FEBio User Manual(extended 2.0)[1]

0.1 Frictional Sliding Contact

0.1.1 Siding_with_gaps (SWG):

The Frictional Siding_with_gaps (SWG) implementation for sliding interfaces can deal with friction on contact surfaces. It allows to formulate a kinematically frictional contact problem based on Coulomb friction law. The interface is similar to a sliding interface, except that the user must define the following properties for the interfaces:

```
<contact type="sliding_with_gaps">
 <...>...</...>
<fric_coeff >1.0</fric_coeff>
<fric_penalty >1.0</fric_penalty>
.
.
.
 <...>...</...>
</contact>
```

In the same way that the penalty parameter ϵ_N controls the contact tractions, the parameter "fric_penalty" [the penalty value ϵ_T (penalty scale factor for friction)] is used to calculate friction. The parameter "fric_coeff" is used to set μ the friction coefficient and its value must be in the range from 0.0 to 1.0.

The slave and master surfaces are defined similarly as for the sliding interfaces. The type attribute is used to specify whether it is a slave or master surface.

Remark: Note that, in FEBio the contact vector for tangential traction will be calculated only if both the friction coefficient and friction penalty factor are non-zero $\mu.\epsilon_T > 0$.

0.2 Thermodynamically coupled Frictional Sliding Contact

0.2.1 Siding_with_gaps (SWG):

The thermodynamically coupled Frictional Siding_with_gaps (SWG) implementation for sliding interfaces can deal with kinematically frictional heating on contact surfaces based on first and second law of thermodynamic and standard procedures in thermodynamics. It allows to heat fluxes across the contact interface. In other words, heat can flow from one side of the contact interface to the other when both contact surfaces are Siding_with_gaps.

To use this feature, the user must define the following properties for the interfaces, namely:

```
<contact type="sliding_with_gaps">
 <...>...</...>
<heat_capacity >1.0</heat_capacity>
<s_heat__coeff >1.0</s_heat__coeff>
<m_heat__coeff>1.0</m_heat__coeff>
<flu_parameter >1.0</flu_parameter>
<user_def >1.0</user_def>
.
.
.
```

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```
.
<fric_coeff>1.0</fric_coeff>
<fric_penalty>1.0</fric_penalty>
.
.
<...>...</...>
</contact>
```

Comments:

1. The parameter $heat\_capacity$ can be used to set heat capacity per unit surface(master and slave) of the trapped debris.

2. The parameter s_heat_coeff can be used to set slave surface heat transfer coefficient.

3. The parameter m_heat_coeff can be used to set master surface heat transfer coefficient.

4. The parameter $flu\_parameter$ can be used to set the fluidity parameter (associated with viscoplastic shearing effects).

The parameter "user_def"(κ_us) deserves a little more attention. First we define a slip function Φ with respect to the definition of t_N, t_T the contact pressure and the frictional stress, by using a user prescribed function(control function of the evaluation of the frictional stress under steady state conditions) $K(\alpha + T_m)$, shown as

$$\Phi = \mid t_T \mid - t_N \underbrace{[K(\alpha + T_m) + \mu(T_m)]}_{\mu(\kappa\_us)}, \tag{1}$$

,

where μ is the friction coefficient. During sliding we have $\Phi = 0$, so the above equation can be used to express the relation between $t_N, t_T, K(\alpha + T_m), \mu(T_m)$ as the following

$$\frac{\mid t_T \mid}{t_N} = \underbrace{[K(\alpha + T_m) + \mu(T_m)]}_{\mu(\kappa\_us)}, \tag{2}$$

which can be used to define the parameter κ_us.

Remark(1): Note that, the user will still need to set the values of the parameter (fric_penalty) and the parameter (fric_coeff) prior to FE analysis.

The slave and master surfaces are defined similarly as for the sliding interfaces. The type attribute is used to specify whether it is a slave or master surface.

0.3 Sliding Contact with Cohesive Force(Cohesive Fracture Model formulation through Contact Mechanics)

0.3.1 Facet-to-facet sliding (F2F):

The modified Facet-to-facet sliding (F2F) implementation for sliding interfaces can deal with Cohesive Fracture Model on contact surfaces. It allows to enforce the contact constrains within a strong Mixed Mode Cohesive Law formulation which clearly takes the place of the original sliding contact constrains formulation and in the case of the physical requirement of impenetrability and compressive interaction between two bodies, it enforces the original sliding contact constrains.

To use this feature, the user must define the following properties for the interfaces, namely:

```
<contact type="facet-to-facet sliding">
 <...>...</...>
<n_interf_strength>1.0</n_interf_strength>
<t_interf_strength>1.0</t_interf_strength>
<n_char_op>1.0</n_char_op>
<t_char_op>1.0</t_char_op>
 .
 .
 .
 <...>...</...>
</contact>
```

Comments:

1. The parameter $n\_interf\_strength$ can be used to set the maximum value for the normal opening traction(the interfacial normal strength).

2. The parameter $t\_interf\_strength$ can be used to set the maximum value for tangential opening traction(the interfacial tangential strength).

3. The parameter n_char_op can be used to set the characteristic opening length of the normal direction.

4. The parameter t_char_op can be used to set the characteristic opening length of the tangential direction.

The slave and master surfaces are defined similarly as for the sliding interfaces. The type attribute is used to specify whether it is a slave or master surface.