The free body diagram:

y

ma

x

τ,Ic α

N

φ

Ff

c

mgsin(Ө)

mgcos(Ө)

Ө

Where is the net torque i.e. (motor torque minus the mechanical losses)

Equations of motion:

 (1)

 (2)

 (3)

For sure you want to avoid sliding i.e.  differentiate once , once more:

 (4)

where , , is the wheel radius, and  is the moment of inertia about the wheel center.

4 unknowns, namely, in the above 4 equations.

Please note that the friction force is NOT equal to because in rolling without slipping the friction force is of the static type i.e. .

So when you get the friction force after solving the 4 equations you should make sure that its magnitude is  and from this condition, you get the minimum required coefficient of friction that forbids sliding (in the design phase). But in the off-design case:

Solving

 where 

For  “horizontal accelerating motion”

 and so the velocity keep increasing till sliding occurs.

Sliding occurs when

 i.e. when the applied torque reaches: . At this moment, the friction force is no longer an unknown (magnitude and direction) but equals:



In the opposite direction of the motion. And so the linear acceleration is constant “doesn’t depend on the applied torque anymore” and equals (using (1)):

 and the velocity decreases till rolling without slipping occurs again.