable files are copied to the destination.

Setup - UM Drillstring Analysis
Select Destination Location Where should UM Drillstring Analysis be installed?
Setup will install UM Drillstring Analysis into the following folder.
To continue, click Next. If you would like to select a different folder, click Browse.
C:\Program Files (x86)\UM Software Lab\Drillstring Analysis\1 Browse
At least 243,7 MB of free disk space is required
Actease 245.7 Mb Of Thee disk space is required.
< <u>B</u> ack <u>N</u> ext > Cancel

Program databases and sample projects are installed in C:\Documents and Settings\All Users\Documents\ UM Software Lab\Drillstring Analysis\1 for Windows XP and c:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1 for Windows 7/8/10 by default.



Setup - UM Drillstring Analysis	
Select Start Menu Folder Where should Setup place the program's shortcuts?	
Setup will create the program's shortcuts in the following Start	: Menu folder.
To continue, click Next. If you would like to select a different folder, click	k Browse.
UM Drillstring Analysis 1 x32	Browse
< <u>B</u> ack Next >	Cancel

Setup - UM Drillstring Analysis	
Select Additional Tasks Which additional tasks should be performed?	
Select the additional tasks you would like Setup to perform while installing Analysis, then click Next.	g UM Drillstring
Create desktop icons	
Pin to <u>t</u> ask bar	
Associate files *.dsaproj with UM DSA	
< <u>B</u> ack <u>N</u> ext >	Cancel



Setup - UM Drillstring Analysis	• X
Ready to Install Setup is now ready to begin installing UM Drillstring Analysis on your computer.	
Click Install to continue with the installation, or click Back if you want to review or change any settings.	
Destination location: C:\Program Files (x86)\UM Software Lab\Drillstring Analysis\1 Start Menu folder: UM Drillstring Analysis 1 x32 Additional tasks: Create desktop icons Associate files *.dsaproj with UM DSA	*
< ۱	Ŧ
< <u>B</u> ack Install	Cancel

Microsoft DirectX installation

Microsoft DirectX 9 or higher, and Microsoft Visual C++ 2013 Redistributable should be installed on the workstation to enable 3D visualization of drillstring in wellbore. Installations of the components are included in DSA Installation.







Completion of installation will require the restart of workstation. After rebooting UM Drillstring Analysis Software is ready to run.



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1. Graphical User Interface

This section contains general information related to UM Drillstring Analysis Software concept, main tools used for input of source data for Static, Torque & Drag and Time Domain analyses and single project structure.

1.1. Concept

Graphical User Interface of Drillstring Analysis is assigned for the input of source data, formulation of the tasks for the solvers, control of calculation process and results post-processing for Static Analysis and Torque&Drag Analysis; Time Domain analysis solver, integrated to the DSA GUI, enables results output during simulation process as well post-processing of the results.

The interface enables storage of source data related to various types of analyses in format of specialized databases, visualization of the calculated results and reporting data in text, MS Excel and PDF formats.

Static analysis

Graphical User Interface of DSA software is oriented on the choice of the bottom hole assembly optimal for work in one or several locations in the definite well on the base of comparison of the results of Static analyses: contact forces, torques, bending moments, stresses, etc.

Torque&Drag analysis

DSA GUI enables description, evaluation and results comparison for a set of combinations of operational conditions for single or several technical operations; estimation of critical levels of operational loads; analysis of friction factor influence on the axial forces and torque distribution, etc.

Time Domain Analysis

The program enables time domain simulation of BHA/drillstring motion in the wellbore with high CPU efficiency; kinematic characteristics as well as forces acting on the assembly can be output during simulation, and stored for post-processing.

Time Domain Analysis functionality is oriented on determination of dangerous dynamic effects having place in the assembly, estimation of stress load of drillstring components, optimization of drilling tools characteristics and operational settings.

Data structure

Static, Torque & Drag and Time Domain analyses are carried out within the drillstring analysis project (*Project*). GUI enables run of single or several projects of the following content:

• Drilling Information

Source data on well trajectory, wellbore intervals, BHA and drillstring design cases used in the project.

• Analysis

Each type of analysis within the *Project* can contain any number of parameter sets – *scenarios* – that can be run in parallel threads or one by another. *Scenario* corresponds to the definite position of drillstring/BHA in the well, set of operational settings and options specific for the analysis. GUI enables analysis of calculated results for single scenario as well as comparison of the outputs for a set of scenarios.

Report Generator

The interface enables automatic generation of the reports on the analysis in PDF format. The user has an ability to customize the content of the report. Reports can include all the project data or just single results or source data view.

Main window

Graphical User Interface is based on **Main Window** which enables access to the general GUI settings, databases and projects, as well as separate tools for input data items description.

Input of source data, analyses customizing and processing, results postprocessing and report generation is carried out in single **Project Window**.



System of Units

The interface supports Imperial (API) and International System of Units (SI) and automatic conversion of source data and results from one system to another.

The user can customize unit system settings to select SI or Imperial system for output of different types of parameters.

User Modes

The user can customize the functionality of the interface by selecting *User* or *Advanced User* mode. *User* mode hides the settings which are not necessary for analyses of standard problems.

1.2. Workflow

Procedure of drill string analysis within single *Project* can be illustrated with the following scheme.



1.3. General GUI settings

Select **Settings** item of **Main window** head menu to specify general GUI settings: system of units (Si, or Imperial, or Custom) and interface mode (*User*, or *Advanced user*, or *Developer*), list of analysis and tools, main menu style, desktop wallpaper, color scheme, etc.

General Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image: Constant of the settings Image:		👷 UM DSA - Drillstring Analysis Software (Universal Mechanism)
Settings General Unit Settings Unit settings Modules Si Imperial (API)	s lst vically Horizontally imize all Restore all Close all Windows	General Wei Open project project Databases D
 Mode User Advanced user Developer Hydraulic analysis Static analysis Vibration analysis (Critical Speed Map) Nonlinear vibration analysis Directional Tendencies Time domain analysis 		Settings General Unit Settings Unit settings Modules Si Torque & Drag analysis Imperial (API) Stiff-string Torque & Drag Customized Y Static analysis Mode Vibration analysis (Critical Speed Map) User Nonlinear vibration analysis Advanced user Directional Tendencies Developer Time domain analysis
Units: SI UNIts:		Units: SI UNIts:
Style Main menu Wallpaper: Color scheme Silver		Style Main menu Wallpaper: Color scheme Silver

1.3.1. System of Units

The interface supports Imperial and International System of Units (SI) and automatic conversion of source data and results from one system to another.

The user can customize unit system settings to select SI or Imperial system for output of different types of parameters on **Unit Settings** tab.

Ma UM DSA - Drillstring Analysis Software (Universal Mechanism)			
DIS			
General			0
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	Pressure distribution	de 🔲 Vertically 📃 Horizontally	
project project Materials Formations Fluids Part Well Wellbore Dnill database trajectory / E	A Time history generator Settings About Getting started	ze al 🖷 Restore al 📲 Close al	
Projects Databases Tools	Auxialiary tools Settings Help	Settings	×
		Settings	
Settings		General Unit Settings	
General Unit Settings		🕨 🎬 SE API	
Linit settings	Modules	Category	Units
si	Torque & Drag analysis	Length	ft
		Diameter	in
 Imperial (API) 	Ludra dia paolusia	Angle	deg
Customized	mydraulic analysis	Dogleg	deg/100ft
	Static analysis	Mass	lbm
Mode	 Vibration analysis (Critical Speed Map) 	Mass Per Length	ppf
 User 	Nonlinear vibration analysis	Density	Ibm/cu ft
🔿 Advanced user	Directional Tendencies	Force	kip
	Time domain analysis	Torque	lbf*ft
		Stress/Pressure	ksi
Tools		Young Module	ksi
WITSML Data Support	Multithread Calculations	Stiffness	Lbf/ft
-Data directoru		Angular Stiffness	kip*ft/deg
Cillian Dekter Deamen	VD37-VY/-II Funda - C-600V1	Damping	Lbf/(ft/sec)
L: \Users\Public\Documen	skrimokwell Engineering Sortwarekt	Speed	ft/sec
Change location		Temperature	F
		Thermal Expansion Coefficient	1/F
Interface Settings		Dynamic Viscosity	cP
Style		Flow Rate	gpm
Main menu	Ribbon	Speed Ratio	rpm/gpm
Wallpaper:	a 🗴	Power	hp
		Volume	ьы
Color scheme Silver	•	Area	in^2
		Flow Consistency Index	lbf*s^n/(100*ft^2)
Units: SI A		Linear Bending Stiffness	kip/ft^2
		Area Distributed Power	hp/in^2
		Ok Cancel	
UK Cancel			

The label of current system of units (**SI**, **Imperial**, or) is displayed in the left bottom corner of the **MainWindow**. Double click the panel or use **Main Window** | **Options** interface to change the system of units. All data items will be converted automatically.



1.3.2. User Mode

Drillstring Analysis GUI can operate in three modes: *User* mode, *Advanced* $User^{1}$ and *Developer* mode. *User* mode hides or enables settings which are not used in the most cases.

ettings		×		
General Unit Settings				
Unit settings Si Imperial (API) Customized Mode Suser	Modules Torque & Drag analysis Stiff-string Torque & Drag Hydraulic analysis Static analysis Vibration analysis (Critical Speed Mag Nonlinear vibration analysis))	on <u>i</u> <u>por</u> Settings <u>i</u> <u>por</u> About Getting Help	Windows list Gascade Vertically Horizontally Minimize all Restore all Windows
Advanced user Developer	Directional Tendencies			
WITSML Data Support Data directory C:\Users\Public\Documents\ Change location	Multithread Calculation	18 		
Interface Settings Style Main menu Wallpaper:	Ø Ribbon	e X		
Color scheme Silver				
Ok Cancel				

The label of current mode is displayed in the left bottom corner of the **Main Window**. Double click the panel or use **Main Window** | **Options** interface to change the setting.

E	Enter Advanced User User Password
	•••••
	Ok Cancel

Starting of GUI in *Advanced User* or *Developer* mode or switching from *User User* mode is available after password entering only. If entered password is incorrect the GUI will work in *User* mode.

¹ Default Advanced user password is «DSA-DSA»

1.3.4. Source Directory

DSA program uses *Source directory* path for search of databases and projects saving. The *Source directory* is placed in *C:\Documents and Settings\All Us-ers\Documents\UM Software Lab\Drillstring Analysis\1*\ for Windows XP and *C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1*\ for Windows 7, 8, 10 by default.

The list of files and catalogs placed in the directory:

iearch:	No project selected	
:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1	B	
	-	
- Buareport		
databases		
projects		
▷ -		
Þ 🛅 Utils		
wellbores		
⊳ 🖬 ×32		
🔚 Dongle		
🚞 drillstrings		
- 📴 Excitations		
🚞 help		
- 🛅 ini		
🛅 lib		
logos		
- imanual		
pressure		
pressures		
schematics		
wellpaths		
- voipuno		
Display Mode : Show all folders		
\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1\ •••• UM DrillStri	ng 💌	

Options.ini – DSA GUI options;

Databases\ – Material, Fluid, Formation, Drillstring part databases;

Projects\ – Default storage of Drillstring Analysis projects;

Samples\ – Sample project files;

Wellpaths \ – Default storage of files with well trajectory description;

Wellbores\ – Default storage of files with wellbore intervals description;

 $Drillstrings \setminus -$ Default storage¹ of drillstring/BHA design files;

Excitations\ – Default storage of drillstring/BHA excitation description files;

Pressures\ – Default storage of pressure map files;

Temperatures\ – Default storage of temperature distribution files;

Schematics\ – Storage of string parts image files;

Wallpapers\ – Storage of main window wallpaper files;

Manual\ – PDF documentation files;

Utils\,*Templates*\,*ini*\,*help*\,*logos*\,*umentities*\,*x32*\, etc. – Auxiliary file storage.

¹ Default storage means that the user can store these files anywhere he or she wants.

1.3.5. Interface Settings

DSA Main window can be customized by selection of GUI style, and desktop wallpaper.



1.4. GUI Databases & Tools

DSA GUI includes a number of specialized databases and tools for work with source data without starting Drillstring Analysis project.

	General												
New project	Open t project	Materials	Formations	Fluids	Part database	Well trajectory	Wellbore	Drillstring / BHA	 Temperature map Pressure distribution Time history generator 	🖳 Chen solution	Settings	1 About	PDF Getting started
Pro	ojects		Databa	ses			Tools		Auxialiary to	ols	Settings	He	elp

- Databases: Set of data used in drilling information description within Project or Drilling Information editors.
 - Material Database
 - Formation Database
 - Fluid Database
 - String Part Database

The interface of databases is generalized within DSA GUI, and varies by the list of parameters only.

- Tools: Specific tools for drilling information items description without starting *Project*; one can use preliminary prepared data items for the fast *Project* initialization.
 - Well Trajectory Editor
 - Wellbore Editor
 - Drillstring/BHA Editor

The interface of source data editors is similar to *Project* interface of data input.

- Auxiliary tools: Specific tools for scenario(s) input data items description without starting *Project*, as well as auxiliary analysis tools.
 - Temperature map Temperature distribution along the well
 - Pressure distribution Internal/external pressure for drillstring
 - Time history generator Value vs. time dependencies generation for force excitations input.
 - Chen solution Estimation of external mud damping for a pipe oscillating in a wellbore (in accordance to Chen solution).

The interface of source data editors is similar to *Project* interface of data input.

1.4.1. Material, formation, fluid databases

Database wizard GUI is common for material, formation and fluid data.

General view GUI

Each database contains the preset list of items, which parameters cannot be modified by the user¹. One can add new item (\clubsuit) or duplicate (\clubsuit) one from the preset list to describe new item. User's items can be modified or deleted (\frown).

GUI is organized as a table of database items vs. parameters. Use All, Default Only or User Only tabs above the table to display all items or preset or user-defined items correspondently.

Material database												
All Default Only User Only												
+ - + ☆ ⊇ た @ 兽 悪 ■ 2 0 0												
	√ Caption	✓ Comment	Color	♥ Density, kg/m^3	₹ E, GP a	Ƴ G, GPa	V Nu	₹ TEC, 1/C	∀Heat Cap., J/(kg*K) 🔺			
1	Aluminum	Aluminum		2707.1	71.02	26.7	0.33	1.3E-05	880			
2	Aluminum 1953TI	Aluminum 1953TI		2707.1	71	26.69	0.33	1.3E-05	880			
3	Aluminum D 16	Aluminum D16		2707.1	71.02	26.7	0.33	1.3E-05	880			
4	Beryllium-copper alloy	Beryllium-copper alloy		8169.4	134.4	52.31	0.285	1.3E-05	420			
5	Incoloy 925	Incoloy 925		8057.3	220	84.61	0.3	1.59E-05	435			
6	Monel	Monel		8810.2	179.3	68.16	0.315	1.3E-05	427			
7	Non-Mag-316	Non-Mag-316		8000	193	74.23	0.3	1.59E-05	500			
8	P550	P550		7993.2	220	84.61	0.3	1.59E-05	500			
9	P580	P580		7993.2	220	84.61	0.3	1.59E-05	500			
10	SBO P550	SBO P550		7993.2	220	84.61	0.3	1.59E-05	500			
11	SBO P580	SBO P580		7993.2	220	84.62	0.3	1.59E-05	500			
12	Steel	Steel		7850	200	76.92	0.3	1.3E-05	500			
13	Steel AISI 1340	Steel AISI 1340		7801	207	80.23	0.29	1.3E-05	473			
14	Steel AISI 4145	Steel AISI 4145		7801	207	79.62	0.3	6.89E-06	473			
15	Steel E75	Steel E75		7849	199.9	76.9	0.3	1.3E-05	473			
16	Steel G105	Steel G105		7849	199.9	76.9	0.3	1.3E-05	473			
17	Steel S135	Steel S135		7850	199.9	76.9	0.3	1.3E-05	473			
18	Steel S95	Steel S95		7850	199.9	76.9	0.3	1.3E-05	473			
1	Charl VOE	CtLVOF		7050	100.0	76.0	0.2	1 35 65				
Select	ed item count: 37								Close			

Select column with the parameter and click 1 to sort items in the parameter value increasing/decreasing order. Use 1 button to auto-size column headers; click 2 to enable hint mode. Click 2 to validate input data on admissible parameter values.

Use \square toolbar button to activate items filtering mode; click on a column head to turn on filtering by the column parameter.

Database info import (\mathbb{I}) and export (\mathbb{I}) of is available in **Advanced** and **Developer** mode.

¹ Modification is available in Developer mode only

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GUI enables selection of parameters/columns to display in the table; this option is useful if number of item parameters is significant.

Click on \mathbb{E} button to display the **Category tree** panel, which provide an ability to hide/display parameters \mathbb{Z} , and turn on output format of the parameters \mathbb{Z} .

🔡 M	aterial database			3
All	Default Only User On	ly		
\$	- 🗣 🛛 🖻 🗟 🛛	📴 🖷 🛛 👪 🕅 🚱	•	
	√ Caption	Comment Color	Density, kg/m^3 A Parameters setting	٦
1	Aluminum	Aluminum	2707.1 📃 🚅 📰 🔛 🐼 🖌 🍘	
2	Aluminum 1953TI	Aluminum 1953TT	2707.1	
3	Aluminum D16	Display parameter	er tree: 07.1	
4	Beryllium-copper alloy	Berylli Doromotoro	69.4 Comment	
5	Incoloy 925	Parameters	VISIDIE 57.3	
6	Monel	Output forma	at 10.2 Density	=
_7	Non-Mag-316		8000 Density	
8	P550	P550	7993.2	
9	P580	P580	7993.2	
10	SBO P550	SBO P550	7993.2	- 1
11	SBO P580	SBO P580	7993.2	
12	Steel	Steel	7850 🖳 Mechanical Anisptropic	
13	Steel AISI 1340	Steel AISI 1340	7801	
14	Steel AISI 4145	Steel AISI 4145	7801	-
15	Steel E75	Steel E75	7849 Format [G]:	
16	Steel G105	Steel G105	7849 Data Format General	
17	Steel S135	Steel S135	7850 Digits number 4	
18	Steel S95	Steel S95	7850 Decimals number 2	1
Ĩ.	Charle Vor	CtLVOF	Column width 52	1
Select	ed item count: 37		Close	

Parameters are grouped in categories; the user can hide/show a category at all by one click.

Item details view

Double click on the item in general view table, or select the item and click on \square button to see the item data in separate window.

M N	aterial databa	ase												23
All	Default On	ly User Or	nly											
¢	- + ₊	r 🔁		1 🛱 🗄	• 1	0								
	Y Cap	ion	Y	Comment	∀ Color	∀ De	ensity, ke	g/m^3	3 ₽ E, GP a	Ƴ <mark>G, GP</mark> a	₹ Nu	∀ TEC	, 1/C	ю., л
1		Aluminum		Aluminur	n			2707.1	1 71.02	26.7	0.33	1.3	3E-05 8	380
2	Alumin	ım 1953TI	0	Material [Steel]	- details.	.(defa	ault)	1000		-			2	
3	Alu	ninum D16	- i	AND					1 10.000	100				
4	Beryllium-co	pper alloy		General Mechanic	al Isotropic	The	rmal Str	ength	S-N Fatigue	e: Tension	S-N Fati	gue: Be	endii 👎	
5	I	icoloy 925		Parameter	Value		Units	des	cription.					
6		Monel		Caption		Steel		Paran	neter Name					
_7	Nor	-Mag-316		Comment		Steel		C	omment					
8		P550	11	Color				Sch	eme color					
9		P580		Density		7850	kg/m^3	Mate	rial Density					
10		SBO P550												
11		SBO P580												
12		" Steel	-											
13	Steel	AISI 1340	-											
. 14	Steel	AISI 4145	-											
15		Steel E75												
16	:	Steel G105	-											
17		Steel S135		L						_				
18		Steel S95									ОК		Cancel	
19		Steel X95	C		_	-	_				-			
Ĩ.		T		T				10003		222.5	0.00		- 05	•
Select	ted item count:	37										(Cle	ose

Click **Ok** to save changing to database; click **Cancel** to exit without saving.

Note: The *Item data view* mode enables modification of any item (preset or user-defined). If the user does not have access to preset data modification, the GUI will propose to save the item with another name as a user-defined item.

1.4.1.1. Material Database

Material database is stored in *MaterialDB.mtl* file placed in *Source directo-ry\Databases* catalogue. The database is loading from the file when GUI starts.

Use Materials button of the head menu to open material database editor.

New project	Open project	Materials	Formations	Fluids	Part database	Well trajectory	Wellbore	Drillstring / BHA	 Temperature map Pressure distribution Time history generator 	Chen solution
Proj	Projects Databases			Tools		Auxialiary to	ools			

Material parameters

Database contains wide list of material parameters; list of parameters required for Static, T&D and Time Domain Analysis in DSA application is stated below.

Parameter	Ur	nits	Description						
i di dificici	SI Imperial		Description						
		Gen	eral category						
Caption			Unique caption of the material within the database.						
Color			Color the material is displayed on the drillstring						
			side section view.						
Density	Kg/m ³	Lbm/ft ³	Material density.						
	Ì	Mechanica	I Isotropic category						
Modulus of elasticity	GPa	ksi	Modulus of elasticity of the material.						
Poisson's Ratio			The signed ratio of transverse strain to axial strain.						
	Thermal category								
TEC	1/C	1/F	Thermal expansion coefficient.						

1.4.1.2. Formation Database

Formation database is stored in *FormationDB.fdb* file placed in *Source directo-ry\Databases* catalogue. The database is loading from the file when GUI starts.

Use Formations button of the head menu to open formation database editor.

New Open project project Projects	Formations Fluids Part Databases	Well Wellbore Tools	Drillstring / BHA	Frempera	ture map 📕 Chen solution distribution cory generator Auxialiary tools				
All Default Only User Only									
\$ = * ↓ ≦ ≥			1 40 7	CD V	7				
1 Andesite	Comment	Color Density, I	2700	, GPa • NU 60.2 0.2	1ue compressive streng				
2 Basalt			2800	25 0.1	3 50				
3 Chalk			1700	20 0.3	5 5				
4 Chert			2540	72 0.3	3 300				
5 Clay			1900	0.1 0.3	2 0.7				
6 Coal			1370	1.2 0.36	5 14.32				
7 Dolerite			2780	50 0.2	5 140				
8 Dolomite			2670	8.5 0.26	5 81.9				
9 Gabbro			2700	40 0.1	5 175 🔻				
•					4				
Selected item count: 32					Close				

Formation parameters

Database contains wide list of formation parameters; list of parameters required for Static, T&D and Time Domain Analysis in DSA application is stated below.

	Ur	nits	
Parameter	SI	Imperi-	Description
		al	
		Gen	eral category
Caption			Unique caption of the formation within the data-
			base.
Color			Color the formation is displayed on the wellbore
			section view.
Modulus of elasticity	MPa	psi	Modulus of elasticity of the formation.
Poisson's Ratio			The signed ratio of transverse strain to axial strain.
Density	Kg/m ³	Lbm/ft ³	Formation density.
	R	GD model	parameters category
Rock specific strength	MPa	psi	Rock specific strength parameter for RGD model of
(epsilon)			PDC bit-rock interaction
Bit-rock contact stress	MPa	psi	Bit-rock contact stress parameter for RGD model of
(sigma)			PDC bit-rock interaction

UM

1.4.1.3. Fluid Database

Fluid database is stored in *FluidDB.ldb* file placed in *Source directo-ry\Databases* catalogue. The database is loading from the file when GUI starts.

Use Fluids button of the head menu to open fluid database editor.

New project Pro	Open project jjects	Databases	rt base t	Well Wellbore Drillstring / BHA Tools	 Temperature Pressure dis Time history 	e map <u>II</u> Chen solution tribution generator Auxialiary tools			
말을 Flu All 수	All Default Only User Only - + + - + +								
	√ Caption		7 Color	♥ Static density, kg/m^3	ŸH, W/(K*m2)	Yynamic viscousity, F 🔺			
1	Drilling Fluid	Default Fluid = Mud		1400	0	0.07			
2	Air	Air		1.1983	0	1.86E-0005			
3	Diesel	Diesel		800.44	0	0.0762			
4	Mineral Oil	Mineral Oil = Mud		934.65	0	0.041			
5	Silicone Oil	Silicone Oil		956	0	0.145			
6	Water	Water		1000	0	0.001			
7	Fluid_1	Default Fluid = Mud		1400	0	0.07			
8	12345	Default Fluid = Mud		1400	0	0.07			
9	Air_SampleHydraulics	Air		1.1983	0	1.86E-0005			
10	DF_NJB	Default Fluid = Mud		1400	0	0.07			
11	Drilling Fluid_new	Default Fluid = Mud		1400	0	0.07			
12	Air_new	Air		1.1983	0	1.86E-0005			
13	Mineral Oil_new	Mineral Oil = Mud		934.65	0	0.041 👻			
•						•			
Select	ed item count: 14					Close			

Fluid parameters

Database contains wide list of fluid parameters; list of parameters required for Static, T&D and Time Domain Analysis in DSA application is stated below.

Parameter	Un	nits	Description				
i di dificici	SI Imperial		Description				
		Gen	eral category				
Caption			Unique caption of the fluid within the database.				
Color			Color the fluid is displayed on the schemes.				
Density	Kg/m ³	Lbm/ft ³	Fluid density.				
		Mecho	anical category				
Mud dynamic Pa · sec cP		cP	Dynamic viscosity (or absolute viscosity) of the				
viscosity			fluid: $cP = 0.01P = 1 mPa \cdot s = 0.001 Pa \cdot s$.				

1.4.2. String Part Database

DSA GUI enables description of the bottom hole assembly and drillstring design with the set of components, that can be taken from *String Part Database* or described internally by *Drillstring Part Editor* tools.

String Part Database GUI

The database is stored in *.pdb file placed in *Source directo-ry\Databases\StringPartDatabase* catalogue and its sub-catalogues. The database is loading from the files when GUI starts.

StringPartDatabase catalogue contains by default *Training database.pdb*, which items are read only; and *User database.pdb* available for editing.

Use Part Database button of the head menu to open database editor.



Database navigation is organized by database tree structure on the left panel. Database file is displayed in the database structure tree (\blacksquare) , and contain a set of drillstring parts (\boxdot) grouped into categories (\clubsuit) .

Head menu tools and *Drillstring Part Editor* GUI, placed on the right panel, enables access to the database items description.

Database structure editing

Tools for the database data structure modification are available on the **Part Database** tab of the head menu:

- i add new database catalogue folder;
- Image: delete selected database catalogue folder with all entities;
- \blacksquare duplicate selected database catalogue folder at the current level¹;
- Is add new database file in the selected database catalogue folder;
- I delete selected database file with all entities;
- Image: duplicate selected database file at the current level¹;
- I add sub category for the selected category node;
- 4 delete selected category node with all entities;
- I duplicate selected category at the current level;
- I add new part to the current category;
- delete selected part;
- I duplicate selected part;
- 😐 collapse/expand tree branches;
- ✤ move node up;
- 🕂 move node down;
- 1 copy node;
- I paste copied node;

¹ Available in **Developer** mode only

- 4 enable/disable Search mode:
- **I** import data from *.pdb file to the current category;
- **u** export data from the current category to *.pdb file.

Search mode

The **Search** panel is adding to the bottom of the database tree panel if the *Search mode* is enabled. The only parts containing search mask, defined in the **Part Caption** field, are displayed in the database tree if the *Search mode* is enabled.

OFIL	Drillstring Parts Databases				
Part Database Part Editor			0		
 New DB folder Add new database Delete DB folder Delete database Duplicate DB folder Duplicate database String Part Databases 	Add category at Add new part Delete category Delete part Duplicate category to Duplicate part Database Content	Expand/Collpase Copy Move Up Paste Move Down Search	y Import data from file Save data to file Import/export data		
Default		Bit			
Image: Grinds Image: Grinds <td< th=""><th>$\begin{array}{c c c c c c c c c c c c c c c c c c c$</th><th>nnection Uniform 3.375 Body Uniform 3.375 nnection Uniform 3.375</th><th>LD, III CD, III Length, II 1.25 3.375 31 1.25 3.375 1.6667 1.25 3.375 0.33333</th></td<>	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	nnection Uniform 3.375 Body Uniform 3.375 nnection Uniform 3.375	LD, III CD, III Length, II 1.25 3.375 31 1.25 3.375 1.6667 1.25 3.375 0.33333		
		111	•		
Search		Surface			
Part: 3 3/8	StringPartDatabase -> Default \ Sample units\D	Drilling Collar \ 3 3/8",Drill Collar,NC	226		
		ОК	Apply Cancel		

Part parameters output/editing

Parameters of the part selected in the *Database tree* are controlled by the *Part Editor GUI* - panel right to the tree panel; additional tools are placed on the **Part Editor** tab of the head menu.

1.4.2.1. Drillstring Part Editor

The *Drillstring Part Editor* GUI provide tools for description of the wide range of drilling tools within the generalized format: bits, drilling pipes, collars, stabilizers, mud motors, "place-the-bit" and "push-the-bit" steering systems, etc.



Note! Modification of part description is available for the not-read only database files only.

Part description concept

In accordance to the generalized description any part is presented by set of pipes; the first one (or the single for simple parts) is the *shaft pipe*, the rest ones are the *outer pipes*.



Each pipe consists of arbitrary set of *Uniform* and *Blade* sections. Each section can be presented by flexible beam element, or absolutely rigid body; 3D finite element model of non-uniform component can be incorporated in the description¹.



Part-wellbore interaction is defined by *circle-cylinder* and *points-cylinder* contact forces; contact circles and points are placed on the part, hole is modeled by cylinder.

Several kinds of sibling section connections are supported: tool joint, hinge, CV joint, bend sub, arbitrary bushing connection, mud motor pump. Several kinds of section ends - wellbore interaction are supported: none, contact, offset, pad, fixed node.

Any outer pipe should be linked directly or by other pipes to the shaft pipe; different types of bearings, bushings, hydraulic/mechanical positioning systems, mud motor interaction and bushings are available.

Detailed description of the drillstring part model in DSA environment is presented in Setc.x of the Manual.

¹ The 3D FEM model usage functionality is not presented in the current documentation.

Part Editor GUI

Part Editor GUI consists of several elements:

Head menu

Head menu contains basic and advanced tools for part structure description, as well as auxiliary visualization tool controls:



- add pipe;
- delete selected pipe (Note: *Shaft* pipe cannot be removed);
- I → duplicate selected pipe;
- [™] display/hide pipe links editor¹;
- add new section for the pipe;
- delete selected section;
- Image: Image: A section of the se
- $\widehat{\mathbf{r}}$ move section close to the downhole end of part;
- \clubsuit move section far from the downhole end of part;
- validate part description.

Advanced editing tools enables detailed description of blade section geometry and model settings (Blade geometry), well-interaction model for the upper end point of section (Well contact) and parameters of connection with upper section (Sections connection).

One can use **Part structure** button to display/hide *Part structure tree* that can be useful for navigation in the description of the complex components.

Use **Side section** button to show the side section image of the part. The image is updating interactively during modification of the part description, and can be used for visualization of links, connections and nonstandard contacts marking.



¹ Description will be added in the next version of the Manual

Parameter table

Table control is used for output and editing of pipes and section parameters; one can edit white-colored fields to modify the description.

	Bit													
Α	+		Part/Section	Туре	OD, mm	ID, mm	CD, mm	Length, m	Alignment, m					
đ	-	1	Shaft		203.2	71.12	203.2	9.144	0					
¥	-	1.1	1	<u>Uniform</u>	203.2	71.12	203.2	0.9144						
M	-	1.2	2	Uniform	152.4	71.12	152.4	1.8288						
7	-	1.3	3	Uniform	177.8	71.12	177.8	0.9144						
2	-	1.4	4	Uniform	152.4	71.12	152.4	1.8288						
\$	-	1.5	5	Uniform	177.8	71.12	177.8	0.9144						
Le1	-	1.6	6	Uniform	152.4	71.12	152.4	1.8288						
[2]		1.7	7	Uniform	203.2	71.12	203.2	0.9144						
	< 7 o se	able utput ttings	5											
	•		III						Þ					
	Surface													

Table output can be customized by **Table settings** tools placed on the left vertical panel. GUI enables selection of parameters/columns to display in the table; click on **Table settings** button, or use the fast access buttons to select parameters for the table and turn on output format if necessary.





Parameters

Part description contains wide list of parameters.

Parameter	Units		Description
	SI	Imperial	Description
<i>General</i> category - A fast access button.			
Pipe/Section			Pipe / section caption; used for specifying point on
			the part in analyses.
Description			Pipe / section description.
Count			Part quantity.
			Not available in Part Editor: used in Drillstring edi-
			tor only.
Geometry category - \swarrow fast access button.			
Туре			Section type: Uniform or Blade.
OD	mm	inch	Section: outer diameter of the pipe section.
			Pipe: maximal outer diameter of the pipe sections.
ID	mm	inch	Section: inner diameter of the pipe section.
			Pipe: minimal inner diameter of the pipe sections.
CD	mm	inch	Section: Contact diameter of the pipe section.
			Pipe: Maximal contact diameter of the pipe sec-
			tions.
			Note : Contact diameter is equal to the outer diame-
			ter for <i>Uniform</i> sections and set automatically; con-
			tact diameter of <i>Blade</i> section is defined
			additionally, and can be equal or greater then outer
			diameter of blade section body.
Length	m	ft	Length of the section.
Alignment	m	ft	Parameter of multi-pipe parts description: distance
			from the lower end of <i>Shaft pipe</i> to the lower end of
			Outer pipe.
			Note: Alignment field is available for Outer pipe
			items only.
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	Inerti	a category	fast access button.
Material			Material of the section.
			If material is assigned for all pipe sections, the ma- terial caption is displayed in the pipe material field; the field is empty otherwise.
			The user can set material for the section, or for all pipe sections, or for all part sections by popup menu tools.
			Note: Material is selected from <i>Material Database</i> ; one needs to edit the database if part material is not included in the database.
Lin. mass	kg/m	lbm/ft	Linear mass of the section/pipe.
			Linear mass of section is calculated automatically from material density and cross section geometry.
			Pipe linear mass is taken from the corresponded mass value divided by the length value.
Mass	kg	lbm	Mass of the section/pipe.
			Mass of section is calculated automatically from material density and section geometry.
			Pipe mass is taken from the masses of the sections.
			Note: Linear mass and Mass of section/pipe value
			can be set manually in Advanced User and Devel -
			oper modes. One needs to select the corresponded
			pop up menu.
			✓ Auto mass for all elements [Shaft]
	Summa	<i>iry</i> categoi	$ry - \sum$ fast access button.
Acc. Length	m	ft	Accumulated length reference value (read only):
			• for section: distance from lower point of the
			pipe to the top point of section.
			• for pipe: distance from lower point of the pipe to the top point of pipe = pipe length.
			Note: Value is available for the <i>Shaft pipe</i> only.
Acc. Mass	kg	lbm	Accumulated mass reference value (read only):
			• for section: mass of all sections from lower
			end of pipe to the current section inclusively.
			• for pipe: mass of all pipe sections.
			Note: Value is available for the <i>Shaft pipe</i> only.

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	Stiffne	ss categor	y - 🗧 fast access button.
Model type Lin. Axial. Stiff	kPa	ksi	 <i>Pipe</i> model type: <i>Flexible</i> – pipe sections are simulated by flex- ible uniform beams; <i>Rigid</i> – pipe is modeled with absolutely rigid body of the prescribed geometry; <i>3D FEM model</i> – pipe model is described by 3D finite element model (*.fss file), imported from FEM software in accordance to the mod- al finite element approach. Linear axial/bending/torsional stiffness of the sec-
Lin. Bend. Stiff	kN/m ²	kip/ft ²	 tion/pipe. Linear axial stiffness of section is calculated automatically from material characteristics and cross section geometry. Pipe axial stiffness is taken from the stiffness and geometry of the sections.
			Note: <i>Linear axial/bending/torsional stiffness</i> of section/pipe value can be set manually in Ad-vanced User and Developer modes. One needs to select the corresponded row in the table and disable
Lin. Tors. Stiff	kN/deg	kip/ deg	Auto axial/bending/torsional stiffness option by pop up menu. Auto axial stiffness for all elements [Shaft] Auto bending stiffness for all elements [Shaft] Auto torsion stiffness for all elements [Shaft]
	Safet	y category	- [S] fast access button.
Max. T	kN*m	kip*ft	Value of the maximal admissible torque/force can be applied to the section/pipe.
Max. F	kN	kip	 Note: Parameters are available for the <i>Shaft pipe</i> only. Note: Parameters are not used in the current version of the DSA software.

1.4.3. Well Trajectory Editor

Use **Well Trajectory Editor** button of the head menu to generate or edit file of survey description.



Well survey is described by set of survey points; *tortuosity* is described additionally and added to the basic survey if enabled.

Trajectory can be saved in or loaded from xml file of special format (*Wellpath file *.wlp*). The files are saved and loaded from *Source directory**wellpaths*\ folder by default. The user can also **Paste** data from Excel table.

Survey station description

The GUI enables description of survey by point-by-point table input, or by set of constant build/turn rate intervals defined from surface or from the selected measuring depth.

G					Sa	mple Wellp	ath.wlp - Well T	rajectory Editor		x
	Well Trajectory									
₽ ++	New point Delete point Delete point Delete point Clear Description[Well Trajectory]							 New plot Create copy Delete plot 	V Point on surface 1002 Full View Show survey points Plot output style PD Trajectory smoothing PDF)F ort R
#	MD, ft	Inc, deg	Azi, deg	TVD, ft	VSEC, ft	N+/5-, ft	E+/W-, ft)og	leg, deg/1001 ^	Plots 3D scheme	
1	0.000	0.00	0.00	0.000	0.000	0.000	0.000	0.00	TVD vs. Horizontal Displacement MD vs. Dogleg	
2	473.425	0.00	0.00	473.425	0.000	0.000	0.000	0.00		
3	557.743	0.53	145.54	557.742	0.211	-0.322	0.221	0.63		וו ר
	Input	fields	2.30 8.82	Auto	o-calcu	ulated f	ields	1.53 0.23	0 20b0 40b0	
6	793.963	0.53	42.44	793.953	-1.558	1.180	1.217	0.14		
7	889.108	0.26	45.16	889.095	-2.172	1.657	1.667	0.28		
8	994.094	0.09	145.53	994.081	-2.348	1.757	1.883	0.28	e -	
9	1089.239	0.09	46.48	1089.226	-2.375	1.746	1.980	0.14	l și l	
10	1181.102	0.09	42.70	1181.089	-2.509	1.849	2.081	0.01	4000	-
11	1276.247	0.09	292.49	1276.233	-2.579	1.933	2.062	0.16		
12	1371.391	0.09	8.69	1371.378	-2.651	2.035	2.005	0.12		
13	1466.535	0.18	266.38	1466.522	-2.658	2.100	1.867	0.23		
14	1555.118	0.18	272.01	1555.104	-2.547	2.096	1.589	0.02		
15	1650.262	0.35	143.51	1650.248	-2.345	1.867	1.612	0.51	Horizontal Displacement, ft	
16	1837.270	0.18	168.56	1837.254	-1.810	1.120	2.010	0.11		

♣, ➡ and ♣ buttons enable adding new, delete and copying survey points presented by lines in Well Trajectory Editor table.

Trajectory is described by editing of **MD**, **Inclination** and **Azimuth** values in the lines of the table.



UM Drillstring Analysis

TVD, *VSEC*, N+/S-, E+/W- and *Dogleg* parameters are evaluated automatically from the input data. Editable fields of the table have white coloring, auto-calculated ones are marked with grey.

Input trajectory is visualized automatically by 2D plots and 3D view placed right to the input table:

➢ <u>2D plots</u>

All the table parameters can be added on 2D plots; one can add (\Box) , delete (\Box) or duplicate (\Box) plot to the right panel, and customize the parameters on horizontal and vertical axes by pop up menu controls.

						Sample We	llpath.w	lp - Wel	ll Trajectory I	ditor			- • ×
<u>rs</u>	Well Tr	ajectory											0
₽ +	New point Delete point Duplicate po	■ 1 ま 1 に 1 1 1 1 1 1 1 1 1 1 1 1 1	Insert before Insert after Clear escription[W	e Trajector	tory Tortuo ator	ity Check	Settir Settir	ngs t	New plot	y Point on s Show surv Trajectory Plo	urface 1002 Fi vey points 💮 Pl v smoothing ts	ull View lot output style	PDF report PDF R
#	MD, ft	Inc, deg	Azi, deg	TVD, ft	VSEC, ft	N+/S-, ft 🔺	Plots	3D s	cheme				
1	0.000	0.00	0.00	0.000	0.000	0.000	TVD	vs. Ho	rizontal Disp	acement MD vs.	Dogleg		
2	473.425	0.00	0.00	473.425	0.000	0.000							
3	557.743	0.53	145.54	557.742	0.211	-0.322							
4	626.640	0.62	12.30	626.638	0.017	-0.220							
5	707.021	0.53	28.82	707.014	-0.780	0.531		0		1000 2	2000 30	· 000	4000 5000
6	793.963	0.53	42.44	793.953	-1.558	1.180							
7	889.108	0.26	45.16	889.095	-2.172	1.657							
8	994.094	0.09	145.53	994.081	-2.348	1.757							
9	1089.239	0.09	46.48	1089.226	-2.375	1.746						<u>-</u>	
10	1181.102	0.09	42.70	1181.089	-2.509	1.849		2000	Ord	linate	,		
11	1276.247	0.09	292.49	1276.233	-2.579	1.933		2000	Ab	scissa		MD	
12	1371.391	0.09	8.69	1371.378	-2.651	2.035			Exc	hange abscisse-or	dinate for plot	Inc	
13	1466.535	0.18	266.38	1466.522	-2.658	2.100	±		0.0	tions		Azi	
14	1555.118	0.18	272.01	1555.104	-2.547	2.096	j ș					TVD	
15	1650.262	0.35	143.51	1650.248	-2.345	1.867			. Sno	ow all		Horizor	tal Displacement
16	1837.270	0.18	168.56	1837.254	-1.810	1.120		1000	Sho	w according the r	uler pointers	Ni /S	in a spracement
17	1929.134	0.45	130.54	1929.116	-1.580	0.744		4000	Co	oy to clipboard		14+/5-	
18	1968.504	1.40	185.94	1968.481	-1.072	0.165			Pri	nt		E+/W-	
19	2066.929	4.35	198.25	2066.772	3.802	-4.577			Fix	tool panel		Dogleg	
20	2165.354	7.34	200.58	2164.674	13.808	-14.010			Sho	w ruler			
21	2263.780	10.34	201.56	2261.919	28.926	-28.114				e to file * csv			
22	2293.734	11.25	201.76	2291.343	34.535	-33.328			Sav	e to me ".csv			
23	2362.205	11.25	201.76	2358.499	47.891	-45.734		6000	Sho	w ordinate value			
24	2460.630	11.25	201.76	2455.033	67.090	-63.568			Sav	e parameters to fil	e		
25	2559.055	11.25	201.76	2551.567	86.289	-81.401			Rea	d parameters fron	n file		
Ĩ	2017 400	11.05	201 20	0040 101	105 400	4	174		1-00-				

GUI enables the following plot output format settings:

- add surface survey point on plots (if not defined in the table);
- 🛰 highlight survey point on plots;
- smooth plots by adding intermediate points between survey stations in accordance to minimal curvature equations;
- set full view for all plots;
- switch between 2D plot display modes: one plot for tab, or several plots on single panel.

➤ <u>3D view</u>

Spatial well trajectory view is available on **3D scheme** page of the right panel.



Trajectory intervals generation

The GUI enables generation of survey stations from the set of Turn Rate / Build Rate intervals defined from the end point or from the surface point of the well trajectory (end point).

One can use **Trajectory generator** wizard to define **Bit Point** measured depth, inclination and azimuth, step of generating survey stations (**MD Increment**) and list of intervals defined by end point measured depth, build rate and turn rate.

	Well traje	ctory: Constant curvature	intervals					x		
-De	Description type									
C) Intervals f	rom surfase 🧕	Intervals from bit		MD Inc	rement,ft		10 🔲		
Bi	t point	os 🥌 Instruction of		-i	15	m				
MI	J,R 139	1.35 🔤 Inclination, d	eg 45 🗾 🧍	vzimutn, deg	15					
- (+	, — 4	≌= ‼= 🗙 🧕								
	MD, ft	Build rate, deg/100ft	Turn rate, deg/100ft	Interva	ıl, ft	Inc, deg	Azi, deg			
1	500.000	4.00	0.00	1500.000 -	500.000	5.00	15.00			
2	400.000	1.00	0.00	500.000 -	400.000	4.00	15.00			
3	300.000	0.00	0.00	400.000 -	300.000	4.00	15.00			
						Generate		Close		

Click Generate button to create survey stations in accordance to the input data.

Well tortuosity description

GUI enables description of well trajectory as the combination of basic survey points defined in the table, and tortuosity intervals – intervals of harmonic variation of inclination and/or azimuth along the trajectory.

Click **Tortuosity** button on the head menu to take into account tortuosity intervals, which can be defined on the bottom table:

G)				Sam	ple Wellpath	.wlp	- Well	Trajeo	tory Editor*			• X
r s	Well Ti	rajectory											0
₽ ++	New point Delete point Duplicate po	t Hand Hand	Insert before Insert after Clear escription[W	e I Trajecto generat	Tortuosi tor	ty Check	5	Settings Settings] New plot] Create copy] Delete plot	Point on surface Show survey points Trajectory smoothing Plots	100% Full View	PDF report PDF R
#	MD. ft	Inc. dea	Azi, dea	TVD. ft	VSEC. ft N	+/5ft 🔺	P	lots	3D sc	heme			
1	0.000	4.00	15.00	0.000	0.000	0.000	Шг	TVD vs	. Hori	zontal Displacement	MD vs. Dogleg		
2	300.000	1.44	11.93	299.637	14.226	13.794	Ш.						
3	310.000	2.30	12.96	309.632	14.552	14.112							
4	320.000	3.23	14.07	319.620	15.035	14.581				· · · · · · ·		· · · · ·	
5	330.000	4.18	15.22	329.599	15.681	15.207			0		φ ε	sp	120
6	340.000	5.13	16.36	339.566	16.493	15.988				\	Tortuosity	effect visu	-
7	350.000	6.04	17.45	349.519	17.465	16.918					alization o	n 2D plots	
8	360.000	6.87	18.44	359.455	18.588	17.987				. 🐧 🛛	[grov bloo	$k^2 = w/a tak$	
9	370.000	7.60	19.32	369.375	19.844	19.178			200	<u></u>	[gray-black	$K_{\rm J} = W/0$ (0)	-
10	380.000	8.19	20.03	379.281	21.213	20.472			200		tuosity;		
11	390.000	8.63	20.56	389.173	22.669	21.844					[red-blue]	- with tortu	-
12	400.000	8.91	20.89	399.056	24.187	23.270					osity		
13	410.000	9.10	21.00	408.933	25.743	24.731					conty.		
14	420.000	9.11	20.89	418.807	27.317	26.209							
15	430.000	8.94	20.57	428.683	28.878	27.676		e, o	400				
Tor	tuosity						1	μ.		. \			
-	- +	X 🛛 🏹											
#	From. ft 1	o.ft Lens	th.ft Amr	olitude, deg	Period, ft	Variation				-	k		
1	0	1000	1000	5	328.084	Inc			600		<u>\</u>		
2	0	1000	1000	6	328.084	Azi				-			
3	1000	1500	500	5	328.084	Inc				-			
	_									-			
	То	rtuosit	y para	meters	input					-	^{**}		
			field	IS					800				
						_					I		
										Hor	izontal Displacement, f	t	
Ľ.							IL						

Data verification

Well trajectory description can be verified with the **Verify Data** button placed on the top panel of the **Well Trajectory Editor** window.

Data reporting

Well trajectory description can be reported as PDF document with the 🖹 button placed on the head menu of the editor window. 1.4.4.

Wellbore Editor

Use **Wellbore Editor** button of the head menu to generate or edit file of wellbore construction description.



Wellbore construction is described by set of intervals defined by inner diameter vs. measured depth; hydraulics parameters of the wellbore can be defined optionally.

Wellbore data can be saved in or load from xml file of special format (*Wellbore file *.wlb*). The files are saved and loaded from *Source directory**wellbores*\ folder by default. The user can also **Paste** data from Excel table.

Wellbore construction description

♣, ➡ and ♣ buttons enable adding new, delete and copying wellbore intervals presented by lines in Wellbore Intervals Editor table.

6	A		Sample Wel	lbore.wlb - String Edit	or*		• X
	Wellbore cor	nstruction					0
4	다 Add interval 그 Delete interval 다eate copy	Insert before selected	Verify data	aterials Formations	Weak Pressure zones gradients	A Marks 100% Show all	PDF report
	D	escription[Wellbore]		Databases	Wellbore Hydraulics	Wellbore scheme	PDF re
#	f Interval Type	Name Measure	ed Depth, ft	Inner Diameter, in	Overgauge, in Frict	ion Factor Material/	Formation
	Surface		0.000	15.00	0.25	0.200	Steel
1	L Cased hole	1	500.000	15.00	0.25	0.200	Steel
2	2 Cased hole	2	1500.000	12.50	0.25	0.200	Steel
3	3 Open hole	3	7000.000	12.25	0.15	0.200	Marble

Wellbore interval is defined with *Measured Depth* of the end point, interval type (*Open hole* or *Cased hole*), hole diameter calculated from basic *Inner diameter* value and *Clearance* adding, and drillstring-wellbore walls *Friction factor*. *Material* is specified for *Cased* interval; *Formation* – for *Open hole* section.

Parameters of the intervals can be specified by editing of the values in the table lines.

Diameter of the hole for analysis is calculated by summation of the *Inner diameter* and *Clearance* values. One feet transient sections are used for smoothing of hole diameter between sibling intervals, see the scheme on figure below.



Input data is visualized automatically on the scheme placed right to the table.

			Sample V	Vellbore.wlb - String	Editor*			• X
	Wellbore cor	nstruction						0
4 0 \$	→ Add interval → Delete interval → Create copy	Insert before s Insert after sel Clear escription[Wellbore]	elected ected Verify data	Materials Formati	Scheme Relationships and the scheme Relations	PDF report PDF re		
#	Interval Type	Name	Measured Depth, f	ft Inner Diameter	in rgaug		Wellbore Intervals	
1 2 3	Surface Cased hole Cased hole Open hole	1 2 3	0.00 500.00 1500.00 7000.00	200 11 200 11 200 12 200 12	0.00 0.25 0.00 0.25 0.50 0.25 0.25 0.15	0 500 1 000 1 500 2 200 3 3 000 4 000 5 500 6 000 6 500	(1) (2) (2) (2) (2) (2) (3) (3) (3) (2.402	
•					Þ	-2	20 0 Inner Diameter,	20 in

Data verification

Wellbore description can be verified with the **Verify Data** button placed on the top panel of the **Wellbore Intervals Editor** window.

Data reporting

Wellbore description can be reported as PDF document with the D button placed on the head menu of the editor window.

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1.4.5. Drillstring / BHA Editor

Use **Drillstring/BHA** button of the head menu to generate or edit file of drillstring or assembly description without starting new project.



Drillstring and bottom hole assembly design is described as the set of drillstring parts in <u>"from bit to surface"</u> order.

Division between drillstring and BHA description in DSA GUI is conventional; real drillstring is normally described in DSA GUI by *BHA* and the upper *drillstring*. Input GUI and internal format are identical, but *drillstring* description is stored in XML file with *.drs extension, *BHA* file has *.*bha* extension. The files are saved and loaded from *Source directory**drillstrings*\ folder by default.

List of parts / pipes / pipe sections is stated in the main input table; **Side Section** and **Part Images** buttons on head menu enables visualization on the assembly during creation.

)				Sample Rotary	BHA.bha - Sti	ring Editor				×
	2 D	rillstring									0
][* - }*	Add pa Delete Duplica	art A part D ate part Descr	dd section elete section uplicate section iption[BHA 1]	Move up Move dow	n Part Database	Part B editor geo	Advanced editin	Sections connection •	Side Part sections image Additional tool	Generate report PDF Report	
						Bit					
A	+	Part/Secti	Description	Count	Туре	OD, in	ID, in	CD, in	Length, ft	Material	
đ	₽-	12 1/4" PD		1		12.25	1	12.25	1.5026	Steel	
<i>¥0</i>		Cutting str			Uniform	12.244	1	12.244	0.16732	Steel	
M		Body			Uniform	12.25	2.8	T - 1.1	f		
Σ		Shank			Uniform	8.25	2.8	I able c	or parts/ p	ipes /	=
1	나타	12 1/4 Sta		1		8.25	3	section	s narame	otors	
2		Bottom			Uniform	8.25	3	30000	is param		
亦		Blade			Blade	8.25	3	12.20	2.0013	Steel	
444		Top			Uniform	8.25	3	8.25	0.49869	Steel	_
[S]	14	Collar		1	11	0.25	2	0.25	5	Steel	
		1 MED to al		1	Uniform	0.25	5 2 2	0.25	27,000	Steel	_
	I X	12.2/16" C		1		0.25	5.25	0.20	27.999	Steel	
	IX-	12 5/10 S		1		0.25	5.1	12.100	22.001	Steel	
8.0	1	1		1	Uniform	8.25	5.17	8.25	22.001	Steel	
81 v	_ m−	Crossover		1	omorm	8.25	3	8.25	20013	Steel	
80	古	12 1/4 Roll		1		12.25	2.8	12.25	10.003	Steel	
ı—ı	I T	1		-	Uniform	8.25	2.8	8.25	2 0013	Steel	
		2			Uniform	12.25	2.8	12.25	6.0007	Steel	
5		3			Uniform	8.25	2.8	8.25	2.0013	Steel	-
						Surface					
1002	'n,'n					Side sectio	n	Δ	ccombly		
DC	mete	5 Augusta	Banan	H AL HAR				visua	lization to	ols 🛏	_
	ter Dia	5 Frank	- Caller and the	ar de ar de		ZAVZ ^B ZZIEZB	NAN BUNK		AF778-AF28-	in the second	
	III	0 50	100	150	200	250 Distance fr	300 350 om bit, ft) 400	450	500 550	o T

GUI enables several variants of the assembly description:

Adding parts from String Part Database

One can open **String Part Database** window by main menu, or **Part Database** button on the head menu.

Drag-drop parts from the database tree to the editor table to add the part to the end of the list (top end of the assembly). Parameters of the part are displayed in the last lines of *String part table*. One can use **Move Up** ($\textcircled{\circ}$) or **Move Down** ($\textcircled{\circ}$) buttons on the top of the table to change the order of the parts in the list.



If it is necessary to add multiple instances of a part one can repeat drag-drop procedure several times, or just specify the number of repetitive parts in **Count** column of the table. The **Plural** part image is used for the part in string scheme if the count is more than one.

➢ <u>New parts creation</u>

Drillstring Editor GUI enables creation of new parts and modification of the units taken from *String Part Database*. One can use head menu buttons to add new part (1, delete (1, or duplicate (1, the selected part.

Drillstring Editor parts description tools are based on *String Part Editor* interface (see Sect.1.4.2.1). Head menu controls enable description of simple "single shaft" parts. One can select a unit and click on **Part Editor** button to create/modify the multi-pipe component in separate *String Part Editor* window.



Click Accept *is* to apply part description changing, or **Cancel** *is* to reject the modification.

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Parameters

Description of input table parameters specific for *part* rows are stated below.

Darameter	Units		Description				
1 draineter	SI	Imperial	Description				
	Gener	al categor	y - A fast access button.				
Part/Section			Part / section caption.				
Description			Part description.				
Count			Part quantity.				
			Not available in Part Editor; used in Drillstring edi-				
			tor only.				
	Geome	try categoi	ry - 💋 fast access button.				
Туре			Section type: Uniform or Blade.				
OD	mm	inch	Maximal outer diameter of the part.				
ID	mm	inch	Minimal inner diameter of the part.				
CD	mm	inch	Maximal contact diameter of the part.				
			Note : <i>Contact diameter</i> can be not equal to <i>outer</i>				
			<i>diameter</i> for parts containing blade sections.				
Length	m	ft	Length of the part, calculated from the length of				
			Shaft pipe.				
Alignment	m	ft	Parameter of multi-pipe parts description: distance				
			from the lower end of <i>Shaft pipe</i> to the lower end of				
			Outer pipe.				
			Note: Alignment field is available for <i>Outer pipe</i>				
			items only.				
	Inerti	a category	y - M fast access button.				
Material			Material of the part elements (reference info field).				
			If material is assigned for all sections of the part,				
			the material caption is displayed in the pipe materi-				
			al field; the field is empty otherwise.				
			The user can set material for the section, or for all				
			pipe sections, or for all part sections by popup				
			menu tools.				
			Note: Material is selected from <i>Material Database</i> ;				
			one needs to edit the database if part material is not				
			included in the database.				
Lin. mass	kg/m	lbm/ft	Linear mass of the part.				
			Part linear mass is taken from the corresponded				
			mass value divided by the length value.				

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Mass	kg	lbm	Mass of the part.
			Mass of section is calculated automatically from
			material density and section geometry.
			Note: Linear mass and Mass of section/pipe value
			can be set manually in Advanced User and Devel-
			oper modes. One needs to select the corresponded
			row in the table and disable Auto mass option by
			pop up menu.
			✓ Auto mass for all elements [Shaft]
	Summe	ary categoi	$y - \sum$ fast access button.
Acc. Length	m	ft	Accumulated length reference value (read only),
			taken with the account of part quantity.
			Value is calculated as the accumulated length of the
			previous part, plus <i>Shaft</i> pipe length multiplied on
			part quantity.
			Note: First part Acc. length value is equal to the
			part length; the last part value is equal to the total
Acc. Mass	ko	lhm	Accumulated mass reference value (read only)
<i>Tee.</i> 141055	ĸs	10111	taken with the account of part quantity.
			Value is calculated as the accumulated mass of the
			previous part, plus part sections mass multiplied on
			part quantity.
			Note: First part <i>Acc.mass</i> value is equal to the part
			mass; the last part value is equal to the total assem-
			bly mass.
	Stiffne	ess categor	y - <i>≰</i> fast access button.
Model type			Part pipes model type (reference value):
			• <i>Flexible</i> – all part sections are simulated by
			flexible uniform beams;
			• <i>Rigid</i> – all pipes are modeled with absolutely rigid bodies of the prescribed geometry:
			 3D FFM model – all pipe model are described
			by 3D finite element models (*.fss file), im-
			ported from FEM software in accordance to
			the modal finite element approach.
			• <i>Flexible</i> + <i>Rigid</i> , <i>etc</i> . – combinations of the
			0

UM Drillstring Analysis

AUM

Lin. Axial. Stiff	kPa	ksi	Linear axial/bending/torsional stiffness of the part. Part axial stiffness is taken from the stiffness and geometry of the sections.
Lin. Bend. Stiff	kN/m ²	kip/ft ²	part value can be set manually in Advanced User and Developer modes. One needs to select the cor- responded row in the table and disable Auto axi- al/bending/torsional stiffness option by pop up menu.
Lin. Tors. Stiff	kN/deg	kip/ deg	 Auto mass for all elements [Collar] Auto axial stiffness for all elements [Collar] Auto bending stiffness for all elements [Collar] Auto torsion stiffness for all elements [Collar]
	Safet	y category	- [S] fast access button.
Max. T	kN*m	kip*ft	Reference value of the maximal admissible torque/force can be applied to the part pipes.
Max. F	kN	kip	Note: Parameters are not used in the current version of the DSA software.

Data verification

String description can be verified with the $\boxed{2}$ button placed on the head menu of the editor windows.

Data reporting

String description can be reported as PDF document with the D button placed on the head menu of the editor window.



1.5. GUI Drillstring Analysis Project

DSA Software enables solution of different types of problems related to drillstring dynamics. Problem formulation for different types of analysis requires diverse source data.

Project structure

To simplify the analysis procedure of for the user the DSA GUI units all the source data related to the different types of analysis, as well as analyses settings and calculated results in a Drillstring Analysis project (*Project*).

GUI enables run of single or several projects of the following content:

• Drilling Information

Source data on well trajectory, wellbore intervals, BHA and drillstring design cases used in the project.

• Analysis

Each type of analysis within the *Project* can contain any number of parameter sets – *scenarios* – that can be run in parallel threads or one by another. *Scenario* corresponds to the definite position of the drill-string/BHA in the well, set of operational settings and options specific for the analysis.

Project data storage

The following catalogues/files structure is used for project data storage:

🚞 < Drillstring analysis project >\



Projects files are stored in *Source directory**projects*\ folder by default.

1.5.1. Start New Project

Click button on the Main window top panel to start a new project. New **Project window** will be opened. The user can **Save** or **Save as** the project with the buttons placed on the head of **Project** window. One can also use buttons of the **Main window** head menu to save or save as the active project.

The structure of the window pages is described in details in Sect.1.5.4.

General			
New Open project Projects Databases	Part database Well Wellbore Drillstring trajectory / BHA Tools	 Temperature map Chen solution Pressure distribution Time history generator Auxialiary tools 	Settings Settings
Project info Drilling information T&	New - Project D: General Operations Static Analysis Time domai	in analysis Project report	× 0
Project structure	Project Information Analysis Date: 16.07.2020 Project Version:	Project File Info Full path: Drilling Contractor Contractor Name: Product Lines: Primary Engineer: All Engineers Involved: Contractor Logo No Logo	
< <u>III</u> Þ	Well Information Client: Region: Country: Field: Site:	Comments	

1.5.2. Save Project

New project is not saved to hard drive automatically. Click **Save as...** Is button and specify the new project location in **Save drilling project** dialogue window to save the project to disk.

DIS	÷	5 88 1	C Tanan	Sample	Project.dsapro	oj - Project
AUM	Recent projects		Static Analysis	Time domain ar	nalysis Pr	oject report
🗃 Loa	d	ata)/ IM O. J Oamala Draiaat				
Sav Sav	0. C:\Users\Public\Docume	nts\UM S\Sample Project				
Sav	e as				Project File I	nfo
Set	ings		16.07.2020		Full path:	C:\Users\Pu \DrillstringA
					Drilling Cont	ractor
	Diversional Driversional	Parent Company Na	ime:		Contractor	Name:
	nD analysis	Local Legal Entity N	ame:		Product Li	nes:
	General Operations	Pagion:				
Sav	e or Save as	Region.				
	the project	Country:			Primary Er	igineer:
		Country Office:			All Engine	ers Involved:
		Sample Project.dsaproj	- Project	domain analysis	Project rep	
FIUJ		xD. General Operations	Static Analysis Time	domain analysis	Flojectiep	JIL U
G	의의 Save Drilling project as			1	×	
	Search:		Project	ict	A	
	C:\Users\Public\Documents\UM Softwa	re Lab\Drillstring Analysis\	filename	s\Public\Documents\		
	C:\Users\Public\Documents\UI Nabors-BHA1 Sample Project Training project	M Software Lab\Drillstring Analysis	 + Project info Date: 16.07.2020 + TnD analysis General Operation FF Calibration [Tot + Static Analysis Scenarios [Total/D + Transient Dynamics Scenarios [Total/D 	s [Total/Done]: 0 / 0 al/Done]: 0 / 0 one]: 0 / 0 Analysis one]: 0 / 0	E Istri Istri e: ▼	s\Public\Docu ng Analysis\1\j
	Project caption	1	Client Logo	Contractor Log	ю —	
	Display Mode : Show folders w Sample Project Ok Cancel	ith Drilling project files only	V Unrvessal acconnist	iftwore 1 No Log	ər: Jo volv	ed:
U			30311	rar c		
		Universal 🧧	MECHANIS			No Logo
•	III. •	-Well Information		Comm	ients	

The project name is displayed on the **Project window** header.

Save I button is enabled and '*' postfix is added to the project name while any changing are made in the project.

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1.5.3. Open Project

One can load the previously created drilling project with Load 🖻 button on the head menu.

Program scans the **Source directory** automatically for available drillstring analysis projects. The list of projects lying in the **Source directory** or its sub-catalogues is displayed on the left panel of the **Open drilling project** window. The right panel contains the brief data on the selected project.

Click **Ok** to load the selected project in the new **Project window**. Click **Cancel** to close the dialog without project loading.

General General	
New Open Project Materials Formations Fluids Part database Well Wellbore trajectory Projects Open project Tools Open Drilling project Search: C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1\p escape C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\ Malysis Materials Formations Fluids Part database Vell Wellbore Training project	Image: Second construction Image: Second construction Image: Second construction Image: Second c
Display Mode : Show all folders Training project UM DrillString Ok Cancel	No Logo

One can use **Recent projects** list of application menu to load on of the recently opened projects.

(D S A UM			1			
			Recent projects				
	1.	New project		h.		Temperature map	🛄 Chen solution
			U. C:\Users\Public\Documents\UM Soft\Training project	F.		Pressure distribution	
		Open proiect	1. C:\Users\Public\Documents\UM Softw\Sample project	ore	Drillstring	NA Time bistony secondary	
					/ BHA	Time history generator	
				s		Auxialiary to	ols

1.5.4. **Project window**

DSA *Project* window interface enables access to the *General project info*, *Drilling information*, and *Static*, *T&D* and *Time Domain* analyses data.

1.5.4.1. Project navigation tools

Navigation on project items is implemented by **Project structure** tree placed on the left panel, and partially duplicated by the head mean pages.

DS P					Sa	ampleProje	ct.dsaproj ·	Project*	
Project info Drilling informatio	n T&D:	Genera	I Operatio	ns St	atic Analys	sis Tim	e domain a	analysis	Project report
² Open ¹ New point ¹ Inser ¹ Save ¹ Delete point ¹ Inser ¹ Save ¹ Delete point ¹ Clean ¹ File ¹ Duplicate point ¹ Clean	t before t after , ption[Well T	Trajectory	t ory tor]	sity Ch	eck Wellh Wellp	ead Sever tion wells	al Settir		ew plot reate copy elete plot
Project structure		🦻 📻	MD ft	Inc. dea	Azi dea	TVD ft	VSEC ft	N+/5- ft	F+/W- ft)oal
🖃 🔟 Project [SampleProject]			0.000	0.00	0.00	0.000	0.000	0.000	0.000
Drilling information		2	473.425	7.01	0.00	472.245	-26.683	28.928	0.000
🖳 🔨 Well Trajectory [Well Trajector	y]	3	557.7			140	-38.731	45.171	-7.600
Wellbore construction [Wellbo	re]	4	626.6	Hea	id meni	. 30	-38.713	48.335	-15.204
BHA[BHA1]		5	707.0	page	e contro) ₈₃	-43.605	51.854	-10.938
Drillstring [Sample DS]		6	793.963	10.17	42.44	/86.150	-63.546	68.721	0.407
DinD analysis		7	889.108	-19.11	45.16	879.975	-56.908	63.827	-5.092
General Operations		8	994 094	3.84	145.53	982.875	-38.957	48.676	-15.382
Slide Drilling 1	Clic	k to h	ide the	Pro-	46.48	1076.409	-50.933	56.347	-2.695
Rotation Off Bottom 1	iec	et etru	<i>cture</i> n	anel	42.70	1167.087	-55.428	59.464	1.497
Pick Up 1	,00	. 3110	ciure p	and	292.49	1261.040	-46.338	48.294	4.637
SlackOff 1		12	1371.391	18.19	8.69	1354.062	-61.007	59.148	16.696
Back Reaming 1		13	1466.535	3.93	266.38	1447.614	-74.091	73.760	15.677
Reaming 1		•							
🔤 💕 Fishing 1		Tor	tuositv						Contractor in the
🖨 👩 Static analysis 🚽 💕 Scenario 1		ቀ	- + ₄	X 🧕					
Scenario 2		#	From, ft	To, ft I	ength, ft	Amplitude	deg Per	riod, ft Va	riation
🖨 👩 Time domain analysis		1	328.08	3280.8	2952.8		20	328.084	Inc
🔤 💕 Scenario 1		2	0	0	0		1	328.084	Inc
🔤 💕 Scenario 2		3	0	0	0		1	328.084	Inc
🔤 Project report									
Project structure									
navigation tree									

1.5.4.2. General project info page

Project Info page of the head menu contains general description of the project.

- ✓ Project & project file information
 - Analysis date date of the last run of analysis or the project creation date.
 - Project version
 - Project file full path (with direct access to project folder by pop up)
- ✓ Client and Drilling Contractor information
- **Note:** Double click on the **Client Logo** / **Contractor Logo** field to upload the logo from file. Default set of logo image files is placed in *Source directory**logos*\ folder. Select **Clear logo** menu item from the pop up menu to erase the logo.
- ✓ Well information
- ✓ Project comments

DS E	Sample	Project.dsaproj - Projec	t*		
Project info Drilling information	on T&D: General Operations	Static Analysis Tir	ne domain analysis 🛛 🖡	Project report	
	Project Information		Project File I	Info	
	Analysis Date:	15.07.2020	Full nath:	C:\Lleare\Pul	hlic/Documents/RiMo/Well
Project (sampleProject) Drilling information Well Trajectory (Well Trajectory)	Project Version:	15.07.2020	run paul.	Engineering	Software\1\projects ect
Wellbore construction [Wellb	ore] Client Information		Drilling Cont	tractor	
BHA[BHA1]	Parent Company Name:	Client Company Ltd	Contractor	Name:	Contractor Company Inc
O ThD analysis	Local Legal Entity Name:	Client local entity	Product Li	nes:	Line 1, Line 2
Rotary Drilling 1	Region:	Oil region			
if Slide Drilling 1	Country:	Some country	Primary Er	ngineer:	Engineer
Pick Up 1	Country Office:	Country Office	All Engine	ers Involved:	All the team
Static analysis Scenario 2 Time domain analysis		Client Logo CANRIG DRILLING TECHNOLOGY LTD.		- Contractor Logo Mind Mesh	
Scenario 2	Well Information		Comments		
🖾 Ριοίεςι ιεbοιι	Client:	Client	Sample dril	llstring analysi	s project
	Region:	Oil region			
	Country:	Some country			
	Field:	Field 1			
	Site:	Site 35			

1.5.4.3. Drilling Information page

Access to the *Drilling information* items of the project – well trajectories, wellbore cases, BHA and drillstring cases – is realized by *Project structure* tree.

Project drilling info is displayed in the tree under **Drilling Information** node as the sub nodes, grouped under **Well Trajectories**, **Wellbores**, **BHA Cases**, **Drillstring Cases** nodes.

DS F	SampleProject.ds	aproj - Project*		
Project info Drilling information T8	D: General Operation	s Static Analysis	Time domain analy	vsis Project report 🕜
Image: Constraint of the second s	re selected r selected Verify data	Materials Formations Databases	Litem edit	or tools scheme report PDF re
Project structure	# Interval Type	Name Measured Dept	h, ft ıner Diameter,	Wellbore Intervals
Project [SampleProject] Drilling information Wellpath Cases Well Trajectory Wellbore Cases Wellbore Cases Wellbore Cases Wellbore Cases Delete wellbore Dilling information Clear calculated results Time domain analysis Project report	1 Open hole 2 Open hole 3 Open hole	 1 500 2 1500 3 7000 	2.000 15.00 0.000 15.00 0.000 12.50 0.000 12.25 2.000 12.25 12.25 etails the right the right hel	0 500 1 000 2 000 2 000 2 000 2 000 3 500 4 000 5 500 5 500 6 000 5 500 6 000 1 000 2 .40 2
	•		٢	-20 0 20 Inner Diameter, in

One can select a node to display/edit the item details on the right panel; head menu **Drilling Information** page is initialized by the corresponded item editor tools.

The pop up menu enables the following operations with the selected item:

- ✤ add new item;
- delete selected item;
- ♣ duplicate selected item;
- ¹ clear calculated results (delete results of all scenarios the item is used).

Note: The item data is read-only if the item is used in one or several calculated scenarios. The icon is used for read-only items in the *Project structure* tree.

If one will try to delete the read-only item the request on **Clear calculated results** will be generated automatically.

Well trajectory cases

Well trajectory item description functional is described in Sect.1.4.3.



Wellbore cases description

Wellbore item description functional is described in Sect.1.4.4.

DS T	Sample	Project.dsaproj - Project*			
Project info Drilling information Ta	&D: General Operation	s Static Analysis	Time domain analys	is Project repo	rt 🕑
Correl Correl </td <td>ore selected r selected Verify data</td> <td>Materials Formations</td> <td>Weak Pressure zones gradients Wellbore Hydraulics</td> <td>Scheme 1002 Show a</td> <td>II PDF report PDF re</td>	ore selected r selected Verify data	Materials Formations	Weak Pressure zones gradients Wellbore Hydraulics	Scheme 1002 Show a	II PDF report PDF re
Project structure	# Interval Type	Name Measu	ured Depth, ft Inner	Diameter, in au	Wellhove Interrals
Project (SampleProject) Project (SampleProject) Wellpath Cases Wellpath Cases Wellbore	Interval type Surface 1 Open hole 2 Open hole 3 Open hole	Name Press	0.000 500.000 1500.000 7000.000	15.00 25 15.00 25 12.50 25 12.25 15	Wellbore Intervals
	•			•	Inner Diameter, in

BHA cases description

Assembly description functional is described in Sect.1.4.5.



Drillstring cases description

Assembly description functional is described in Sect.1.4.5.

DIS T	SampleProject.dsaproj - Project*	
Project info Drilling information T	&D: General Operations Static Analysis Time domain analysis Project report	0
Load Save Save as File Duplicate part Duplicate part Dup	h Move up ↓ Move down tion validate DS] Move down ↓ Validate Database Jeff Drill Pipe] Blade Well Sections details geometry contact * connection * Advanced editing Advanced editing	Generate report PDF Report
Project structure	Bit	
Project [SampleProject]	A Part/Secti Description Count Type OD, in ID, in	CD, in
Wellpath Cases Well Trajectory Well Trajectory Wellbore Cases Wellbore construction 1 Wellbore construction 1 Wellbore SHA1 BHA2 Drillstring Cases Sample DS Drillstring 1 O TnD analysis O General Operations Static analysis	M ∑ ≷ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$ \$	Þ
Project report		



1.5.4.4. Analysis GUI

Drillstring analysis project can include any number of *scenarios* – blocks of input data, analysis settings and calculated results. List of scenario nodes is placed under the analysis node in the *Project structure* tree.



DSA Analysis GUI enables description of source data and analysis settings, validation of the inputs, generation of internal dynamic models, running the analysis and results output for single scenario, as well as for all scenarios for an analysis.

The pop up menu enables the following operations with the selected analysis or scenario nodes:

- 🕂 add new scenario
- delete selected scenario;
- 🔩 duplicate selected scenario;

✓ Operations available for single scenario, or all the scenarios:

- ♣ validate the scenario;
- ✤ generate model;
- 🔩 run analysis;
- 😼 clear calculated results;
- generate PDF report for single scenario or an analysis (see Sect.);
- select 2D plot line color for scenario.

One can select a scenario node to display scenario data on the right panel:

✓ Analysis Setup

Analysis setup page contains tools for basic and advanced scenario parameters description, visualization of the assembly position in the well, as well as the analysis run and evaluation progress control.

Basic parameters

Set of basic drilling scenario inputs placed on the middle panel: information (well trajectory, wellbore, bit position, assembly, drilling fluid, etc.), operation settings and solver settings.



Advanced settings

Advanced settings of dynamic model of the assembly and fine turning of the solver parameters are available in Advanced User and Developer mode. Content of the page depends on the analysis type.

Note: Setup parameters are read-only if the scenario is calculated, or running, or already calculated. The icon is used for read-only items in the *Project structure* tree. One needs to **Clear calculated results** to change the inputs.

Visualization of the assembly position in the well

Position of the assembly in the wellbore is displayed on **Position** page by the – *Horizontal displacement vs. TVD* plot, *Well trajectory* 3D view and *Wellbore scheme* (optionally).

Analysis run and evaluation progress control

Event Log page for control of analysis procedure and warning / error messages output.

Analysis Setup Results		
Scenario Caption	Advanced Settings Position Event Log	
Caption: Scenario 1	F	
Well Case	Event Log	Running Scenarios
Well Trajectory		Scenario: Scenario 2: 80%
Wellbore	No errors or warnings found.	
Wellbore		Scenario: Scenario 3: 52%
Bit Position, ft 3 743	Calculations Started	
		Scenario
Drilling Information	Analysis event log	evaluation
	Analysis event log	
		progress bars
Drillstring Case		
Sample DS		
		<u> </u>
V/OR kin 10	Run / interrupt analysis controls + 1	hread count control
10 IS		
	Run analysis Interrupt analysis Number of Pro	ocesses: 4 🏄 4Processors Available
	Done: 1/3	
	Analysis com progress of all	pletion progress bar: the analysis scenarios

Click **Run analysis** button to start evaluation of all the scenarios.

Analysis calculations are processing in parallel threads – one thread per scenario; the user can specify the maximal number of threads involved in the analysis by **Number of Processes** control on the bottom panel before or during simulation.

Individual progress bars are added to the right panel for each of the proceeding scenarios during the analysis.

Interrupt analysis control enables breaking of evaluation procedure.

✓ Results

Results page contains set of tools for calculated results output for single scenario, or selected set of scenarios.

2. Training project

This section contains the step-by-step description of the procedure of the training project creation, drilling information input, Static and Transient analysis scenarios description, analyses run, evaluation control and results post-processing within DSA application GUI.

Step 1.1. Create New project by the head menu button; the project window will be opened.

	General							
New project	Open project	Materials Formations	Fluids Part database	Well Wellbo	re Drillstring / BHA	Image: Temperature map Image: Temperature map Image: Pressure distribution Image: Temperature map Image: Temperature map Temperature map	settings	About Getting
Prot	iects	Datab	ases	Tools		Auxialiary tools	Settings	Help

also =	New - Project	
Project info Drilling information T&D: Ge	neral Operations Static Analysis Time domain analy	ysis Project report 🕜
Project info Drilling information T&D: Ge Project structure Project (New project) Trilling information Wellbore construction [Wellbore construct Wellbore construction [Wellbore construct BHA[BHA] General Operations Static analysis Time domain analysis Project report	Project Information Analysis Date: 16.07.2020 Project Version:	vsis Project report Project File Info Full path: Drilling Contractor Contractor Name: Product Lines: Primary Engineer: All Engineers Involved: Contractor Logo No Logo
	Well Information Client Region: Country: Field:	Comments
< >	Site:	

2.1. General project data input

Step 2.1. Use **Project Info** tab to input general project information like project date and version, client and drilling contractor information, location data, well information and some comments on the project.

Project Information						
Analysis Date:	14.08.2018					
Project Version:	1					
Client Information		Drilling Contractor				
Parent Company Name:	Drilling Customer	Contractor Name:	Contractor			
Local Legal Entity Name:	Legal Name	Product Lines:	Line 1, Line 2			
Region:	Some Region					
Country:	Some Country	Primary Engineer:	Engineer			
Country Office:	Some Office	All Engineers Involved:	All the team			
	TECHNOLOGY LTD.					
Well Information		Comments	Comments			
Client:	Rich Client	Sample project- sample d	Irillstring project for illustration of me Domain Analysis in RiMo			
Region:	Oil Region	software.	software.			
Country:	Warm Country					
Field:	Gas-Oil field					
Site:	Site					

You can add client and drilling contractor logos to make project more recognizable. Double click on **Client Logo** and **Contractor logo** panel to load of the logos from *Source directory**logos*\ default folder, or any other location.



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Step 2.2. Save modified project as **Training project**. The name will be added to the **Project window** caption.

Save Drilling project as	X
Search: C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1\projects C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1\projects Nabors-BHA1 Sample Project	Project : Sample Project Project path : C:\Users\Public\Documents\UM Si + Project info Date : 16.07.2020 + TnD analysis General Operations [Total/Done]: 0 / 0 FF Calibration [Total/Done]: 0 / 0 + Static Analysis Scenarios [Total/Done]: 0 / 0 + Transient Dynamics Analysis Scenarios [Total/Done]: 0 / 0 Client Logo Contractor Logo
Display Mode : Show folders with Drilling project files only Training Project Ok Cancel	University account of the second seco

Step 2.3. Click the Save project as bottom again and select the project from the list. You can see that the input data is stated on the right panel of the Open/Save project dialog window.

Close the dialog by clicking **Cancel**.

Open Drilling project	×
Search: C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1\projects	Project : Training Project Project path : C:\Users\Public\Documents\UM S
C:\Users\Public\Documents\UM Software Lab\Drillstring Analysis\1\projects Sample Project Training Project	 Project info Date : 16.07.2020 TnD analysis General Operations [Total/Done]: 0 / 0 FF Calibration [Total/Done]: 0 / 0 Static Analysis Scenarios [Total/Done]: 0 / 0 Transient Dynamics Analysis Scenarios [Total/Done]: 0 / 0
Brief view of the project general info	Client Logo Contractor Logo
Display Mode : Show all folders Training Project Ok Cancel	Universal accounts No Logo

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2.2. Drilling information description

In this section we will path through the input of source data general for Static, Torque&Drag and Time Domain analyses.

2.2.1. Well trajectory

The interface of **Well Trajectory Editor** placed on the page and program capabilities in survey data description are described in Sect.1.4.3 Well Trajectory Editor.

DIS F		Tra	ining project.dsapro	- Project*		
Project info Drilling information	T&D: General	Operations Stat	ic Analysis Tim	e domain ana	lysis Project	report 🕑
the sector of the sector	New point elete point uplicate point	Insert before Insert after Clear Description[Well Tra	Trajectory generator jectory]	Check	3 d Several Wellpath collision c.	Bettings Settings Settings
Project structure	# MD, ft	Inc, deg Azi, deg	TVD, ft VSEC, f	t N+/S-, ft	E+/W-, ft 🔺	Plots 3D scheme
🖃 🔟 Project [Training project]	1 0.00	0.00 0.00	0.000 0.0	0.000	0.000	TVD vs. Horizontal Displacement MD vs. Dogleg
Drilling information	2 478,42	5 0.00 0.00	473.425 0.0	0.000	0.000	
Well Trajectory [Well Traje	3 55 .74	3 0.53 145.54	557.742 0.2	-0.322	0.221	
Wellbore construction [Wellbore]	4 626.64	0 0.62 12.30	626.638 0.0	-0.220	0.480	
Drillstring (Sample DS 1	5 707.02	1 0.53 28.82	707.014 -0.7	0.531	0.752	0 2000 4000
	6 793.96	3 0.53 42.44	793.953 -1.5	58 1.180	1.217	
General Operations	7 889.10	B 0.26 45.16	889.095 -2.1	2 1.657	1.667	
Static analysis	8 994.09	4 0.09 145.53	994.081 -2.3	1.757	1.883	
Scenario 1	9 1089.23	9 0.09 46.48	1089.226 -2.3	75 1.746	1.980	
💿 Time domain analysis	10 1181.10	2 0.09 42.70	1181.089 -2.5	9 1.849	2.081	2000
Project report	11 1276.24	7 0.09 292.49	1276.233 -2.5	79 1.933	2.062	
	12 1371.39	1 0.09 8.69	1371.378 -2.6	2.035	2.005	문 문 문 문 문 문 문 문 문 문 문 문 문 문 문 문 문 문 문
	13 1466.53	5 0.18 266.38	1466.522 -2.6	58 2.100	1.867	2
	14 1555.11	8 0.18 272.01	1555.104 -2.5	2.096	1.589	
	15 1650.26	2 0.35 143.51	1650.248 -2.3	1.867	1.612	4000
	16 1837.27	0 0.18 168.56	1837.254 -1.8	1.120	2.010	
	17 1929.13	4 0.45 130.54	1929.116 -1.5	0.744	2.313	
	18 1968.50	4 1.40 185.94	1968.481 -1.0	2 0.165	2.381	
	19 2066.92	9 4.35 198.25	2066.772 3.8	02 -4.577	1.087	
	20 2165.35	4 7.34 200.58	2164.674 13.8	-14.010	-2.293	6000
	21 2263.78	0 10.34 201.56	2261.919 28.9	26 -28.114	-7.750	0000
	22 2293.73	4 11.25 201.76	2291.343 34.5	-33.328	-9.821	Horizontal Displacement, ft
	23 2362.20	5 11.25 201.76	2358.499 47.8	-45.734	-14.773 +	
4					•	

- Step 3.2. Click the Open is button on the head menu to load survey data from Source directory\wellpaths\ Sample Wellpath.wlp file. Loaded data will be displayed in the table and on the right hand plots.
- **Note.** If you've already input some data to the table program will ask you to save it before loading.
- **Step 3.3.** Click the **button** placed on the head menu. The 'No errors or warnings found' message will appear if the input data is correct.

Step 3.1. Select the **Drilling Information** | **Well trajectory** *Project tree* node to input survey data.



2.2.2. Wellbore construction

Step 3.4. Select the **Drilling Information** | **Wellbore construction** *Project tree* node to describe the wellbore.

The interface of **Wellbore Editor** placed on the page and the internal description of wellbore cross section are described in Sect. 1.4.4 Wellbore Editor.

DIS -	Training project.dsaproj - Project*	
Project info Drilling information T&D:	eneral Operations Static Analysis Time domain analysis Project report	0
the set of the s	ral Z clear Description[Welbore] Descri	ව DF sort re
Project structure	# Interval Type Name Measured Depth, ft Inner Diameter, in Overgauge, in tion Fa	Wellbore Intervals
Project [Training project] Project [Training project] Project [Training project] Project report Vellbore construction [Vellbore] Vellbore construction [Vellbore] Project report	Surface 0.000 15.00 0.25 0.200 1 Open hole 1 500.000 15.00 0.25 0.200 2 Open hole 2 1500.000 12.50 0.25 0.200 11 3 Open hole 3 7000.000 12.25 0.15 0.200 11	0 (1) 15.250 (2) 12.750 000 500 000 500 000 (3) 12.402 000 500 000 500 000 12.402 000 12.402
	61 70 *	500 -20 0 20 Inner Diameter, in

- Step 3.5. Click the Open button on the head menu to load wellbore description from *Source directory\wellbores\Sample Wellbore.wlb* file. Loaded data will be displayed in the table and on the right hand plots.
- **Note.** If you've already input some data to the table program will ask you to save it before loading.
- **Step 3.6.** Click the **button** placed on the head menu. The 'No errors or warnings found' message will appear if the input data is correct.



2.2.3. BHA Cases

Step 3.7. Select the **Drilling Information** | **BHA** *Project tree* node to describe the bottom hole assembly design.

The interface of **BHA Editor** placed on the page and the internal description of assembly design are described in Sect. 1.4.5 Drillstring / BHA Editor.



Note. One can load the Sample Rotary BHA model from the *Source directo-ry\drillstrings\Sample Rotary BHA.bha* file with the **Open** [□] button on the head menu, ignore **Steps 3.8 - 3.13** and come to page 72.

Getting Started **D**S **A**UM

2.2.3.1. Rotary BHA description

Let's create rotary assembly consisted of the components listed in the table below:

	Description	Count	Acc. length, ft
1	12 1/4" PDC Bit	1	1.45
2	12 Stabilizer	1	4.55
3	Collar	1	9.45
4	MFR tool	1	37.45
5	12 3/16" Stabilizer	1	43.45
6	MWD tool	1	65.45
7	Crossover	1	67.45
8	12 1/4" Roller Reamer	1	77.45
9	Collar	1	107.45
10	Float Sub	1	109.45
11	XO Sub 3.0	1	111.45
12	4 x 6 5/8" HWDP	4	231.05
13	8" Jars	1	261.05
14	5 x 6 5/8" HWDP	5	410.05
15	Accelerator	1	440.06
16	2 x 6 5/8" HWDP	2	500.4
17	XO Sub 2.8	1	502.4
18	5" Drill Pipe	1	533.4
19	Dart Sub	1	536.4
20	5 " Drill Pipe	1	567.4

Step 3.8. Click the **Part Database** button on the head menu to open the database wizard. The delivered database contains all the elements of the assembly.





Step 3.9. In String Part Database window select 12 ¹/₄ PDC Bit part from the Drill Bits category and drop it to the *String Editor* table.

The new component will be added to the Rotary BHA case string, PDC **Bit** figure will be shown on the bottom.



Step 3.10. Add sequentially in the same manner the following components 12¼"
Stabilizer, Collar, MFR tool, 12 3/16" Stabilizer, MWD tool, Crossover, 12 1/4" Roller Reamer, Collar, Float Sub and XO Sub 3.0.

New components are added to the end of the list. Use buttons on the head menu to change the order of the components if necessary.



Step 3.11. Now we need to add four sections of 6 5/8" HWDP. We can drag the HWDP component to the table four times, but the easiest way is to add the part single time and set Count parameter (four) in the table row.



Step 3.12. Add sequentially the rest components: 8" Jars, 5 x 6 5/8" HWDP, Accelerator, 2 x 6 5/8" HWDP, XO Sub 2.8, 5" Drill Pipe, Dart Sub and 5"Drill Pipe.



Finally check, that the total length of the Rotary assembly is equal to 567.4 feet.

Step 3.13. Click the **b**utton placed on the head menu. The 'No errors or warnings found' message will appear if the input data is correct.

2.2.4. Drillstring Cases

Step 3.14. Select the **Drilling Information** | **Drillstring** *Project tree* node to describe the bottom hole assembly design.

The interface of **String Editor** placed on the page and the internal description of assembly design are described in Sect. 1.4.5 Drillstring / BHA Editor.



- Step 3.15. Click the Open button on the head menu to load the drillstring description from *Source directory\drillstrings\Sample Drillstring.drs* file. Loaded data will be displayed on the right hand panel.
- **Note.** If you've already input some data to the table program will ask you to save it before loading.
- **Step 3.16.** Click the **D** button placed on the head menu. The 'No errors or warnings found' message will appear if the input data is correct.

Description of drilling info items for Static and Time Domain Analysis completed.

Step 3.17. Save the Project.
2.3. Static Analysis

The section contains brief overview of the Static Analysis concept, and step-bystep description of Static analysis of the Rotary BHA assembly in the sample well trajectory.

Static analysis overview

DSA application provides set of tools for the study of the equilibrium state of the assembly for the definite position in the well. Time domain simulation is used for evaluation of equilibrium state of the assembly:

- Assembly is placed in the wellbore along the well axis in accordance to the user-defined bit position
- Bit/top constraints and forces/torques are applied to the assembly model.

Default loading scheme is the following: axial motion of the bit is constraint, axial force – defined as "Weight-on-Bit" – is applied to the top point of the assembly.

Note: Static scenario boundaries (bit and top constraints of the assembly model) can be modified in **Advanced User** and **Developer** mode.

- Time domain simulation of the model motion is started; the model reaches an equilibrium state under action of applied forces and boundaries, contact interaction with wellbore walls, gravity forces and internal/external damping forces.
- Equilibrium state is fixed by the attenuation of kinetic energy of the system.
- Deformed shape of the assembly, distribution of assembly-wellbore contact forces, internal force factors, and stress state of the assembly units at the equilibrium state are evaluated and saved to binary result files.

Static Analysis GUI enables study of any number of test cases – *scenarios* – within single project. Static Analysis scenario (or *Static scenario*) is defined by the following basic inputs:

- Well case info: well trajectory case, wellbore case and bit position.
- Drilling Info: BHA case and drilling fluid.
- Operational settings: Weight-on-Bit value, corresponded (by default) to the axial force at the top point of the assembly.
- Set of advanced settings available for the Advanced User or Developer.

2.3.1. Scenario description

Step 4.1. Select the **Static Analysis** *Project tree* node to access the Static Analysis GUI, and **Add scenario** by popup menu or head menu button.

	Training project.dsaproj - Project*	
Project info	Drilling information T&D: General Operations Static Analysis Time domain analysis	Project report 🛛 😧
Add scenario Delete scenario Add scenario Duplicate scenario	B B B B B B B B B B B B B B B B B C B C <thc< th=""> C C C C<td>Display wellbore scheme Advanced model settings</td></thc<>	Display wellbore scheme Advanced model settings
Scenarios	Scenario[<not selected="">] All scenarios Report</not>	GUI Settings
Project [Trainii Project [Trainii Project [Trainii Project [Trainii Wellbor Wellbor BHA[6] BHA[6] BHA[6] O General O General O Static analy O Static analy O Static analy Project repo	Analysis setup ing project sumation ajectory (Well Trajectory) re construction (Wellbore] t4 1 Ing (Sample DS) sis I Operations I Validate all scenario ort Validate all scenario Run analysis Clear results Generate report for analysis I No scenario is selected I S Generate report for analysis	

Scenario 1 test case will be added to the Static Analysis scenario list; the corresponded node will be added to the *Project structure* tree and focused by default; scenario data will be displayed on the right panel, **Analysis Setup** page.

DS F	Training project.dsaproj - Project*	
Project info Drilling information	T&D: General Operations Static Analysis Time domain analysis Project report	0
Add scenario Delete scenario Valdate Generate Ru Valdate Generate Ru Scenarios Scenario[Scenario]	Image: Clear size results Image: Clear size results <thi< th=""><th></th></thi<>	
Project structure	Analysis setup	
Project [Training project] Well Trajectory [Well Trajectory] Well Trajectory [Well Trajectory] Wellbore construction [Wellbore] Wellbore constructin [Wellbore] Wellbore construction [Wellbore] Wellbore co	Scenario Caption: Scenario 1 Vell case Vell trajectory Well trajectory Image: Caption: Driling fluid Image: Caption: Air Image: Caption: Parameter Yalue Weight on bit, kip *ft 0 Top RPM, RPM 0 Drop speed, ft/hr 0	DS position in well 0 500 1000 15250 (2) (2) 2,750 1500 2,000 2,000 3,000 4,000 4,000 5,000 4,000 5,000 4,000 5,000 4,000 5,000 4,000 5,000 4,000 5,000 4,000 5,000 4,000 5,000 4,000 5,000 5,000 4,000 5,000 5,000 4,000 5,000
•	3913 -5842	Inner Diameter, in

Set the basic parameters of the new scenario by the middle panel controls.

- **Step 4.2.** Set **Training scenario** caption for the scenario. The scenario node name will be update in the *Project tree* automatically.
- **Step 4.3.** Select the **Well trajectory** item from the **Wellpath** list; the list contains all the well trajectories defined in the project.

Note: One can click on ^(K) button to come to the **Well trajectory** item description page.

Step 4.4. Select the **Wellbore** item from the **Wellbore** list; the list contains all the wellbore designs defined in the project.

Note: One can click on **E** button to come to the **Wellbore** item description page.

- Step 4.5. Set Bit Position value equal to 6500 ft.
- **Step 4.6.** Select the **BHA 1** item from the **Bottom Hole Assembly** list; the list contains all the bottom hole assembly designs defined in the project.

Note: One can click on button to come to the **BHA 1** item description page.

- **Step 4.7.** Select the **Drilling fluid 1** item from the **Fluid** list; the list contains all the fluids from the Fluids Database (see Sect.1.4.1.3).
- Step 4.8. Set Weight-on-Bit (WOB) value equal to 10 kip; Torque on bit 1 kip*ft; Top RPM 60rpm; Drop speed 15 ft/hr.



Step 4.9. Click on **Validate Scenario** button in the *Project tree* popup menu, or the head menu to validate the description of the scenario.

Event Log page will be displayed automatically on the right panel; the 'No errors or warnings found' message will appear if the input data is correct.

DIS E			Training project.de	saproj	- Project*	
Project info Drilling info	rmation	T&D: General Operatio	ons Static Analysis	Time	e domain analysis Project report	Ø
Add scenario	nerate Ru odel anal ario[Scenario	n Clear ysis results 1]	Generate Run Clear all models analysis results All scenarios	Ge	Report GUI Settings	
Project structure	<u>@</u>	Analysis setup				
Project [Training project] Training project] Training information Well Trajectory [Well Training project]	rajectory]	Scenario Caption Caption: Scenario 1 Well case			Position Event Log	
BHAIBHA 11	[Wellbore]	Well trajectory			- Event Log	Processing scenarios
TnD analysis]	Well Trajectory Wellbore construction Wellbore	• 1 •	*** •	Critical errors not found	
Scenario 1		Bit Position, ft	8 794.75			
Time domain analysis	Add :	scenario		0		
m project report	🗢 Delet	e scenario	u.			
			- -	(Lines)		
	Valid	rate model		-		
	Run a	analysis	•	3		
	Clear	results				
	🖹 Gene	rate report	Value			
	Resu	kip ts output settings 🕨 kir) 10)*ft 1			
		Top RPM, RPM	60		Run analysis Interrupt an: 4	Number of Processes: 4Threads available
		Drop speed, ft/hr	15		Done:0/1	_
٠ III	•				k.	

Training Scenario is described, validated and ready for running now.

Step 4.10. Save the **project**.

Recent projects 0. C:USersiPublic/DocumentsiRiMo\Training project Image: Save as 0. C:USersiPublic/DocumentsiRiMo\SampleProject Image: C:USersiPublic/DocumentsiRiMo/WellVIMK_Test Image: Certification and the second of the seco	DIS	D∓		Training	project.dsapro	j - Project*				
ColdsersiPublic/Documents/RiMo/Training project ColdsersiPublic/Documents/RiMo//SampleProject ColdsersiPublic/Documents/RiMo/Well/TMK_Test Save as ColdsersiPublic/Documents/RiMo/Well/MK_CP-DT ColdsersiPublic/Documents/RiMo/Well/MC-P-DT ColdsersiPublic/Documents/RiMo/Well Engl/DT_1 Position Event Log Position Event Log Processing scenarios Critical errors not found Ortifical errors not found Project report Project report Project report Project report Driling Information Bottom Hole Assembly HA 1 Driling fluid	AUM	Recent projects		Static An	nalysis Tin	e domain anal	ysis Project report			0
Save 1. C:UsersiPublic:Documents/RiMoLSampleProject C:UsersiPublic:Documents/RiMoWellTMK_Test C:UsersiPublic:Documents/RiMoWellMM-C-P-DT 4. C:UsersiPublic:Documents/RiMoWellMM-C-P-DT 4. C:UsersiPublic:Documents/RiMoWell EngiIDT_1 Settings Settings Settings Settings Settings Well Trajectory Well Trajectory Wellore construction Wellore Static analysis Settings Settings Settings Settings Settings Settings Settings Difficition Wellore Settings Settin	🗃 Load	0. C:\Users\Public\Documen	ts\RiMo\Training project	o [©] (•)	E		Display wellbore scheme			
Seve as 3. C:UsersiPublic/Documents/RiMo/WellWAC-P-DT Seve as 4. C:UsersiPublic/Documents/RiMo/WellWAC-P-DT Settings 5. C:UsersiPublic/Documents/RiMo/Well EngiDT_1 Position Event Log Event Log Event Log Critical errors not found Critical errors not found Critical errors not found Driling Information Bit Position, ft 8 794.75 Driling Information Bit Position Hole Assembly BHA 1 Event Log	Save	1. C:\Users\Public\Documen	ts\RiMo\\SampleProject	nerate Run models analys	Clear G sis results	enerate report for analysis	Advanced model settings			
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Well Trajectory Critical errors not found Original Signaple DS] Well Trajectory The density of the den			11.1.2			Event Log		P	Processing scenarios	
Air Image: Constraint of the second seco	☐ Dril ☐ ⑦ TnD ai ⑦ Ge ⑦ Static ◎ Static ⑦ Time c ⑦ Time c	illstring (Sample DS) analysis eneral Operations a analysis enario 1 domain analysis ct report	Well Trajectory Wellbore construction Wellbore Bit Position, ft Dilling Information Bottom Hole Assembly BHA 1 Drilling fluid Air Parameters Parameters Weight on bit, kip*ft Top RPM, RPM Drop speed, ft/hr		▼ Image: Second se	Critical error	<u>s not found</u> alysis	<u>×</u> N	lumber of Processes: 4	4Threads available



2.3.2. Analysis run

Step 4.11. Select **Event Log** page, and click on **Run Analysis** button to start the evaluation of the described scenario.

Individual progress bar will be added to the right **Running Scenarios** panel; "--- **Calculations Started** ----" record will be added to the **Event Log**; scenario inputs will be blocked automatically.

Analysis setup		
Scenario Caption	Advanced Settings Position Event Log	
Caption: Scenario 1	F , #	
Well case	- Event I og	Processing scenarios
Well trajectory		Scenario: Scenario 1: 91%
	Critical errors not found	
Wellbore construction		
Wellbore	Calculations Started	
Bit Position, ft 8 794.75	16.07.2020 15:45:10	Individual
0	Calculations Started	progress bar of the
Drilling Information		processing scenario
Bottom Hole Assembly		
BHA 1		
Drilling fluid		
Air 👻		
Parameters	Dup evolution	
Parameter Value	Run evaluation	
Weight on bit, kip 10		
Torque on bit, kip*ft 1		
Top RPM, RPM 60	Run analysis Interrupt analysis 1 🏂	. Number of Processes: 4Threads available
Drop speed, ft/hr 15	Done:0/1	
		
Scenario inputs are blocked		

- **Note:** Input data validation, and project saving is carried out automatically before process is running.
- **Note:** One can use **Run all scenarios** button from the *Project tree* popup menu or head menu to start the evaluation; the **Run scenario** button enables run of the selected scenario only.



UM Drillstring Analysis

Scenario progress bar displays the current progress of the evaluation procedure. The progress is closed after completion of the scenario calculation; the scenario analysis details are added to the **Event Log**.

Analysis setup				
Scenario Caption		Advanced Settings Posi	tion Event Log	
Caption: Scenario 1				
Well case		o≱ o.*		
Well trajectory		Event Log		Processing scenarios
Well Trajectory	1	Critical errors not found	<u>^</u>	
Wellbore construction				
Wellbore	-	Calculations Started -		
Bit Position, ft	8 794.75		Information	
		16.07.2020 - 15:45:19		
		Calculations Started	Static Analysis: Calculati	ons Completed Successfully.
Drilling Information				
Bottom Hole Assembly		16.07.2020 - 15:45:21		
BHA 1	-	Scenario: Scenario 1		Ok
Drilling fluid		Wellbore Intervals: Well	Ibore	
Air	-	Bit position: 8794.75 ft		
Parameters		Calculations Complete	d Successfully	
Parameter	Value	Evaluation time: 00:00:	02	
Palameter	value			
vveight on bit, kip	10		-	
Torque on bit, kip*ft	1	40.07.0000 46-46-04		 e
Top RPM, RPM	60	Run analysis	Interrupt analysis 1	Number of Processes: 4Threads available
Drop speed, ft/hr	15	Done:1/1		

'Static Analysis Calculations Completed Successfully' message will be generated after the completion of all running scenarios (single scenario in our case). Normally, calculation of the scenario should take about 3-10 seconds.

Step 4.12. Click Ok to close the message.

Results for the scenario has been calculated and stored in the scenario folder on hard drive; calculated scenarios are marked by icon in the Project tree.

Step 4.13. Select the Training Scenario node in the Project tree, and open pop up menu. The Clear results option is available now; one needs to clear the results to modify description of the scenario. Close the pop up.



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2.3.3. Results output

DSA GUI provides the various tools for 2D and 3D graphical output of the calculated deformed shape of the assembly, distributions of contact forces, internal force factors and stresses along the assembly:

- Brief results: set of 2D plots of the various result items on the single page.
- 3D View: 3D visualization of the assembly model in the wellbore.
- 2D View: 2D straightened side section / cross section view of the deformed shape of the assembly in the hole.



Step 4.14. Select the calculated scenario node (Training scenario) in the *Project* tree to make the **Results** page on the right page control visible, and go to the page.



2.3.3.1. Brief results

Step 4.15. Select **Results** | **Brief Results** page to display the set of 2D plots of the various result items.

One can select an output from the check box list – the corresponded dependency of the selected output vs. distance from bit will be displayed on the 2D plot on the right panel.



Step 4.16. Click on ^{III} button to switch between brief and full list of outputs.

Brief list of outputs	Brief Results Coutputs PosX, mm - Horizontal BHA displacements Vertical BHA displacements Cotarace, mm - BHA-wellbore contact forces Cotact Force, kN - BHA-wellbore contact forces Vaz, kN - Axial force MBEnd, RN'm - Bending moment SigmaBend, MPa - Bending stress von Mises Stress, MPa - Equivalent von Mises stress BHA.DogLeg, deg - BHA.DogLeg severity	Full list of outputs	Brief Results Cuputs PosY, mm - Horizontal BHA displacements PosY, mm - Vertical BHA displacements Displacement, mm - Lateral BHA displacement Clearance, mm - BHA-wellbore clearance MX, kN*m - Bending moment in vertical plane MX, kN*m - Bending moment in vertical plane MX, kN*m - Torsional moment QX, kN - Horizontal joint force QX, kN - Horizontal joint force QX, kN - Horizontal joint force QX, kN - Horizontal stress generated by MX SigmaMX, MPa - Normal stress generated by MX SigmaMX, MPa - Normal stress generated by QX TauQX, MPa - Shear stress generated by QX SigmaQZ, MPa - Axial stress generated by QZ MBend, kN*m - Bending moment Q, kN - Joint force SigmaBend, MPa - Bending stress Sigma, MPa - Normal stress (bending + axial) V von Mises Stress, MPa - Equivalent von Mises stress
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2.3.3.2. 3D View

Step 4.17. Select **Results** | **3D view** page to study the 3D position of the assembly in the well.



On can turn on and save the 3D View by the set of options:

- - make the screen short of the 3D view;
- \Box zoom by rectangle (by mouse);
- \square set full view;
- 🕙 move camera by mouse;
- scale by mouse up/down move;
- ☞ rotate by mouse;
- $\widehat{}$ fix rotation point;
- - select one of the standard views;
- display edges only;
- Image: a constraint of the second second
- display faces only;
- \mathbb{R} select the wellbore display mode;
- display survey stations;
- I display well axis line;
- display geo data;
- set camera on bit;
- $\overset{\text{\tiny d}}{=}$ display the wellbore reference frames;

Step 4.18. Click on ⁴ button to display the frame image on the 3D view and add the wellbore reference frame wizard on the right of the page.



The **Local reference frames** tool enables specifying on any number of local reference frames along the hole/assembly, and wide range of display settings of the frames.

The frame position can be defined by **Distance from surface** or **Distance from bit**; the user can show/hide the frame axes, grids and planes, select its size and coloring. One can collapse the unused panel from the wizard.

Step 4.19. Select the Cross section view panel, enable Well cross section and Drillstring cross section to display the scaled cross section view; change the Position to study local position of the assembly in the well.



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2.3.3.1. 2D View

Step 4.20. Select **Results** | **2D view** page to study the 2D Side / cross section view of the assembly in the well.

The well axis is straightened; **PosX** plot corresponds to the displacement of the assembly points in the Z-X wellbore reference plane (reference frame orientation is calculated at each point) – and can be considered as lateral-horizontal displacement of the assembly in the well; **PosY** - corresponds to the lateral-vertical displacement of the assembly in Z-Y wellbore reference frame.



Step 4.21. Click the button to display the cross section of the well on the right of PosX, PosY plots. Use slider or input Distance from Bit manually to define the cross section position.



2.4. Torque & Drag Analysis

The section contains brief overview of the Torque & Drag Analysis concept, and step-by-step description of T&D analysis of the assembly combined from Rotary BHA and Sample DS assemblies.

Torque & Drag analysis overview

DSA application provides set of tools for the estimation of drag forces and resistance torque distribution along the drillstring for standard set of technical operations on rig within soft-string and stiff-string model of an assembly.

- ✓ Soft-string analysis is the fast solution based on assumption of positioning of assembly along the well trajectory.
 - Drillstring state is estimated analytically by numerical integration of flexible curved beam equilibrium state differential equations; by fact the procedure can be described considered as sequential solution of equilibrium state problem for short drillstring sections from bit to surface.
 - Boundary conditions axial force and torque are defined at bit point in accordance to selected operation type.
 - Contact forces are estimated from the bending of the drillstring section taken from the well curvature at point; friction forces and resistance torque on section are estimated from assembly-wellbore friction coefficient and the considering combination of tripping and section rotation.
 - Axial force at the top point of section is evaluated from the balance of gravity forces and friction forces.
 - Increasing of resistance forces by sinusoidal and helical buckling effects are considered from the conventional analytical equations.
 - Drag forces and resistance torque, contact forces, internal force factors and stress state of the assembly components, as well as elongation of the assembly are estimated.
 - Effects on temperature elongation of the assembly units can be considered optionally by account of temperature map.
 - Internal / external pressure effects on the resultant stress state can be considered optionally by account of pressure distribution.
- ✓ Stiff-string analysis is the detailed analysis considering local deformations and lateral displacements of assembly units in the borehole; application of Static Analysis approach (Sect.2.3) for the whole drillstring.

UM Drillstring Analysis

Torque & Drag Analysis GUI enables study of any number of test cases – *scenarios* – within single project. Torque & Drag Analysis scenario (or T&D scenario) is defined by the following basic inputs:

- Well case info: well trajectory case, wellbore case and bit position.
- Drilling Info: BHA case, Drillstring case and drilling fluid.
- Operational settings: type of technical operation and corresponded parameters (Weight On Bit, Torque on Bit, Penetration rate, Surface RPM, etc.).
- Set of advanced settings: Temperature map and Pressure distribution data.
- Advanced model settings available for the **Advanced User** or **Developer**.

2.4.1. Scenario description

Step 5.1. Select the **TnD Analysis** | **General Operations** *Project tree* node to access the analysis GUI, and **Add scenario** by popup menu or head menu button.

DS E	Training project.dsaproj - Project	
Project info	Drilling information T&D: General Operations Static Analysis Time domain analysis Project report	0
Add scenario Delete scenario Luplicate scenario	Image: Constraint of the sector of the se	
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Project s Project [Trainin Project [Trainin Drilling infor Well Dray BHA[BH/ Drillstring OrnD analysis Project State BHA[BH/ Drillstring Project State BHA[BH/ Drillstring Project State BHA[BH/ Drillstring Project State State Project State Project State Pr	structure Seconstruction [Wellbore] Analysis setup Construction [Wellbore] Ang Seconstruction [Wellbore] S Operation Ang Add scenario	
⊕ O Static analys ⊕ O Time domai ⊕ Project repo Project repo	sis Validate all scenarios rt Validate all scenarios Generate all models Clear results Generate report for analysis	

Rotary drilling 1 test case (default naming is taken from operation caption) will be added to the TnD Analysis | General Operations scenario list; the corresponded node will be added to the *Project structure* tree and focused by default; scenario data will be displayed on the right panel, **Analysis Setup** page.

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Training project.dsaproj - Project*





Set the basic parameters of the new scenario by the middle panel controls.

Step 5.2. Select the Well trajectory item from the Wellpath list; the list contains all the well trajectories defined in the project.

> Note: One can click on ^[15] button to come to the Well trajectory item description page.

Step 5.3. Select the Wellbore item from the Wellbore list; the list contains all the wellbore designs defined in the project.

> Note: One can click on **u** button to come to the Wellbore item description page.

Set **Bit Position** value equal to 6500 ft. **Step 5.4.**

Rotary Drilling

Select the BHA 1 item from the Bottom Hole Assembly list; the list Step 5.5. contains all the bottom hole assembly designs defined in the project.

> Note: One can click on 🗮 button to come to the **BHA 1** item description page.



4 500

- Step 5.6. Select the Sample DS item from the Drillstring list; the list contains all the Drillstring cases designs defined in the project.
 Note: One can click on button to come to the Sample DS item description page.
- **Step 5.7.** Select the **Drilling fluid 1** item from the **Fluid** list; the list contains all the fluids from the Fluids Database (see Sect.1.4.1.3).
- Step 5.8. Select Rotary Operation scenario, and define parameter values: Weight-on-Bit - 10 kip; Torque on bit – 1 kip*ft; Top RPM – 60rpm; Penetration Rate – 15 ft/hr.

Step 5.9. Select **Soft-string** solver type.

Analysis setup											
Scenario Caption			Adva	nced Se	ettings	Positio	on Even	t Log			
Caption: Rotary Drilling 1			2D P	lot 3D	schem	•		-		20	
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Well trajectory	(#*)		*	Ō		10	ଙ୍ [ଦ୍	1		, v	
Well Trajectory			<u> </u>							500	
Wellbore construction					TVD.	A					
Wellbore	- 1				,					1 000	12 00
Bit Position, ft	6 500 🔳			2000				1			
0				2000						1 500	
Drilling Information	т. т. т.									2 000	
Bottom Hole Assembly											
BHA 1	-									2 500	
Drillstring							Horizo	ntal Displace	ement, ft		
Sample DS	- ₩				L.	2	2000	4000	,	3 000	
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Slide drilling					11					W 5 000	
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TOP POINT RPM, RPM	60			-0000						8 500	
Church and											
Soft-String Stiff-string	a							1		Tua	0 er Diameter
Sole Sure Sure Sure Sure Sure Sure Sure Sur	9	-									ter Diameter,

Step 5.10. Select **Advanced Settings** | **Temperature map** page to describe temperature map distribution for the well on the right panel.

Click the **Open** E button on the head menu of the *Temperature map editor* to load the sample temperature distribution from *Source directo-ry**temperatures*\ *Sample temperature map.tmf* file.

Click the Motion to visualize the distribution on plot.



Step 5.11. Select Advanced Settings | Pressure distribution page to describe internal/external pressure distribution for the drillstring on the right panel.
Click the Open 🖆 button on the head menu of the *TPressure distribution editor* to load the sample from *Source directory*/pressures\ Sample pressure map.pmf file.

Click the Motion to visualize the distribution on plot.

Analysis setup		Advor	ood Cottin	1							
	£.	Advar	iced Settin	gs In Event	Log						
Caption: Rotary Drilling 1		Tem	perature m	ap Pressure distrib	ution						
Well case		Pres	ssure dist	ibution							
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Well Trajectory 👻				아 ᅳ `+ #" హ	<u>∧ ⊠ ⊠</u> ⊠						
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Bottom Hole Assembly		7	1968.5	5221.36	2		$\mathbf{X} = \mathbf{X}$				
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Drilletring			2624.67	5511 43	2	4000	····\				
			2024.07	5511.45			· · · · · · ·				
Sample DS 🔹 🔻		10	2952.76	5656.47	3						
Drilling fluid		11	3280.84	5801.51	3						
		12	3608.92	5946.55	4		· · · · · · · ·				
Air 🔹		13	3937.01	6091.58	4						

Getting Started A UM

Step 5.12. Select the *Rotary Drilling 1* scenario node in the *Project tree* and click *Duplicate scenario*.



Step 5.13. Change the *Rotary Drilling 2* scenario and change the operation to Slide drilling. The scenario caption will be changed to *Slide drilling* automatically.

DS E			Train	ning project.dsa	proj - Pro	ject*			
Project info	Drilling information	T&D: Gene	ral Operations	Static Ana	lysis	Time	domain anal	ysis Project report	0
 ♣ Add scenario ⇒ Delete scenario ♣ Duplicate scenario Scenarios 	Validate Generate Rur scenario model analy Scenario[Rotary Drill	Clear sis results	Validate all Ger scenarios all A	o ^o D nerate Run models analysis	Clear results	Ger	nerate report for analysis Report	III Display wellbore scheme	
Project	structure 👔	Analysis s	etup						
Construction	ang project] immation jectory [Well Trajectory] e construction [Wellbore] A 1] g [Sample DS] is Operations ry Drilling 1 Drilling 1 Sis in analysis ort	Scenario C Caption: Well case Well traje Well Traj Wellbore Bit Position Bit Position Drilling Infin Bittom H Bittom H Bittom H Bittom H Bittom H Drillstring Sample D Drilling flu Air Operations Rotary Side d Rotation	aption Slide Drilling 1 ectory ectory construction on, ft mation tole Assembly id brilling in Off Bottom				Advanced S 2D Plot 3C	ettings Position Event Log	Image: Second
· ·	4	© Pick Up)			-			

Now our project contains 2 T&D scenarios that we can compute and compare the results.

Step 5.14. Click on **Validate Scenario** button **D** in the *Project tree* popup menu, or the head menu to validate the description of the scenario.

Event Log page will be displayed automatically on the right panel; the 'No errors or warnings found' message will appear if the input data is correct.

DIS CE -			Training proje	ct.ds	aproj - Project*				
Project info Drilling inf	formation T&D: Gen	eral Operations	Static Analysis	Time	e domain analy	sis Project	report		0
Add scenario	8° • E	2 o ^o	•			👯 Display wellb	ore scheme		
Publicate scenario Validate Si Scenario	enerate Run Clear model analysis results	Validate all Genera scenarios all mod	ete Run Clear els analysis results	Ge	enerate report for analysis				
Scenarios Scera	ario[Rotary Drilling 1]	All so	enarios		Report	GUI Sett	tings		
Project structure	Analysis s	etup							
😑 🔟 Project (Training project)	Scenario C	aption		*	Advanced Se	ttings Position	Event Log		1
Crilling information Well Trajectory (Well 1	Caption:	Rotary Drilling 1			N				
- The Wellbore construction	n [Wellbore] Well case	ctory			- Event Log -				Processing scenarios
BHA[BHA1]	Well Tra	ectory	-						
TnD analysis	Wellbore	construction			Critical error	s not found			
🗄 👩 General Operations	Wellbore		•	Ξ					
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Time domain analysis	 Delete scenario 								
Project report	the Duplicate scenario		~						
	Validate scenario.	nbly							
	Generate model		-	_					
	Run analysis								
	Clear results		-						
	Generate report	,							
	Describe extended and		▼ .						
		angs •			Run ana	lysis Inte	rrupt analysis 4	🔀 Number of Pi	rocesses: 4Threads available
	Rotary	Drilling			Done:0/1				
•	Slide d	rilling		Ψ.					

Rotary Drilling 1 and Slide Drilling 1 scenario are described, validated and ready for running now.

Step 5.15. Save the **project**.

DS	(d) 🔁) =	Training p	roject.c	dsaproj - F	roject*					
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~	Load	0. C:\Users\Public\Document	s\RiMo\Training project	o [©]	۲			2	👖 Display w	vellbore scheme	
	Save	1. C:\Users\Public\Document 2. C:\Users\Public\Document	s\RiMo\\SampleProject s\RiMo\Well\TMK_Test	nerate models	Run analysis	Clear results	Gen fi	ierate report or analysis			
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¢.	🗿 TnD an	alysis	Wellbore construction								
	≕ 🚺 Gen	eral Operations Rotary Drilling 1	Wellbore			_					
		Slide Drilling 1	Bit Position, ft		6 5	00 🔳					
.	Static a Time do 🖹 Project	nalysis omain analysis report	Drilling Information Bottom Hole Assembly BHA 1		,0,	, ,					
•		• •	Drillstring Sample DS			• #	Ŧ				



2.4.2. Analysis run

Step 5.16. Select **Event Log** page, and click on **Run Analysis** button to start the evaluation of the described scenario.

Individual progress bar will be added to the right **Running Scenarios** panel; "--- **Calculations Started** ----" record will be added to the **Event Log**; scenario inputs will be blocked automatically.

T&D: Gener	ral Operation	s Stat	tic Analy	/sis	Time	e domain analy	vsis Proje	ect report						0
₩	F	d ⁰	•				👯 Display w	vellbore sche	eme					
n Clear sis results	Validate all scenarios	Generate all models	Run analysis	Clear results	Ger	nerate report for analysis								
ig 1]		All scenario	DS			Report	GUI	Settings						
Analysis s	etup													
Scenario Ca	aption				-	Advanced Se	ettings Posi	ition Ever	nt Log				-	
Caption:	Slide Drilling	1								Analys	is comr	letion		
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Well Traj	ectory			- 1		Critical array	o not found				-	F-10111		
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Wellbore				-			(y)	
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Bottom H	Iole Assembly													
BHA 1				-		16.07.202 Scenario:	0 - 17:14:12 Rotary Drillin						Ok	
Drillstring						Well Traje	ctory: Well Tr	ajectory	-	-	-			
Sample D	S					Bit positio	n: 6500.00 ft	libore						
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Operations	0					↓						-		
	Scenal are b	locked	S			Run ana	alysis	Interrupt a	nalysi	s 4	1	lumber of Pro	ocesses: 4Threads ava	ailable
Rotatio	n Off Botton	1	_			Done:2/2								
O Pick Up)				-									

- **Note:** Input data validation, and project saving is carried out automatically before process is running.
- **Note:** One can use **Run all scenarios** button from the *Project tree* popup menu or head menu to start the evaluation; the **Run scenario** button enables run of the selected scenario only.

'General Operations: Calculations Completed Successfully' message will be generated after the completion of all running scenarios (single scenario in our case). Normally, calculation of the Soft-string scenario should take less than 1 second.

Step 5.17. Click Ok to close the message.

Results for the scenario has been calculated and stored in the scenario folder on hard drive; calculated scenarios are marked by icon in the *Project tree*.



2.4.3. Results output

DSA GUI provides the output of the calculated T&D results in 2D plot and Table formats:

- 2D plots: set of 2D plots of the various result items on the single page.
- Table output: table view of the calculated result items.

GUI enables output of the results of single (selected) scenario, as well as the output of the multiple scenarios results for comparison.



Step 5.18. Select the calculated scenario node (Training scenario) in the *Project tree* to make the **Results** page on the right page control visible, and go to the page.



2.4.3.1. 2D plots

Single scenario results output

Step 5.19. Select **Results** | **Plots** page to display the set of 2D plots of the various result items.

One can select an output from the check box list – the corresponded dependency of the selected output vs. measured depth will be displayed on the 2D plot on the right panel.



The following 2D Plot display options are available:

- ••• Fit all plots;
- ✓ Turn on advanced 2D plot settings;
- Export plot data to MS Excel;
- [±] Display plot value corresponded to under-cursor-MD in hint window.

Results safety estimation

Safety estimation of the calculated results is available by visualization of **Lim-***its/Criterions* areas on plots.

Limit/Criterion	Description
Helical/Sinusoidal	Estimation of critical helical/sinusoidal buckling force for
buckling force limit	drillstring section by analytical solution
[Axial force]	Max allowable force defined for the drillstring parts
[Torque]	Max allowable torque defined for the drillstring parts
Yield strength	Yield strength of the drillstring parts (from the part materi-
	al properties)

Step 5.20. Check on the [Yield stress] criterion, and vary the SF parameter value to estimate the safety factor for the considering case.





Results comparison mode

Step 5.21. Click on the button above the output list top activate the results comparison mode.

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Checkboxes will appear left to the calculated scenarios nodes in *Project Tree*; the user can select the scenarios, which results should be displayed on one plot.

Step 5.22. Select the *Rotary Drilling 1* and *Slide Drilling 1* scenarios in the Project tree to display the comparison plots.



2.4.3.2. Table output

Step 5.23. Select **Results** | **Tables** page to access to numerical results data, export it to CSV file, or copy to clipboard.

One can select an output from the check box list – the corresponded dependency of the selected output vs. measured depth will be displayed as a column of the table.

Analysis setup Results							
Plots Tables							
		#	MD, ft	Axial force, kip	Torque, kip*ft	Contact force, kip	'on Mises stress, p: 🔺
Outputs		1	0	138.841	8.18704	0	24724.1
Basic results	Â	2	10.4533	138.547	8.18704	0	24392.6
		3	41.4533	137.672	8.18704	0	24293.3
Torque		4	72.4533	136.798	8.18704	0	24194.3
Contact force		5	103.453	135.924	8.18704	0	24095.5
🔲 Bending moment		6	134.453	135.05	8.18704	0	23996.9
Von Mises stress		7	165.453	134.176	8.18704	0	23898.6
Axia force safety factor Stress safety		8	196.453	133.301	8.18704	0	23800.5
Torque safety		9	227.453	132.427	8.18704	0	23702.6
Adv: Forces		10	258,453	131,553	8.18704	0	23605
Sin buckling force		11	289 453	13	Save to CSV file.		23507.6
Hel buckling force	E	10	320 453	12	Copy to clipboa	rd 0	23410.4
Axial stress		12	351 453	128 031	8 18704		23010.8
		13	202.452	120.051	0.10704	0	23010.0
Bend stress		14	442 452	120.000	0.10704	0	22912.9
Circum. Av. Stress		15	413.403	127.102	0.10704	0	22615.3
Radial Av. Stress		16	444.453	126.308	8.18704	0	22/1/.8
Stand off ratio		17	475.453	125.434	8.18703	0.000194501	22620.7
		18	506.453	124.56	8.15/11	0.51102	23150.6
Pos X		19	537.453	123.686	8.10211	0.939626	23584.5
Pos Y		20	568.453	122.812	8.07672	0.433567	22851.2
Clearance		21	599.453	121.939	8.00112	1.29136	23829
Adv: DS Deformation		22	630.453	121.065	7.93215	1.17819	23578.2
🔲 Axial offset		23	661.453	120.191	7.92787	0.073143	21760.1
Temperature officet	•	•					•

Note: MD column is common for all the outputs.

2.5. Time Domain Analysis

The section contains brief overview of the Time Domain Analysis concept, and step-by-step description of Time Domain analysis of the Rotary BHA assembly in the sample well trajectory.

Time Domain analysis overview

DSA application provides advanced tools for close-to-real time simulation of an assembly motion in the well with optional account of operational loads, assembly-wellbore side contact, and bit-rock interaction.

Time Domain analysis can be run in multi-scenario mode (like Static Analysis) with result post-processing, or in *Simulation Desk* mode – animation of model motion and results output during simulation.

Simulation includes the following stages:

Initial state evaluation:

Time domain simulation is started from the equilibrium state of the assembly to minimize unrealistic transient effects.

Equilibrium state is evaluated in accordance to the procedure described in Sect.2.3.

Axial force defined for the time domain scenario is applied to the top of the assembly; bit point axial motion is constrained.

Note: Constraints on lateral motion of top/bit point of the assembly can be defined in **Advanced User** and **Developer** mode.

Time domain simulation

Assembly model boundaries are redefined – constraint on axial motion of the top point is added; axial force – calculated at the initial state evaluation stage is applied to the bit point (used for initialization of bit-rock interaction force model, if active).

Rotary speed is provided by control torque applied to the top point of the assembly; rotary speed is set equal to zero, model is speeding up under action of the control torque.

Assembly kinematics and set of force characteristics are stored during simulation automatically, and can be replayed after completion of the analysis; the user can visually control the process by animation window and various 2D plots during simulation in *Simulation Desk* mode.

UM Drillstring Analysis

Time Domain Analysis GUI enables study of any number of test cases – *scenarios* – within single project. Time Domain Analysis scenario (or *TDA scenario*) is defined by the following basic inputs:

- Well case info: well trajectory case, wellbore case and bit position.
- Drilling Info: BHA case, drillstring case and drilling fluid.
- Operational settings: Drillstring weight, block weight, drillstring RPM.
- Simulation settings: simulation time, cut-off-time.
- Bit-rock interaction options.
- Harmonic excitations options.
- Set of advanced settings available for the Advanced User or Developer.

Single scenario corresponds to simulation of the motion of the whole drillstring, or its bottom part, described with BHA case and drillstring case; axial force applied to the top point of the assembly is evaluated as **Drillstring weight** minus **Travelling Assembly Weight** value.

2.5.1. Scenario description

Step 6.1. Select the **Time Domain Analysis** *Project tree* node to access the Static Analysis GUI, and **Add scenario** by popup menu or the head menu.



Scenario 1 test case will be added to the TDA scenario list; the corresponded node will be added to the *Project structure* tree and focused by default; scenario data will be displayed on the right panel, **Analysis Setup** page.

DS		Traini	ing project.dsaproj - Project			
Project info	Drilling information Static Analys	is Time domain analysis	Project report			0
 ↔ Add scenario ⇒ Delete scenario ↔ Duplicate scenario Scenarios 	Validate Generate Run Clear scenario model analysis results Scenario [Training scenario]	Validate all Generate Run scenarios all models analysis All scenarios	Clear results Generate report for analysis Report			
Project (Frain Project (Frain Wellboo	roject structure roject structure ring project] romation ajectory [Well Trajectory] re construction [Wellbore] ases A1 A2 ring [Sample DS] rysis gScenario ain analysis gScenario File File File File File File File File	Ialysis setup		× E	Position Event Log Plots 30 view Plots 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	D5 position in well

Set the basic parameters of the new scenario by the middle panel controls.

Getting Started

- **Step 6.2.** Set **Training scenario** caption for the scenario. The scenario node name will be update in the *Project tree* automatically.
- **Step 6.3.** Select the **Well trajectory** item from the **Wellpath** list; the list contains all the well trajectories defined in the project.

Note: One can click on button to come to the **Well trajectory** item description page.

Step 6.4. Select the **Wellbore** item from the **Wellbore** list; the list contains all the wellbore designs defined in the project.

Note: One can click on **button** to come to the **Wellbore** item description page.

- **Step 6.5.** Set **Bit Position** value equal to **900 ft**.
- **Step 6.6.** Select the **BHA 1** item from the **Bottom Hole Assembly** list; the list contains all the bottom hole assembly designs defined in the project.

Note: One can click on \bowtie button to come to the **BHA 1** item description page.

Step 6.7. Select the **Sample DS** item from the **Drillstring** list; the list contains all the drillstring designs defined in the project.

Note: One can click on 🗮 button to come to the **Sample DS** item description page.

Step 6.8. Select the **Drilling fluid** item from the **Fluid** list; the list contains all the fluids from the Fluids Database (see Sect.1.4.1.3).





Step 6.9. Set operational and simulation parameters:

- > Operational settings
 - Weight on bit = 10 kip;
 - DS RPM = 60rpm

Right click on the parameter value cell and select the option from the popup menu to choose operation parameters set (weight on bit).



- Simulation settings:
 - Simulation time = 20 sec
 - Cut-off-time = 1000 sec.

Parameters Assembly	r
Parameter	<u>Value</u>
 Operational settings 	
Weight On Bit, kip	10
DS RPM, RPM	60
 Simulation settings 	
Simulation time, sec	20
Cutt-off-time, sec	1000



Step 6.10. Activate Bit-rock interaction force control and select Bit Type: Roller cone bit



Step 6.11. Press on button and look on the BRI parameters. By default were accepted such settings:

Bit diameter is equal of the bit diameter, stochastic components are not equal zero by default.

- **Step 6.12.** Look on Top drive tab. By default were accepted such settings: Gain = 1.5e5, iGain = 2e7.
- **Step 6.13.** Click on **Validate Scenario** button ¹ in the *Project tree* popup menu, or the head menu to validate the description of the scenario.

The information message on mismatch of the scenario bit position with the assembly length will be shown again (see above).

'No errors or warnings found' message will added to the **Event Log**, if the input data is correct.



Training Scenario is described, validate and ready for running now.

Step 6.14. Save the project.

2.5.2. Run scenario by Simulation Desk

DSA GUI enables two variants of Time Domain Analysis processing: *Simulation Desk* and multi-scenario solver. In this section the step-by-step description of the scenario processing in *Simulation Desk* mode is considered.

Important! *Simulation Desk* is initialized by the scenario model files; one needs to generate the model (by special command or during the multi-scenarios run) to make the **Simulation Desk** page visible.

Simulation Desk GUI

Simulation Desk interface includes controls for the scenario data processing, simulation process controls, and set of tools for 3D/2D results output.

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Getting Started



Analysis setup Simulation Desk	
💽 ា ฐ 👗 😫 🖻 🥔 Drillstring position in well	
Animation window	Прафики ПВ С
Desktop configuration controls	Variables Time, second Image: Second s
Results output tools	
	Графики 🗖 🗏 🔀
	Variables
	Прафики 🗖 🖻 🕱
Scenario data processing	Variables 1 Image: Top RPM - To Image: RPM Image: Top drive RP Image: Top drive RP
	0.7057 0.027
📆 🕨 II 🔳 🖏 🕞 🎟 Modeltime: CPU time:	Progress: 0%

Scenario data processing:

- clear scenario results.

Simulation process controls:

- start or continue simulation;
- pause simulation;
- stop simulation and clear results.
- start replaying;
- pause replaying;
- stop replaying.

Results output tools:

- add 3D animation window;
- - add 2D straightened side/cross section view;
- 🖾 add 2D plot;
- * show/hide Wizard of variables.

The default desktop configuration for the scenario is loaded automatically during the first loading of the scenario model, or after regeneration of the model files.

Default desktop includes:

- 3D animation window;
- 2D side/cross section view window;
- two 2D plot windows: Bit/Top point axial G-forces, and Bit Position vs. Time dependencies.

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One can click button to regenerate and upload the default desktop.

Step 6.15. Select the Training scenario node in the Project tree, and click on Generate Model option of the pop up menu of the head menu.

DIS		Training project.d	dsaproj - Pr	oject	_ - X
Project info Drilling information	Static Analysis Time dom	ain analysis			0
Add scenario Delete scenario Apuplicate scenario Scen	Run Clear analysis results g Scenario	¢ () () () () () () () () () () () () ()	Generate rep for analys Report	port is	
	y] Well Case	ng Scenario		Advanced Settings Position Eve	ntLog
Weinbore construction (weinbor HAI [BHA] Orillstring (Sample DS) OS Static analysis A Training scenario A Scenario 1 Scenario 2 OTime domain analysis	Welpath Well Trajectory Wellbore Bit Position, ft	• • • • •		EventLog	-Running Scenarios
Add ⇒ Delet \$ Dupl	l scenario ete scenario dicate scenario date scenario	mbly			
₩ Gene Run Clear Gene Clear Gene	erate model analysis a scenario in Simulation Desk ar results erate report	▼ ettinas Veight, kip 47	7	Run analysis Interrupt a	analysis r Processes: 4 2 4Processors Available

Getting Started

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Scenario inputs validation will be started automatically before model file creation.

The success model generation message will be shown finally.



The model files have been created successfully, the model is ready for loading/running by *Simulation Desk GUI*.

Step 6.16. Select Simulation Desk page on the right panel.

Default desktop contains many windows with plots.

Analysis setup Simulation Desk			
💽 🗮 🚎 🥕 🎬 🗳 🖉 Drillstring position in well 🔹			
■Animation window ■ 瓦 氏 予参 中 G ● ⑤ ● 日 ヽ		Tpabwa Venthes Propert Fopont_Axis	Time, acord
		Varables Dif Parlanon Dif Parlanon	Time second 10 12
Drillstring position in well		🗁 Графики	
Bit ← (B) (C) + (X) (B) = + (L) + (Variables 1 Ø Top dive RP Ø Top dive RP Ø BR R9H - BL Ø 62 6.4	Time, second
	CPU time: Progress:	0%	

Note: The request on the model files generation will be output automatically, if the model files are not actual to the current settings of the scenario.



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If one will click **No**, the empty **Simulation Desk** page will be opened; the request will be repeated when one will try to start the simulation process.

2.5.3. Wizard of variables

Step 6.17. Click on Wizard of Variables.

Variables for group of bodies Image: Second Image: Se	Analysis setup Si	mulation Desk	882	Drillstring position in well
Image: construct of the second sec	Variables J Kinematics	Variables for group (of bodies	ensors
	➡ training scenario ■ DSShaftPipe_1 ■ DSShaftPipe_1 ■ DSShaftPipe_1 ■ DFB =0. ■ DFB =1. ■ DFB =2. ■ DFB =4. ■ DFB =1.	L Selecte [12_1/4. 051] [12. 331] [12. 458] [12. 61] [12. 915] [12. 22] [12. 9915] [12. 2372] [12. 996] [Col 6028] [M 0164] [M 7232] [M 735] [1: 735] [1: 	ed le type lear Angu- ordina Velocity (Axial (Axial (Lateral Vence frame obal referenc Well	ular Accelerat IV I Ibore refere

To add a variable to the graphics window, you need to click on the button "hand";

	🥩 Va	ariables for group of	bodies	
Kinematics		🗮 General	Beam Sensors	
Имя	Dim	Comment		
Scalar variables Bit Position Bit position		III		
Bit Inclination		Bit inclination		
Bit Direction Vector variables		Bit direction		_
Tangent On Bit		Tangent on bit		
Face Normal		Face normal		
Force on Bit		Force on Bit		
Force on Top Set of Vectors		Force on Top		
R		DS-Wellbore resultant contact force		
N		DS-Wellbore normal contact force		
Ffr		DS-Wellbore friction contact force		+
Abscissa Ty	pe			
🔘 Default	(From Surface	From Bit	
t Inclination		Bit inclination		6
Progress:		09	6	
The following types of variables are available used in DSA GUI:

- Scalar variables (Bit position, Inc, Direction, etc.) are displayed in graphical window as a vs. time plot;
- Vector variables, Set of Vectors (Tangent on bit, Ffr, Axial, etc.) are displayed in animation window.
- Plot variables (Well Inc, MBend, etc.) are used for output of parameters distribution along the assembly.

Wizard of variable consist several group.

- **Step 6.18.** Choose tab 'General', click 'Force on bit' at the 'Vector variables' group and click button 'Hand'. Variable wall be added in 3D window.
- **Step 6.19.** Choose tab 'General', choose 'PosX' at the 'Plot variables' group and click button 'Hand'.
- Step 6.20. Choose tab 'Kinematic', choose the last sensor left, click checkboxes like on picture and click button 'Hand' to output Bit angular velocity on separate graphical window.



Step 6.21. Choose tab 'Beam Sensors', choose the first sensor left, choose 'Qz' and click button 'Hand'.

Step 6.22. If necessary, **arrange the windows as you like**. Those windows that you do not need to calculate, you can collapse or close.

Step 6.23. Click on Start Simulation button

Note: If the scenario already has calculated results (the scenario was done), the additional request will be generated to continue the procedure or cancel it.



Click **Yes** to continue.

Simulation is run. The initial state calculation – evaluation of the equilibrium state for the user-defined boundaries – is processed at the first stage of scenario simulation. The progress bar label indicates the current stage.



Note: If the scenario has been already started, and the input parameters are still actual to the previous run - the initial state will be taken from the saved *Initial state* results; equilibrium state evaluation stage will be missed.

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After the equilibrium state evaluation (30% progress, by default), the time domain analysis of the rotating assembly is started. The progress bar label indicates the stage.



'Simulation over' message will be generated after any of the simulation end conditions will be reached (simulation time, or cut-of-time).

Note: Cut-of-Time is applied to the *Time domain simulation* stage only.



Step 6.24. Click Ok to close the message.

Results for the scenario has been calculated and stored in the scenario folder on hard drive; calculated scenario is marked by icon in the *Project tree*.

2.5.4. Replay calculated scenario by Simulation Desk

Simulation Desk GUI enables replaying of the assembly motion for the calculated scenarios. One can replay the scenario case without starting time domain simulation -2D/3D animation and variables output are provided on the base of the records of kinematical characteristics stored during previous analysis.

Note: Some outputs – related to bit-rock interaction force models, etc. – cannot be restored from the instant kinematics of the model; these outputs have zero values in *Replay* mode. One needs to rerun Simulation, or use **Variables** and **Plots** pages to study the direct records of the outputs.

Simulation replay controls are placed on the bottom panel, left to the simulation process controls.

Step 6.25. Click the **Start replay** button left on the bottom panel to start the process.



Current position on the record is output on the progress bar; 'Simulation replay' label marks the GUI mode. **Note:** Scenario replay functionality is available for the calculated scenarios only. Output step cannot be changed in the *replay mode*. The simulation controls are blocked in the *replay mode*; one needs to stop the player to clear the scenario results or restart the scenario.

Assembly motion record will be output on 2D plots, side section view window and animation window. One can add any new variables/plots to control additional parameters by standard Simulation Desk GUI tools.

Step 6.26. Click the **Pause replay** ^{III} button left to pause the process.

The outputs are not cleared in the pause mode; one can turn on the outputs arbitrary and continue the process or interrupt it.

- Step 6.27. Click the Stop replay button left to interrupt the player. The outputs will be cleared, the assembly position will be restored to the initial.
- **Note:** The process is paused automatically after reach of the end of the record. One needs to **Stop replay** to interrupt the process finally.

2.5.5. Multi-scenario run

DSA GUI enables two variants of Time Domain Analysis processing: *Simulation Desk* and multi-scenario solver. In this section the step-by-step description of the multi-scenario processing is considered.

Step 6.28. Select the **Analysis setup** page on the right panel, and duplicate the **Training scenario** by popup menu or head menu command.

DIS		Trainin	g project.dsaproj - Project*		
Project info	Drilling information Static Ana	alysis Time domain analysis	Project report		θ
Add scenario Delete scenario Add scenario Duplicate scenario Scenarios	Validate Generate Run Clea scenario model analysis resul Scenario [Training scenario]	r Validate all Generate Run scenarios all models analysis All scenarios	Clear results Clear Report Report		
Proje	ect structure	Analysis setup Simulation Desk	Results		
Project [Training Orilling inform	project] nation ctory [Well Trajectory] construction [Wellbore]	Scenario Caption Caption: Training scenario Well case	Po	ition Event Log	
BHACase BHA1	IS	Wellpath Well Trajectory Wellbore	No	ent Log errors or warnings found.	Running Scenarios
☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	[Sample DS] s cenario analysis	Wellbore Bit Position, ft	900		
Project repor	 Add scenario Delete scenario 	nformation I Hole Assembly	-		
l	🔩 Duplicate scenario	Case			
	 Validate scenario Generate model Run analysis Run scenario in Simulation I 	Fluid Ts			
	Clear results Generate report	bly source O Up to s	urface		
	Results output settings	ter uperational settings Weight On Bit, kip DS RPM, RPM	Value 10 60	Run analysis] [Interrupt analysis] ne: 1/1	rocesses: 4 🔏 4Processors Available

Step 6.29. Select and rename the new scenario; set scenario Caption equal to Training Scenario 2. Change WOB to 20 kip.

DIS	Training project.dsaproj - Project*	
Project info Drilling information Static Ar	alysis Time domain analysis Project report	0
Add scenario Delete scenario \$ \u03e4 Juplicate scenario Scenario Scenario Scenario (Training scenario 2) Scenario 2)	Validate all Generate Run Clear scenarios all models analysis results All scenarios Run Clear All scenarios Run Clear Report	
Project structure	Analysis setup Simulation Desk Scenario Caption: Training scenario 2 Caption: Training scenario 2 Wellaces Plots 3D view Wellpath Image: Stepse s	Benefit, ft 4000 4000 4000 4000 4000 5500 6500 6500 6500 7500 8 000 6 500 7 500 8 000 12260 0 1200 1

Step 6.30. Select **Event Log** page, and click on **Run Analysis** button to start the evaluation of the described scenario.

Individual progress bar will be added to the right **Running Scenarios** panel; "--- Calculations Started ----" record will be added to the Event Log; scenario inputs will be blocked automatically.

DIS -	Training proje	ct.dsaproj -	Project	
Project info Drilling information Static A	alysis Time domain analysis Project	report		Θ
Add scenario Delete scenario Addacenario Duplicate scenario Scenarios Scenario Scenario 2	A d ^a O D ar scenarios all models analysis results All scenarios	Generate ro for analy Repor	eport sis t	
Project structure	Analysis setup Simulation Desk			
Project [Training project]	Wellpath	^	Position Event Log	
Well Trajectory [Well Trajectory]	Well Trajectory	- 🔊 _	- ENI	
Wellbore construction [Wellbore]	Wellbore		Event Log	Running Scenarios
BHA1	Bit Position, ft 900		No errors or warnings found.	Scenario: Training scenario 2: 29%
Hillstring [Sample DS] Static analysis A Training Scenario	Drilling Information		Calculations Started	↑
⊖ o Time domain analysis — 🏦 Training scenario	Bottom Hole Assembly BHA 1			Individual
Fraining scenario 2	Drillstring Case Sample DS	-		progress bar of the processing scenario
	Fluid Drilling Fluid			
	<u>Parameters</u> Assembly			
		e	Run evaluation	
	ameter Value Operational settings 22	<u>16</u>		
	Scenario inputs are blocked		Run analysis Interrupt analysis Done: 1/2	of Processes: 4 🕺 4Processors Available

- **Note:** Input data validation, and project saving is carried out automatically before process is running.
- **Note:** One can use **Run all scenarios** button from the *Project tree* popup menu or head menu to start the evaluation; the **Run scenario** button enables run of the selected scenario only.





Scenario progress bar displays the current progress of the evaluation procedure. The progress is closed after completion of the scenario calculation; the scenario analysis details are added to the **Event Log**.

DIS		Traini	ng project.dsa	aproj - Proje	ect		
Project info Drilling i	information Static Ana	Ilysis Time domai	n analysis	Project re	port		0
Add scenario Delete scenario Scenario Scenario Scenario Scenario	Generate Run Clean model analysis result nario [Training scenario 2]	r Validate all Gener scenarios all mo All s	rate Run dels analysis scenarios	Clear results	Generate re for analys Report	eport sis t	
Project struct	ture 😰	Analysis setup Sim	ulation Desk	Results			
Project (Training project) Veil Training project) Weil Traincory (Wu Weil Traincory (Wu Weil Bore construct BHACases BHA1 BHA2 BHA2 Dillstring [Sample Statc analysis Training Scenario Training scenario Training scenario Project report	ell Trajectory] tion [Wellbore] e DS] s	Iven Lease Wellpath Well Trajectory Wellbore Bit Position, ft Drilling Information Bottom Hole Assem BHA 1 Drillstring Case Sample DS Fluid Drilling Fluid Parameters Assembly © By source ameter Operational setting Weight On BR,	bly O Up to su	900 🗐 		Position Event Log Event Log Scenario completed successfully! Evaluation Time: 00:02:51 20.08.2018 - 20:02:45 Calculations finished Evaluation time: 00:02:51	Running Scenaric

'Time Domain Analysis Calculations Completed Successfully' message will be generated after the completion of all running scenarios (single scenario in our case). Normally, calculation of the scenario should take about 60 seconds.

Step 6.31. Click Ok to close the message.

Results for the scenario has been calculated and stored in the scenario folder on hard drive; calculated scenarios are marked by icon in the Project tree.

Step 6.32. Select the Training Scenario node in the Project tree, and open pop up menu. The Clear results option is available now; one needs to clear the results to modify description of the scenario. Close the pop up.



2.5.6. Results output

DSA GUI provides the various tools for 2D graphical output of the calculated time histories of kinematical characteristics, forces and stresses in the assembly parts:

- Initial state: set of 2D plots of the various result items on the single page for the initial equilibrium state of the model.
- Variables: 2D plots of variables vs. model time.
- Plots: 2D plots of output distribution along the assembly.



Step 6.33. Select the calculated scenario node (Training scenario 2) in the *Project tree* to make the **Results** page on the right page control visible, and go to the page.

2.5.6.1. Initial State

outputs.

Step 6.34. Select **Results** | **Initial State** page to display the set of 2D plots of the various result items for the initial state the time domain simulation was started.

One can select an output from the check box list – the corresponded dependency of the selected output vs. distance from bit will be displayed on the 2D plot on the right panel.



Step 6.35. Click on 💷 button to switch between brief and full list of

Brief list of outputs	Brief Results	Full list of outputs	Brief Results Outputs Outputs PosX, mm - Horizontal BHA displacements Displacement, multiple and the displacement Displacement, multiple and the displacement Clearance, mm - BHA-wellbore contact forces MK, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MY, KN [™] m - Bending moment in vortical plane MZ, KN [™] m - Normal stress generated by MX SigmaMY, MPa - Normal stress generated by MX SigmaMY, MPa - Normal stress generated by MZ TauUX, MPa - Shear stress generated by QX TauUX, MPa - Shear stress generated by QZ MBend, kN [™] m - Bending moment Q, KN - Joint force SigmaBend, MPa - Bending stress Sigma, MPa - Normal stress (bending + axial) V von Mises Stress, MPa - Equivalent von Mises stress
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2.5.6.2. Variables

Step 6.36. Change color of scenario plots:



- **Step 6.37.** Select **Results** | **Variables** page to study the time domain dependencies of scalar variables: RPM controls, Force on bit.
- **Step 6.38.** Select several outputs in the list to show results of scenario simulation. The list of calculated scalar variables is displayed on the left panel; one can select any of the variables to display them on separate plots on the right panel.

Initial State Variables Plots					
🔀 🔝 😂 🤣 3D	🖼 🖼 🙆 😌 1007 🗝 🔨 🚹				
Outputs	Time, sec				
Drillstring RPM					
Image: Bit RPM					
🔲 찬 Top RPM					
Image: Image: Market					
Mathematical Control Lorque	0 4 6 12 16 20				
▲ I Force on Bit	1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.1.				
WOB -					
TOB	MARAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA				
✓ Mt DOC	0 4 8 12 16 20				
▲ ■					
TRatio					
NC(AStep)	Landade, Lamb, a contraction deliver of the				
	4 8 12 16 20				
	ables to				
be displaye	ed in the				
The right	panel				
T3DContForces	t				
✓ MealTime	4 8 12 16 20				

2.5.6.3. Plots

Step 6.39. Select **Results** | **Plots** page to study the distributions of displacements, internal forces and stresses, etc. along the assembly in the time domain.

The list of calculated distributions (2D plot) is displayed on the left panel; one can select any of the variables to display them on separate plots on the right panel.



- **Step 6.40.** Select **PosX**, **PosY** and **Mx** outputs in the list to display distributions of lateral displacements in wellbore reference frame, and bending moment along the assembly.
- **Step 6.41.** Click on **Run player** button to animate the output variation histories fixed during simulation.
- Step 6.42. Click on Stop player to interrupt the animation.

2.5.6.4. Functionals

Step 6.43. Look at the **Functionals** and choose 'Min'. On plots will appear min values of output for simulation time.



2.5.7. Excitations

DSA TDA Analysis GUI enables description of various forced excitations for the assembly model (available in **Advanced User** mode):

- Inertial, force, or torque excitations.
- Harmonic excitations or excitation records from text (*.csv) file.

Use the tool which allows you to specify a harmonic or force excitations to any part of BHA.

- Step 6.44. Duplicate 'Training scenario' and rename it to 'Training scenario 3'
- **Step 6.45.** <u>Enable</u> **Harmonic excitations** and <u>disable</u> **Bit-rock interaction** force.
- **Step 6.46.** Change **Result step** to 10 ms.
- **Step 6.47.** Open tab Advanced settings -> **Harmonic Excitations** (available in **Advanced User** mode).
- Step 6.48. Choose 12 ¼ Pdc-bit (the first detail) and click button New excitation parameters will be displayed on the right panel.



Step 6.49. Set the following parameters for the excitation:

- Excitation type: Force
- Component: Z (along the axis of the bore hole).
- Amplitude: 100 kip



Step 6.50. Duplicate Training scenario 3 and disabled Harmonic excitations.

Run calculation for last two scenarios.



2.5.8. Comparison mode

Step 6.51. After calculation go to tab **Results -> Variables**. Enable

comparison mode 🕅 .

When comparing two last scenarios we can see <u>influence of</u> <u>axial excitations</u> to WOB and Axial G-forces.



- **Step 6.52.** Copy the first scenario (Training scenario). Go to bit-rock interaction tab. Change to zero next stochastic parameters :
 - Stohastic components
 Stohastic lateral force RMS, lbf
 Stohastic TOB RMS, lbf*ft
 Stohastic vertical irregularities RMS, "
 Stohastic frequency scale
 Stohastic axial force scale, %

Run scenario and look at the **Results -> Variables** after calculation.

To compare several outputs for **Training Scenario** (with irregularities) and **current** scenario (without).

