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Tech Note

Centralizer Force Calculation

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Contents

Summary

This note provides information about the way Orpheus™ handles centralizers. It also provides help in understanding the wall contact force (WCF) when a centralizer is present.

Rigid Centralizer

If a centralizer is specified as rigid, then the maximum OD of the centralizer is set as the tool's maximum OD, and Orpheus sets a short segment (or element) with the maximum OD at the middle of the tool. No additional calculation is needed due to the centralizer.

Tool Model 1 behaves as if there is no centralizer, except the tool's diameter is increased.

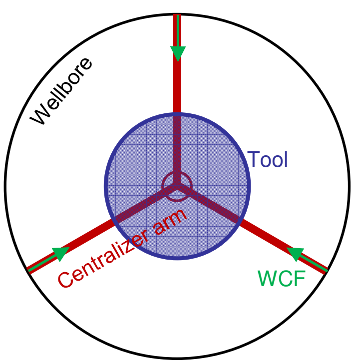
In Tool Model 2, however, the increased OD at the middle of the tool causes more bending if the tool is in an inclined wellbore section, which could therefore change the WCF distribution.

Non-Rigid Centralizer

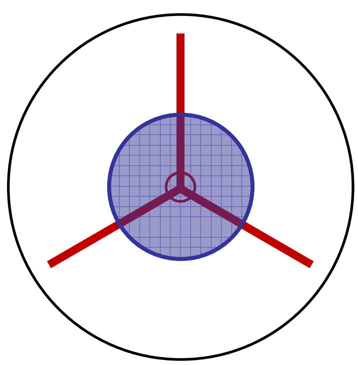
Non-rigid centralizers cause additional WCF between the centralizer arms and the wellbore wall due to the standoff force of the arms. This additional WCF causes additional frictional drag. The calculation methods for non-rigid centralizers are different for Tool Model 1 and Tool Model 2 in Orpheus.

Tool Model 1

Tool Model 1 assumes that additional WCF due to centralizer is solely determined by the maximum OD of the centralizer and the wellbore diameter. If the maximum OD of the centralizer is greater than the wellbore diameter, then there will be additional WCF since the centralizer arms are compressed. If the maximum OD of the centralizer is less than the wellbore diameter, then there is no additional WCF.



Maximum OD of centralizer is greater than wellbore diameter



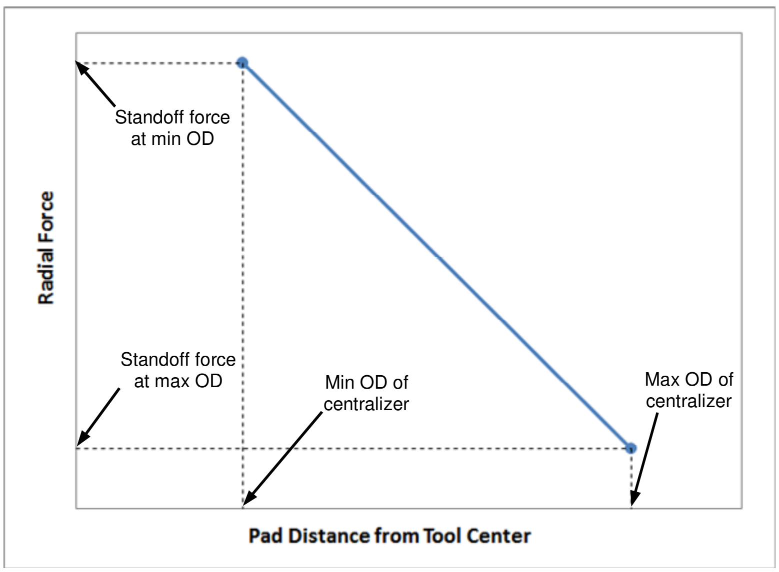
Maximum OD of centralizer is less than wellbore diameter;
No additional WCF

Centralizer Deformation and Resulted Wall Contact Forces – Tool Model 1

Additional WCF is calculated based on following user input parameters:

- Maximum (nominal) OD
- Standoff force at maximum OD
- Minimum OD
- Standoff force at minimum OD

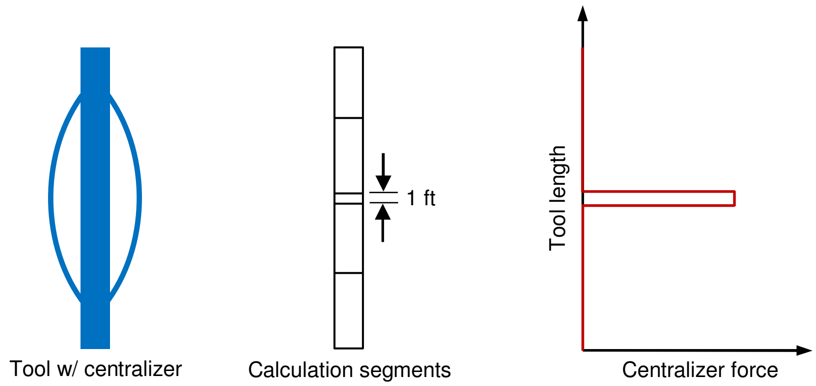
The standoff forces here are the total force of the centralizer's arms. These parameters define the ranges of a centralizer's pad position and standoff forces and the relationship between the centralizer pad position and the standoff force, as shown in the figure below.



Centralizer Pad Position and Radial Force – Tool Model 1

Tool Model 1 assumes that if the wellbore does not allow the centralizer arms to fully extend, then the tool and the wellbore are concentric. This is acceptable for vertical or near-vertical wells. Therefore, the centralizer pad distance is equal to the radius of the wellbore and the radial force is calculated using linear interpolation based on the user input. This radial force is the additional WCF due to the centralizer. If the diameter of the wellbore section is greater than the maximum OD of the centralizer, then there is no additional WCF due to the centralizer.

The following figure shows the calculation setting and resulting centralizer force. A 1-foot segment is set to represent the contact length between the centralizer pads and the wellbore wall.

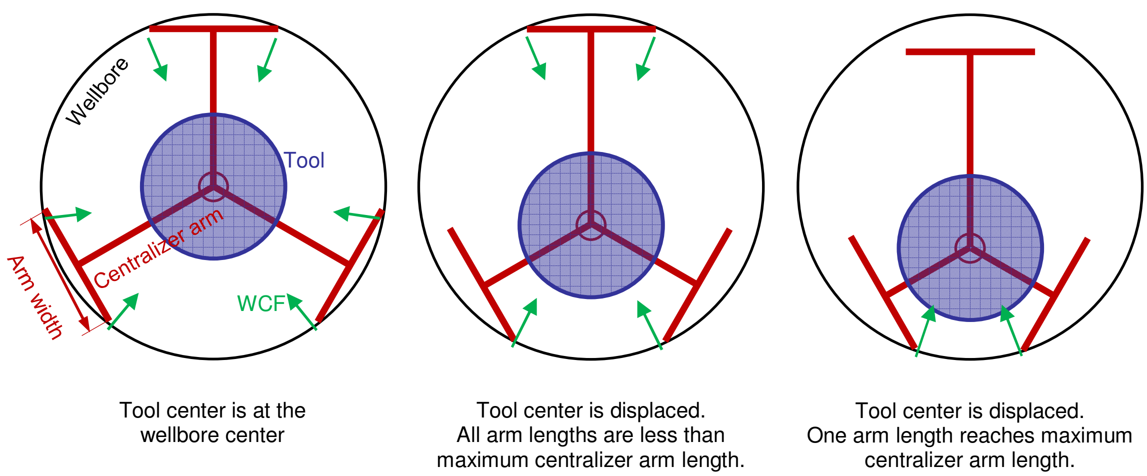


Centralizer Calculation Setting – Tool Model 1

Tool Model 2

With Tool Model 2, the finite element analysis (FEA) engine first calculates the displacement of the tool to obtain the location of the tool center and the pad position of each arm. Radial forces of the arms can then be calculated using linear interpolation based on the user input, which is similar to Tool Model 1. Since the centralizer force will affect the tool's bending, iteration may be needed to find the final centralizer force. The radial forces are then converted to WCF.

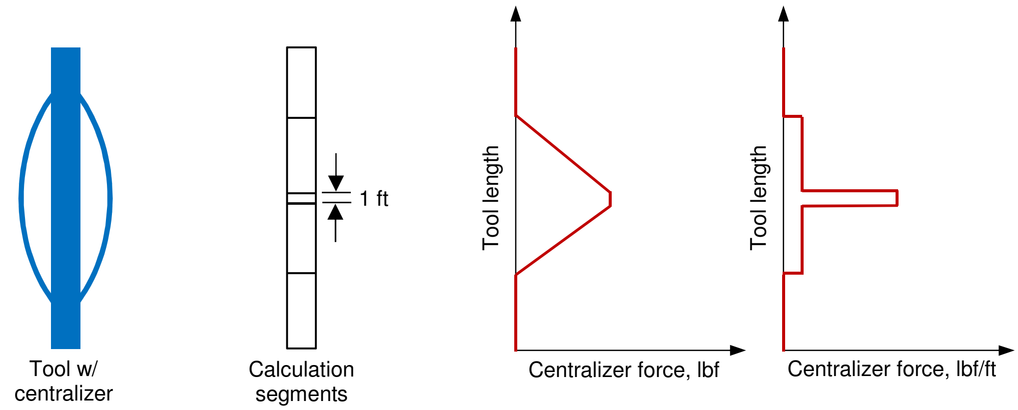
The figure above illustrates different cases of WCF resulting from the centralizer's pads.



Centralizer Deformation and Resulted Wall Contact Forces – Tool Model 2

Obviously, this better reflects the reality, especially when the wellbore section is at a severe dogleg or high deviation.

The following figure shows the calculation setting and resulting centralizer force:



Centralizer Calculation Setting – Tool Model 2

Again, a 1-foot segment is set to represent the contact length between the centralizer pads and the wellbore wall. However, unlike Tool Model 1, the centralizer force exists not only within the 1-foot element, but also within the elements above and below.

Parameters

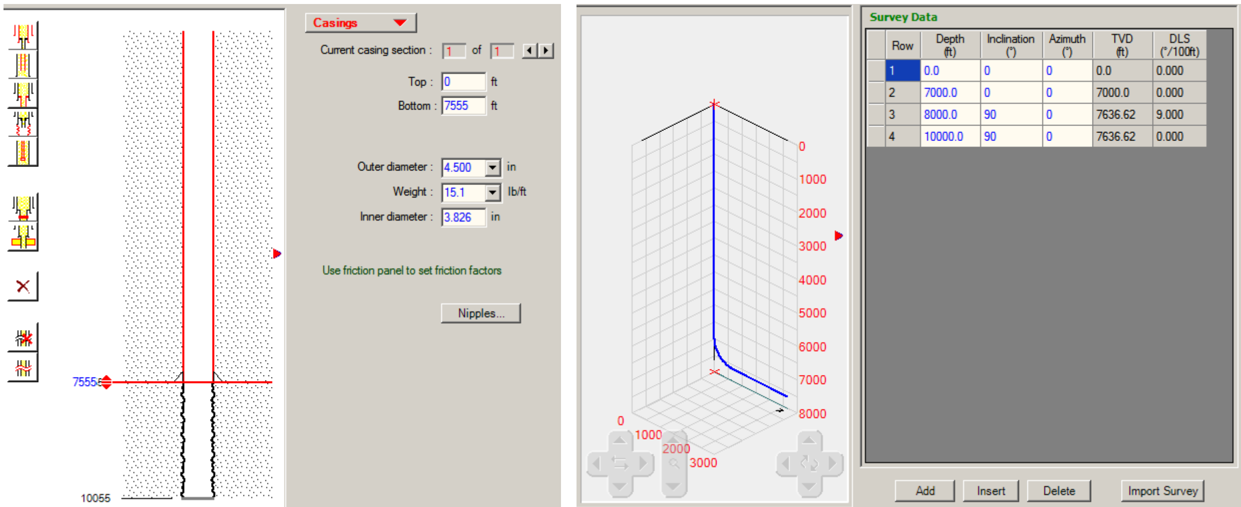
Below is a summary of the centralizer parameters used in different models.

Property	Tool Model	Description
Rigid	1, 2	If this is True, then: • If the centralizer's maximum OD is greater than the tool's maximum OD, then the centralizer's maximum OD is used as the tool's maximum OD • Properties other than maximum OD are irrelevant • No additional special calculation is needed
Number of arms	2	
Arm width	2	Centralizer pad width
Maximum (nominal) OD	1, 2	Maximum distance of a centralizer's pad from tool center
Threshold standoff force	1, 2	Minimum radial force that a centralizer can provide
Minimum OD	1, 2	Minimum distance of a centralizer's pad from tool center
Standoff force at minimum OD	1, 2	Maximum radial force that a centralizer can provide

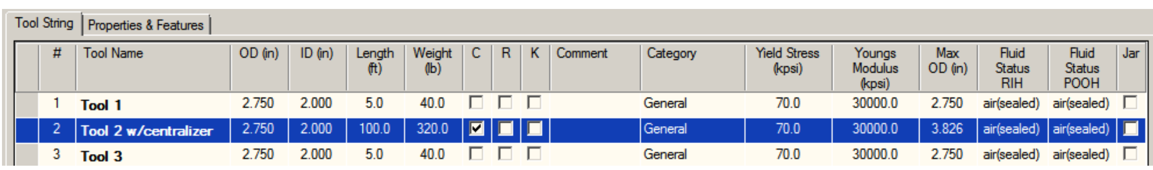
Example

This example loads the data "Example centralizer project.zcy." The results shown below were obtained with Orpheus v11.5.

The project contains an L-well with kick-off at 7,000 ft. The toolstring consists of three tools. The second tool of the toolstring has a six-arm centralizer.



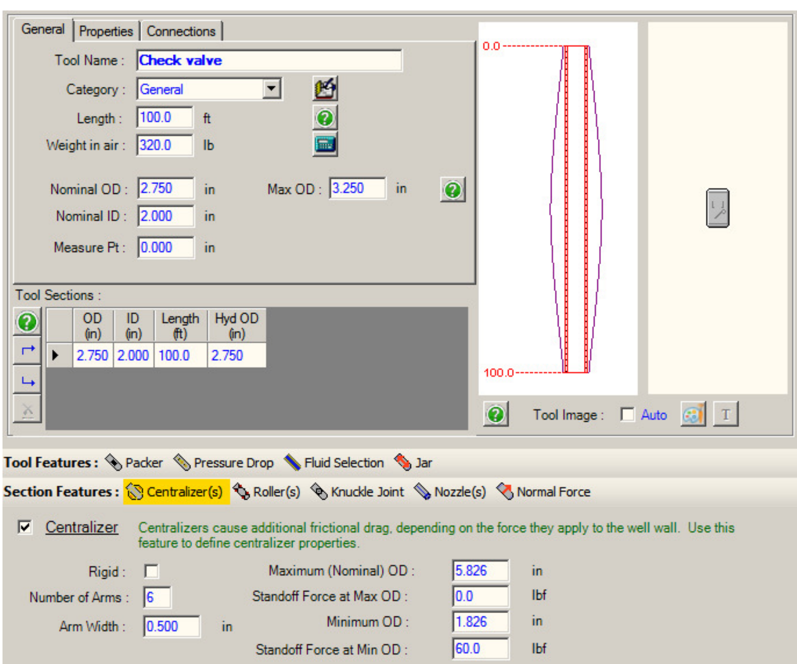
Well



Tool String | Properties & Features

#	Tool Name	OD (in)	ID (in)	Length (ft)	Weight (lb)	C	R	K	Comment	Category	Yield Stress (kpsi)	Youngs Modulus (kpsi)	Max OD (in)	Fluid Status RIH	Fluid Status POOH	Jar
1	Tool 1	2.750	2.000	5.0	40.0	☐	☐	☐		General	70.0	30000.0	2.750	air(sealed)	air(sealed)	☐
2	Tool 2 w/centralizer	2.750	2.000	100.0	320.0	☑	☐	☐		General	70.0	30000.0	3.826	air(sealed)	air(sealed)	☐
3	Tool 3	2.750	2.000	5.0	40.0	☐	☐	☐		General	70.0	30000.0	2.750	air(sealed)	air(sealed)	☐

Toolstring



Tool with Centralizer

Since both the wellbore fluid and the CT fluid are fresh water (8.33 lbs/gal) and the toolstring is open, buoyant weights of the tools are:

- Tool 1: 6.79 lbs/ft
- Tool 2: 1.99 lbs/ft
- Tool 3: 6.79 lbs/ft

The total buoyant weight of the toolstring is 267 lbs. If there is no centralizer, then this should be the WCF between the toolstring and the wellbore wall in the horizontal section.

The entire wellbore diameter is 3.826 in. The centralizer has the settings:

- Max OD: 5.826 in
- Standoff force at max OD: 0
- Min OD: 1.826
- Standoff force at min OD: 60 lbf

If the tool center is at the wellbore center, then the centralizer OD is 3.826 in, which is the midpoint of max OD and min OD of the centralizer. Therefore, the standoff force of the centralizer arms is 30 lbf.

WCF between the toolstring and the wellbore wall is checked below in different scenarios.

Without Centralizer

When the centralizer is not present, there should be no WCF in the vertical well section. This was verified by setting tripping depth to 6,000 ft, with both Tool Model 1 and Tool Model 2, as shown below. In the horizontal section, WCF should be equal to the buoyant weight of the toolstring.

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
4600	0.00	0.00	0.00
4700	0.00	0.00	0.00
4800	0.00	0.00	0.00
4900	0.00	0.00	0.00
5000	0.00	0.00	0.00
5100	0.00	0.00	0.00
5200	0.00	0.00	0.00
5300	0.00	0.00	0.00
5400	0.00	0.00	0.00
5500	0.00	0.00	0.00
5600	0.00	0.00	0.00
5700	0.00	0.00	0.00
5800	0.00	0.00	0.00
5890	0.00	0.00	0.00
5895	0.00	0.00	0.00
5900	0.00	0.00	0.00
5995	0.00	0.00	0.00
6000	0.00	0.00	0.00

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
8600	1.80	1.80	0.00
8700	1.80	1.80	0.00
8800	1.80	1.80	0.00
8900	1.80	1.80	0.00
9000	1.80	1.80	0.00
9100	1.80	1.80	0.00
9200	1.80	1.80	0.00
9300	1.80	1.80	0.00
9400	1.80	1.80	0.00
9500	1.80	1.80	0.00
9600	1.80	1.80	0.00
9700	1.80	1.80	0.00
9800	1.80	1.80	0.00
9890	6.79	6.79	0.00
9895	1.99	1.99	0.00
9900	1.99	1.99	0.00
9995	6.79	6.79	0.00
10000	6.79	6.79	0.00

Vertical section *Horizontal section*

WCF without Centralizer

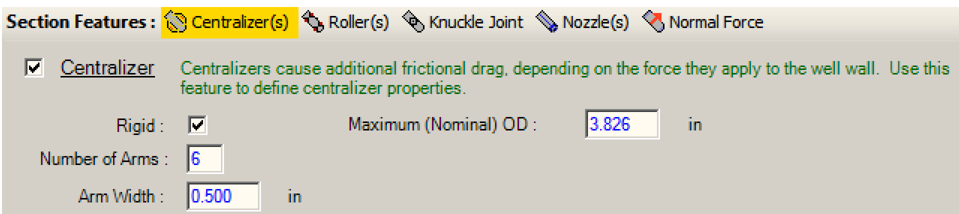
The total WCF between the toolstring and wellbore in the horizontal section can be obtained as follows:

$$
\begin{aligned}
WCF_{Total} &= 6.79 \times (9{,}895 - 9{,}890) \\
&\quad + 1.99 \times (9{,}900 - 9{,}895) \\
&\quad + 1.99 \times (9{,}995 - 9{,}900) \\
&\quad + 6.79 \times (10{,}000 - 9{,}995) \\
WCF_{Total} &= 267 \text{ lbf}
\end{aligned}
$$

Note that the last row WCF is not used in the total WCF calculation.

With Rigid Centralizer

Now activate the centralizer with Tool 2 and set the maximum OD of the centralizer to 3.826 in, which is equal to the wellbore diameter.



In the vertical section, there is not any WCF with both Tool Model 1 and Tool Model 2. In the horizontal section, WCF with Tool Model 1 and Tool Model 2 are shown below:

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
8800	1.80	1.80	0.00
8900	1.80	1.80	0.00
9000	1.80	1.80	0.00
9100	1.80	1.80	0.00
9200	1.80	1.80	0.00
9300	1.80	1.80	0.00
9400	1.80	1.80	0.00
9500	1.80	1.80	0.00
9600	1.80	1.80	0.00
9700	1.80	1.80	0.00
9800	1.80	1.80	0.00
9890	6.79	6.79	0.00
9895	1.99	1.99	0.00
9900	1.99	1.99	0.00
9945	1.99	1.99	0.00
9946	1.99	1.99	0.00
9995	6.79	6.79	0.00
10000	6.79	6.79	0.00

Tool Model 1

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
9600	1.80	1.80	0.00
9700	1.80	1.80	0.00
9800	1.80	1.80	0.00
9890	1.80	1.80	0.00
9890	6.79	6.79	0.00
9895	3.59	3.59	0.00
9905	1.99	1.99	0.00
9915	1.99	1.99	0.00
9925	1.99	1.99	0.00
9935	1.99	1.99	0.00
9945	1.99	1.99	0.00
9946	1.99	1.99	0.00
9956	1.99	1.99	0.00
9966	1.99	1.99	0.00
9976	1.99	1.99	0.00
9986	1.99	1.99	0.00
9995	3.64	3.64	0.00
10000	6.79	6.79	0.00

Tool Model 2

WCF in Horizontal Section with Rigid Centralizer

Total WCF with Tool Model 1 is the same as that without the centralizer, while the total WCF with Tool Model 2 can be obtained as:

$$
\begin{aligned}
WCF_{Total} = {} & 6.79 \times (9{,}895 - 9{,}890) \\
& + 3.59 \times (9{,}905 - 9{,}895) \\
& + 1.99 \times (9{,}915 - 9{,}905) \\
& + 1.99 \times (9{,}925 - 9{,}915) \\
& + 1.99 \times (9{,}935 - 9{,}925) \\
& + 1.99 \times (9{,}945 - 9{,}935) \\
& + 1.99 \times (9{,}946 - 9{,}945) \\
& + 1.99 \times (9{,}956 - 9{,}946) \\
& + 1.99 \times (9{,}966 - 9{,}956) \\
& + 1.99 \times (9{,}976 - 9{,}966) \\
& + 1.99 \times (9{,}986 - 9{,}976) \\
& + 1.99 \times (9{,}995 - 9{,}986) \\
& + 3.64 \times (10{,}000 - 9{,}995)
\end{aligned}
$$

$$WCF_{Total} = 267 \text{ lbf}$$

Note here that the WCF distribution near the top and bottom of the tool, respectively, is different from the distribution without a centralizer.

With Non-Rigid Centralizer

Set the tripping depth to 6,000 ft and complete the Run at Depth calculation with Tool Model 1 and Tool Model 2, respectively. The following WCF results should be obtained:

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
4800	0.00	0.00	0.00
4900	0.00	0.00	0.00
5000	0.00	0.00	0.00
5100	0.00	0.00	0.00
5200	0.00	0.00	0.00
5300	0.00	0.00	0.00
5400	0.00	0.00	0.00
5500	0.00	0.00	0.00
5600	0.00	0.00	0.00
5700	0.00	0.00	0.00
5800	0.00	0.00	0.00
5890	0.00	0.00	0.00
5895	0.00	0.00	0.00
5900	0.00	0.00	0.00
5945	30.00	30.00	0.00
5946	0.00	0.00	0.00
5995	0.00	0.00	0.00
6000	0.00	0.00	0.00

Tool Model 1

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
5600	0.00	0.00	0.00
5700	0.00	0.00	0.00
5800	0.00	0.00	0.00
5890	0.00	0.00	0.00
5890	0.00	0.00	0.00
5895	0.00	0.00	0.00
5905	0.00	0.00	0.00
5915	0.00	0.00	0.00
5925	0.00	0.00	0.00
5935	0.78	0.78	0.00
5945	14.75	14.75	0.00
5946	0.74	0.74	0.00
5956	0.00	0.00	0.00
5966	0.00	0.00	0.00
5976	0.00	0.00	0.00
5986	0.00	0.00	0.00
5995	0.00	0.00	0.00
6000	0.00	0.00	0.00

Tool Model 2

WCF in Vertical Section with Non-Rigid Centralizer

Since the toolstring is in the vertical section of the wellbore, there is not any WCF other than that caused by the centralizer. The total WCF between the toolstring and wellbore with Tool Model 1 can be obtained as follows:

$$WCF_{Total} = 30 \times (5{,}946 - 5{,}945)$$

$$WCF_{Total} = 30 \text{ lbf}$$

Total WCF with tool model 2 is equal to:

$$
\begin{aligned}
WCF_{Total} &= 0.78 \times (5{,}945 - 5{,}935) \\
&\quad + 14.75 \times (5{,}946 - 5{,}945) \\
&\quad + 0.74 \times (5{,}956 - 5{,}946) \\
WCF_{Total} &= 29.95 \text{ lbf}
\end{aligned}
$$

Set the tripping depth to well TD (10,000 ft) and complete the Run at Depth calculation with Tool Model 1 and Tool Model 2, respectively. The following WCF results should be obtained:

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
4800	0.00	0.00	0.00
4900	0.00	0.00	0.00
5000	0.00	0.00	0.00
5100	0.00	0.00	0.00
5200	0.00	0.00	0.00
5300	0.00	0.00	0.00
5400	0.00	0.00	0.00
5500	0.00	0.00	0.00
5600	0.00	0.00	0.00
5700	0.00	0.00	0.00
5800	0.00	0.00	0.00
5890	0.00	0.00	0.00
5895	0.00	0.00	0.00
5900	0.00	0.00	0.00
5945	30.00	30.00	0.00
5946	0.00	0.00	0.00
5995	0.00	0.00	0.00
6000	0.00	0.00	0.00

Tool Model 1

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
5600	0.00	0.00	0.00
5700	0.00	0.00	0.00
5800	0.00	0.00	0.00
5890	0.00	0.00	0.00
5890	0.00	0.00	0.00
5895	0.00	0.00	0.00
5905	0.00	0.00	0.00
5915	0.00	0.00	0.00
5925	0.00	0.00	0.00
5935	0.78	0.78	0.00
5945	14.75	14.75	0.00
5946	0.74	0.74	0.00
5956	0.00	0.00	0.00
5966	0.00	0.00	0.00
5976	0.00	0.00	0.00
5986	0.00	0.00	0.00
5995	0.00	0.00	0.00
6000	0.00	0.00	0.00

Tool Model 2

WCF in Horizontal Section with Non-Rigid Centralizer

Notice, since the toolstring now is in the horizontal section of the wellbore, the WCF between the toolstring and the wellbore includes the toolstring weight and the centralizer standoff force. The total WCF in the horizontal section can be obtained as follows:

$$
\begin{aligned}
WCF_{Total} &= 6.79 \times (9{,}895 - 9{,}890) \\
&\quad + 1.99 \times (9{,}900 - 9{,}895) \\
&\quad + 1.99 \times (9{,}945 - 9{,}900) \\
&\quad + 31.99 \times (9{,}946 - 9{,}945) \\
&\quad + 1.99 \times (9{,}995 - 9{,}946) \\
&\quad + 6.79 \times (10{,}000 - 9{,}995) \\
WCF_{Total} &= 297 \text{ lbf}
\end{aligned}
$$

While the total WCF with Tool Model 2 can be obtained as follows:

$$
\begin{aligned}
WCF_{Total} = {} & 4.39 \times (9{,}895 - 9{,}890) \\
& + 2.34 \times (9{,}905 - 9{,}895) \\
& + 1.99 \times (9{,}915 - 9{,}905) \\
& + 1.99 \times (9{,}925 - 9{,}915) \\
& + 1.96 \times (9{,}935 - 9{,}925) \\
& + 1.78 \times (9{,}945 - 9{,}935) \\
& + 14.75 \times (9{,}946 - 9{,}945) \\
& + 1.75 \times (9{,}956 - 9{,}946) \\
& + 1.99 \times (9{,}966 - 9{,}956) \\
& + 1.99 \times (9{,}976 - 9{,}966) \\
& + 1.96 \times (9{,}986 - 9{,}976) \\
& + 2.41 \times (9{,}995 - 9{,}986) \\
& + 4.34 \times (10{,}000 - 9{,}995) \\
WCF_{Total} = {} & 258 \text{ lbf}
\end{aligned}
$$

Notice that the total WCF with Tool Model 1 is greater than that predicted by Tool Model 2. One reason is that Tool Model 1 superposes the tools' buoyant weights and the centralizer force, while Tool Model 2 uses the maximum of the buoyant weight and centralizer force. Tool Model 1 assumes that the entire toolstring, except where the centralizer is located, lies on the inclined or horizontal wellbore wall, therefore over-predicting the WCF. Tool Model 2 uses finite element analysis to find the shape of the toolstring in the wellbore. Obviously, the tool near the centralizer does not contact the wellbore wall. Also notice that the bending due to the presence of the centralizer may transfer part of the WCF to the coiled tubing. However, this is not fully understood yet.

Heavy Tool with Non-Rigid Centralizer

Now change weight in air of Tool 2 to 3,200 lbs. The buoyant weight of the toolstring is then 3,147 lbs. It would be expected that the centralizer will have very little effect, if any, on the WCF in the horizontal section, and this was verified by Tool Model 2.

The WCF with Tool Model 1 and Tool Model 2 are shown below:

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
8800	1.80	1.80	0.00
8900	1.80	1.80	0.00
9000	1.80	1.80	0.00
9100	1.80	1.80	0.00
9200	1.80	1.80	0.00
9300	1.80	1.80	0.00
9400	1.80	1.80	0.00
9500	1.80	1.80	0.00
9600	1.80	1.80	0.00
9700	1.80	1.80	0.00
9800	1.80	1.80	0.00
9890	6.79	6.79	0.00
9895	30.79	30.79	0.00
9900	30.79	30.79	0.00
9945	60.79	60.79	0.00
9946	30.79	30.79	0.00
9995	6.79	6.79	0.00
10000	6.79	6.79	0.00

Tool Model 1

Wall Contact Forces			
Depth (ft)	WCF RIH (lbf/ft)	WCF POOH (lbf/ft)	Buckling Wall Force (lbf/ft)
9600	1.80	1.80	0.00
9700	1.80	1.80	0.00
9800	1.80	1.80	0.00
9890	1.80	1.80	0.00
9890	6.79	6.79	0.00
9895	22.79	22.79	0.00
9905	30.79	30.79	0.00
9915	30.79	30.79	0.00
9925	30.79	30.79	0.00
9935	30.79	30.79	0.00
9945	30.79	30.79	0.00
9946	30.79	30.79	0.00
9956	30.79	30.79	0.00
9966	30.79	30.79	0.00
9976	30.79	30.79	0.00
9986	30.79	30.79	0.00
9995	22.51	22.51	0.00
10000	6.79	6.79	0.00

Tool Model 2

WCF in Horizontal Section with Non-Rigid Centralizer

The total WCF with Tool Model 1 can be obtained as follows:

$$
\begin{aligned}
WCF_{Total} &= 6.79 \times (9{,}895 - 9{,}890) \\
&+ 30.79 \times (9{,}900 - 9{,}895) \\
&+ 30.79 \times (9{,}945 - 9{,}900) \\
&+ 60.79 \times (9{,}946 - 9{,}945) \\
&+ 30.79 \times (9{,}995 - 9{,}946) \\
&+ 6.79 \times (10{,}000 - 9{,}995) \\
WCF_{Total} &= 3{,}177 \text{ lbf}
\end{aligned}
$$

Again, the tool's weight and the centralizer force were superposed in the mid of the tool here.

While the total WCF with Tool Model 2 can be obtained as follows:

$$
\begin{aligned}
WCF_{Total} &= 6.79 \times (9{,}895 - 9{,}890) \\
&+ 22.79 \times (9{,}905 - 9{,}895) \\
&+ 30.79 \times (9{,}915 - 9{,}905) \\
&+ 30.79 \times (9{,}925 - 9{,}915) \\
&+ 30.79 \times (9{,}935 - 9{,}925) \\
&+ 30.79 \times (9{,}945 - 9{,}935) \\
&+ 30.79 \times (9{,}946 - 9{,}945) \\
&+ 30.79 \times (9{,}956 - 9{,}946) \\
&+ 30.79 \times (9{,}966 - 9{,}956) \\
&+ 30.79 \times (9{,}976 - 9{,}966) \\
&+ 30.79 \times (9{,}986 - 9{,}976) \\
&+ 22.51 \times (9{,}995 - 9{,}986) \\
&+ 6.79 \times (10{,}000 - 9{,}995) \\
WCF_{Total} &= 3{,}146 \text{ lbf}
\end{aligned}
$$

Example Summary

The centralizer standoff force is 30 lbf if the tool with the centralizer and the wellbore are concentric.

		Total WCF, lbf			
Toolstring Buoyant Wt.	**Centralizer**	**Vertical Section**		**Horizontal Section**	
		Tool Model 1	**Tool Model 2**	**Tool Model 1**	**Tool Model 2**
267 lbs	No	0	0	267	267
	Rigid	0	0	267	267
	Non-rigid	30	29.95	297	258
3,147 lbs	Non-rigid			3,177	3,146