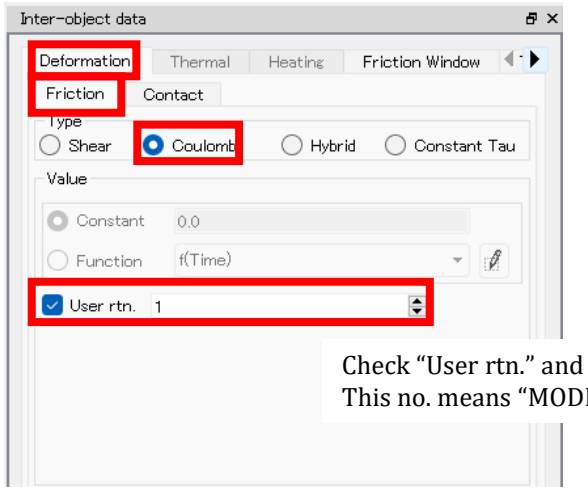
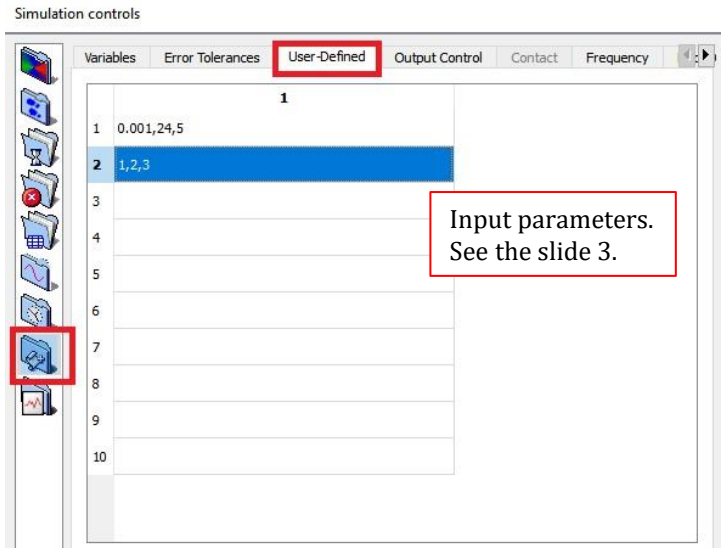
How to use?

1) All the tool contacted with workpiece are set as the deformable body
2) Edit “inter-Object Data definition”



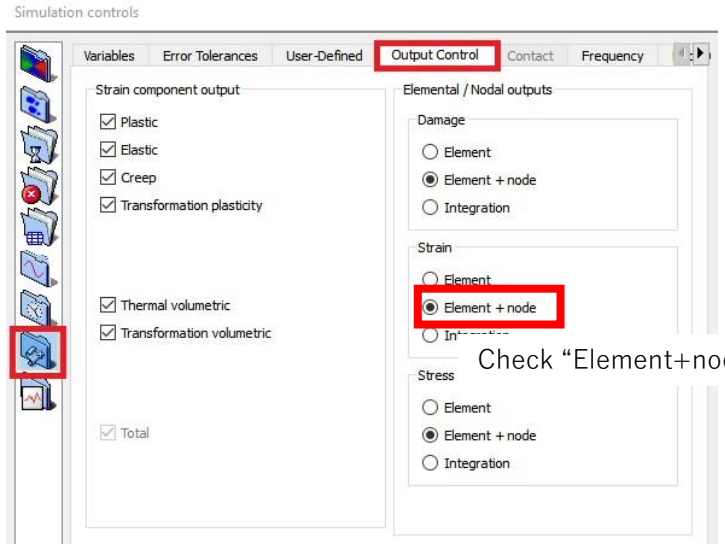
Check “User rtn.” and select 1-4.
This no. means “MODEL” in the next slide.

3) Edit “User-Defined” in “Simulation controls”



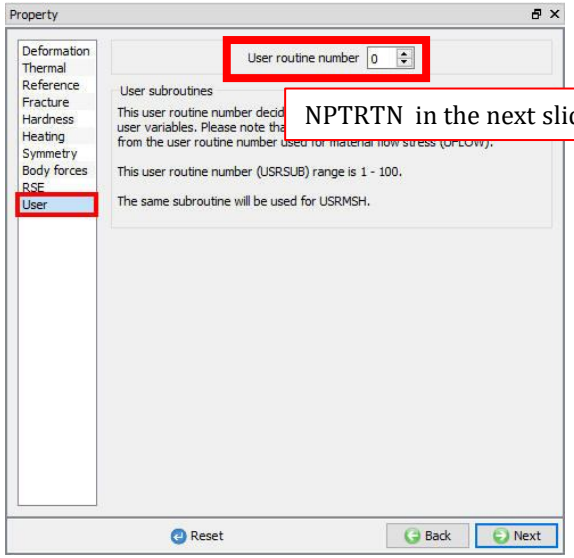
Input parameters.
See the slide 3.

4) Edit “Output Control” in “Simulation controls”



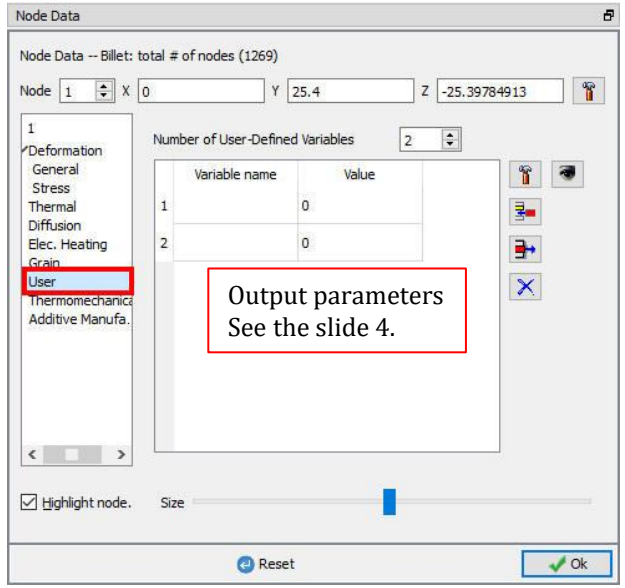
Check “Element+node”

5) Edit “User” in “Property” of each object



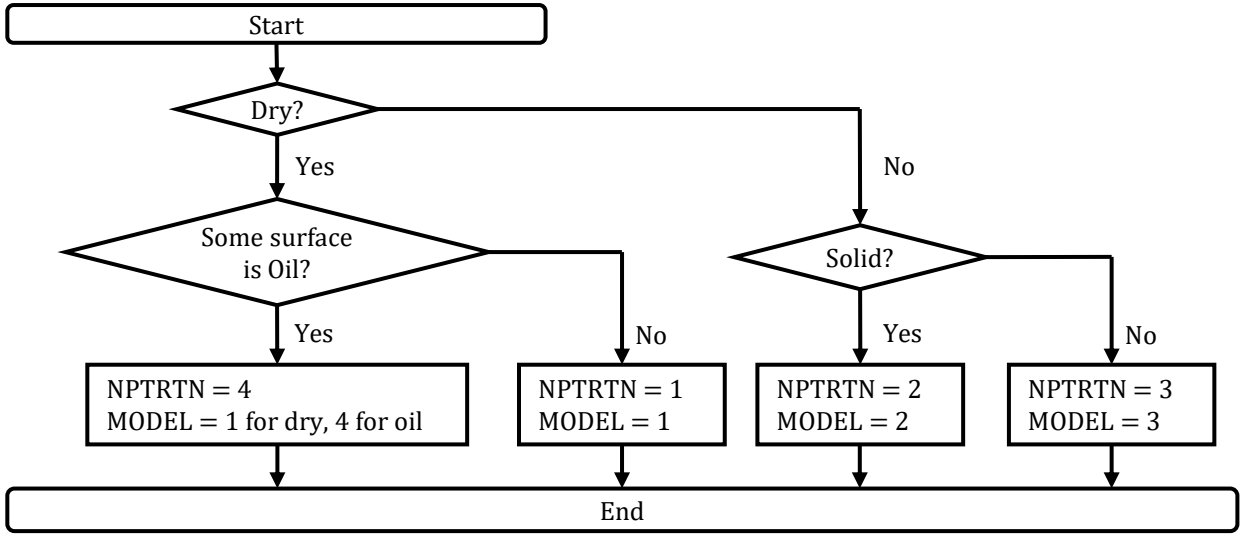
NPTRTN in the next slide

6) Edit “User” in “Node Data”



Output parameters
See the slide 4.

What number should I use in NPTRTN and MODEL?



Input parameters by user in pre-processor

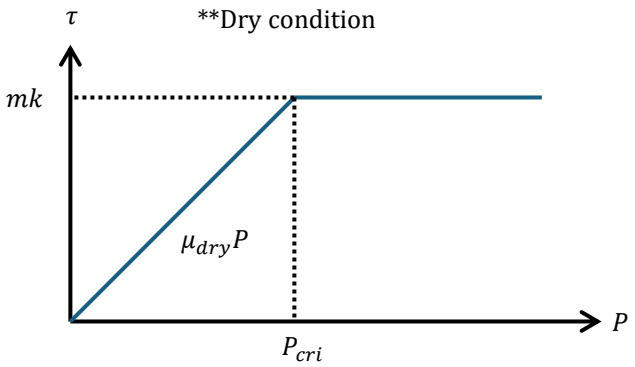
NPTRTN	1		2		3		4	
Num.	Description	Reference value	Description	Reference value	Description	Reference value	Description	Reference value
1	K *	Depend on material	1: Use work temperature 2: Use tool temperature 3: Use average temperature	2	K *	Depend on material	K *	Depend on material
2	n *		μ_0 ***	0.06	n *		n *	
3	ε_0 *		T_0 ***	20	ε_0 *		ε_0 *	
4	μ_{dry} **	0.15	-	-	μ_1 ****	$0.15 = \mu_{dry}$	μ_{dry} **	0.15
5	-	-	-	-	μ_2 ****	$0.07 \approx \mu_1/2$	μ_1 ****	$0.15 = \mu_{dry}$
6	-	-	-	-	P_{cri1}/Y ****	0.5	μ_2 ****	$0.07 \approx \mu_1/2$
7	-	-	-	-	P_{cri2}/Y ****	1.0	P_{cri1} ****	0.5
8	-	-	-	-	-	-	P_{cri2} ****	1.0

(Note)

$*Y = K(\bar{\varepsilon} + \varepsilon_0)^n$

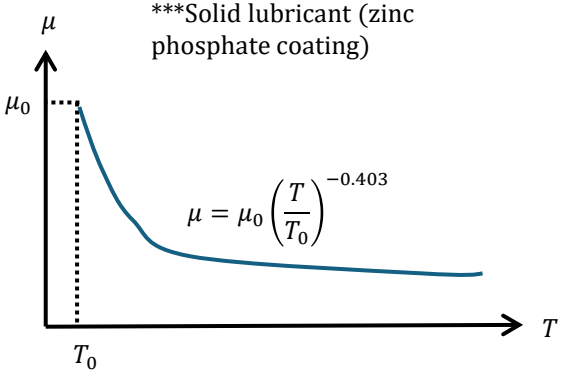
Y: Flow stress
K: Plastic coefficient
$\bar{\varepsilon}$: effective strain
ε_0: Initial strain
n: n-value

**Dry condition



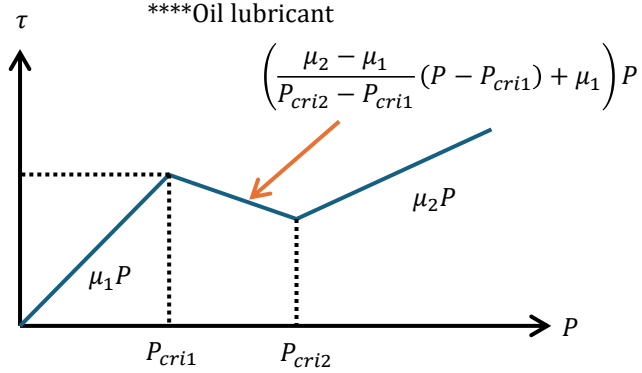
μ_{dry}: Coulomb friction coefficient
m: Shear friction coefficient +
k: Shear yield stress ++
P_{cri}: Critical pressure +
+ Calculated from μ_{dry}
++ Calculated from Y

***Solid lubricant (zinc phosphate coating)



μ_0: Reference coulomb friction coefficient
T_0: Reference temperature
T: Temperature

****Oil lubricant



μ_1: Coulomb friction coefficient 1
μ_2: Coulomb friction coefficient 2
P_{cri1}: Critical pressure 1
P_{cri2}: Critical pressure 2

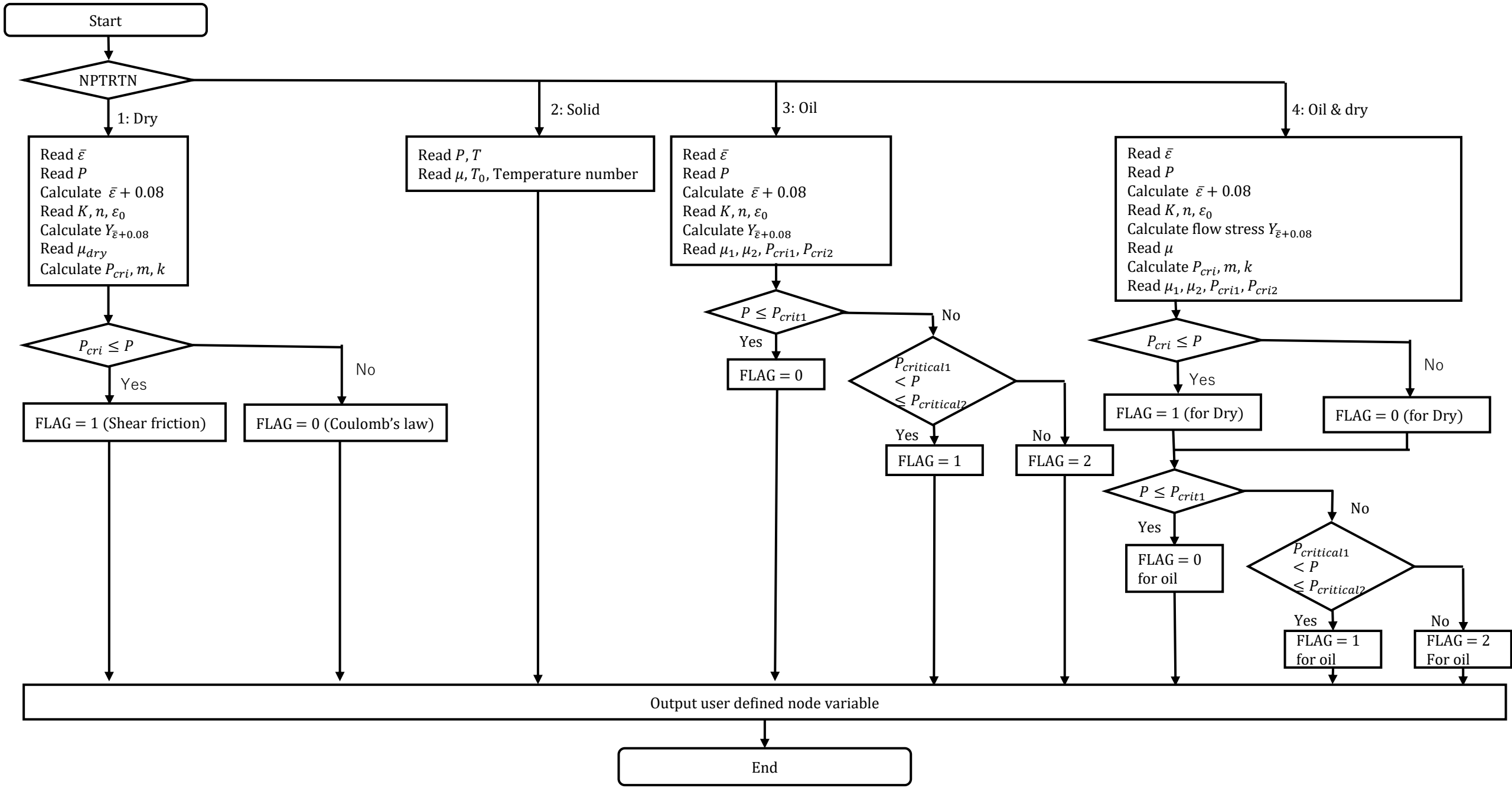
+

$a = -0.48\theta^2 + 2.48\theta - 3.82$
$b = 1.19\theta + 3.0$
$m = \sqrt{3}\mu(a\mu + b)$
$P_{cri} = \frac{2}{\sqrt{3}}Y\left(\frac{1+\sin 2\varphi}{2} + \frac{\pi}{4} + \varphi - \theta\right)$
$\varphi = \frac{1}{2}\cos^{-1} m$
$k = \frac{1}{\sqrt{3}}Y$
θ: wedge slope

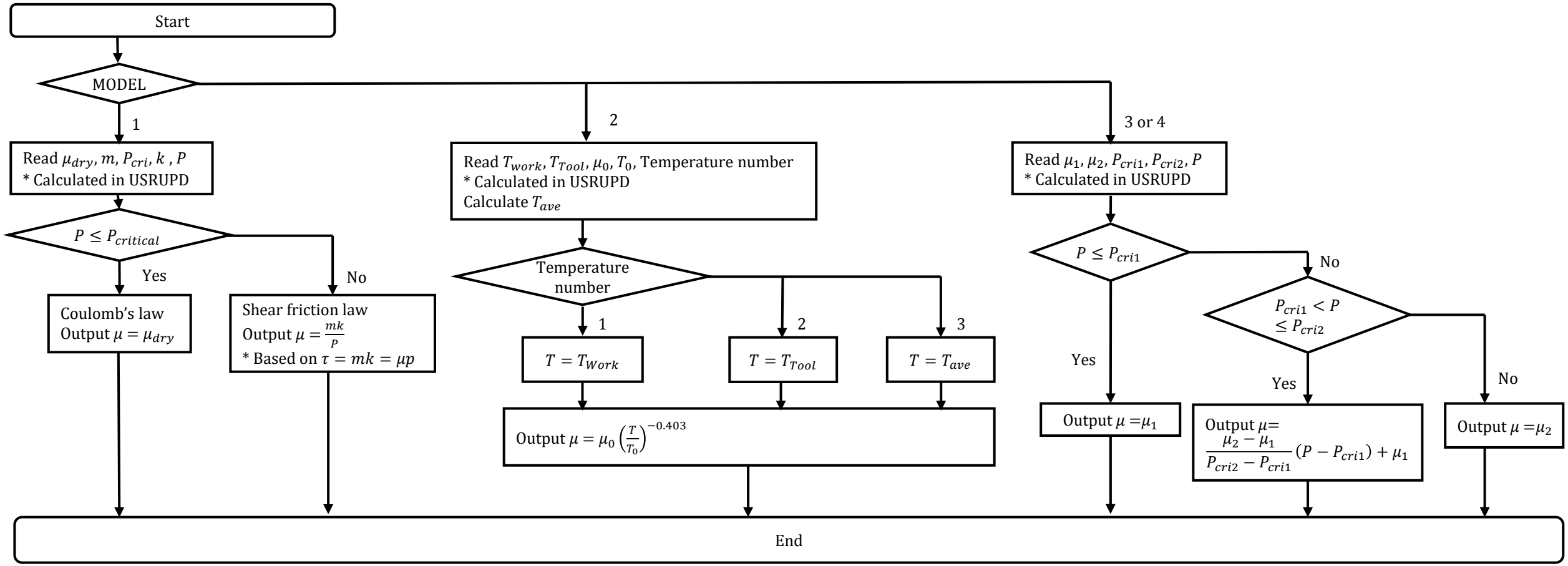
Output parameters (User defined node variable visualized in post-processor)

Num.	NPTRTN = 1	NPTRTN = 2	NPTRTN = 3	NPTRTN = 4
1	$\bar{\varepsilon} + 0.08$	P	$\bar{\varepsilon} + 0.08$	$\bar{\varepsilon} + 0.08$
2	P	T	P	P
3	K	Select number	K	K
4	n	μ_0	n	n
5	ε_0	T_0	ε_0	ε_0
6	Y	-	Y	Y
7	P_{cri}	-	μ_1	P_{cri}
8	μ_{dry}	-	μ_2	μ_{dry}
9	m	-	P_{cri1}/Y	m
10	k	-	P_{cri2}/Y	k
11	Flag 0: Coulomb, 1: Shear friction	-	P_{cri1}	Flag 0: Coulomb's, 1: Shear friction
12	Tangential pressure	-	P_{cri2}	Tangential pressure
13	Norm of pressure	-	Flag 0: μ_1, 1:Linear interpolation, 2: μ_2	Norm of pressure
14	-	-	-	μ_1
15	-	-	-	μ_2
16	-	-	-	P_{cri1}/Y
17	-	-	-	P_{cri2}/Y
18	-	-	-	P_{cri1}
19	-	-	-	P_{cri2}
20	-	-	-	Flag 0: μ_1, 1:Linear interpolation, 2: μ_2

USRUPD


Start
NPTRTN
1: Dry
2: Solid
3: Oil
4: Oil & dry
Read $\bar{\varepsilon}$
Read P
Calculate $\bar{\varepsilon} + 0.08$
Read K, n, ε_0
Calculate $Y_{\bar{\varepsilon}+0.08}$
Read μ_{dry}
Calculate P_{cri}, m, k
$P_{cri} \leq P$
Yes
No
FLAG = 1 (Shear friction)
FLAG = 0 (Coulomb's law)
Read P, T
Read μ, T_0, Temperature number
Read $\mu_1, \mu_2, P_{cri1}, P_{cri2}$
$P \leq P_{crit1}$
FLAG = 0
$P_{critical1} < P \leq P_{critical2}$
FLAG = 1
FLAG = 2
Calculate flow stress $Y_{\bar{\varepsilon}+0.08}$
FLAG = 1 (for Dry)
FLAG = 0 (for Dry)
FLAG = 0 for oil
FLAG = 1 for oil
FLAG = 2 For oil
Output user defined node variable
End

USRBCC


Start
MODEL
1
Read μ_{dry}, m, P_{cri}, k , P
* Calculated in USRUPD
$P \leq P_{critical}$
Yes
No
Coulomb's law
Output $\mu = \mu_{dry}$
Shear friction law
Output $\mu = \frac{mk}{P}$
* Based on $\tau = mk = \mu p$
2
Read T_{work}, T_{Tool}, μ_0, T_0, Temperature number
* Calculated in USRUPD
Calculate T_{ave}
Temperature number
1
2
3
$T = T_{Work}$
$T = T_{Tool}$
$T = T_{ave}$
Output $\mu = \mu_0 \left(\frac{T}{T_0}\right)^{-0.403}$
3 or 4
Read μ_1, μ_2, P_{cri1}, P_{cri2}, P
* Calculated in USRUPD
$P \leq P_{cri1}$
Yes
No
Output $\mu = \mu_1$
$P_{cri1} < P \leq P_{cri2}$
Yes
No
Output $\mu = \frac{\mu_2 - \mu_1}{P_{cri2} - P_{cri1}}(P - P_{cri1}) + \mu_1$
Output $\mu = \mu_2$
End