Stability Analysis of A 4 Wheel Drive Tractor Using ADAMS

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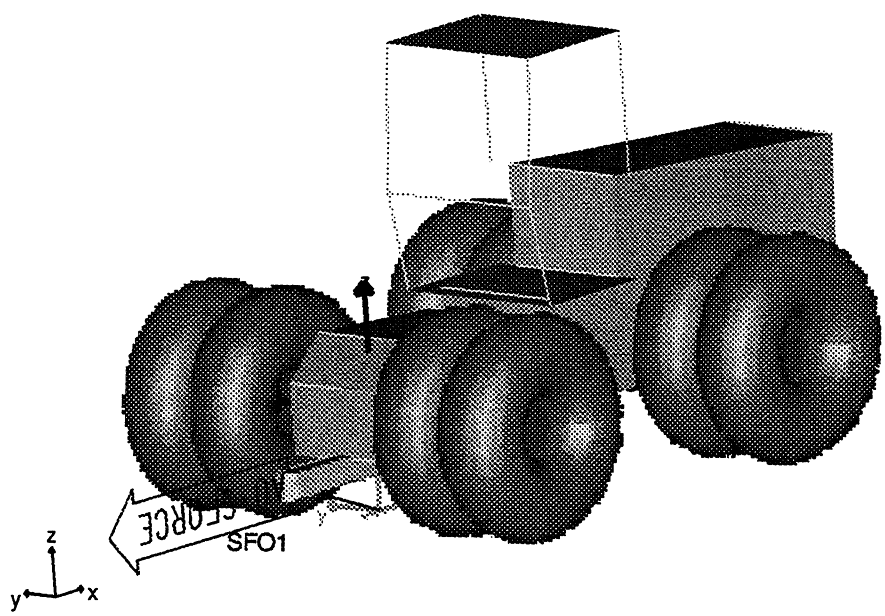
Introduction

The 'Power hop' phenomena is a well documented [1] dynamic instability that occurs in 4 wheel drive(WD) tractors. Figure 1 shows a graphic of a 4WD tractor with a draw bar extending out the back of the tractor. To this draw bar various implements can be attached. As the pull applied by the implement is increased beyond a certain level it is observed that 4WD tractors go into a unstable oscillatory motion that is a combination of the pitch and bounce mode. Increasing the draw bar pull further increases the amplitude of these oscillations to a point that the tractor operator has to take corrective measures. This paper presents a methodology for predicting draw bar pull loads at which there is onset of wheel hop.



Simulation Methodology

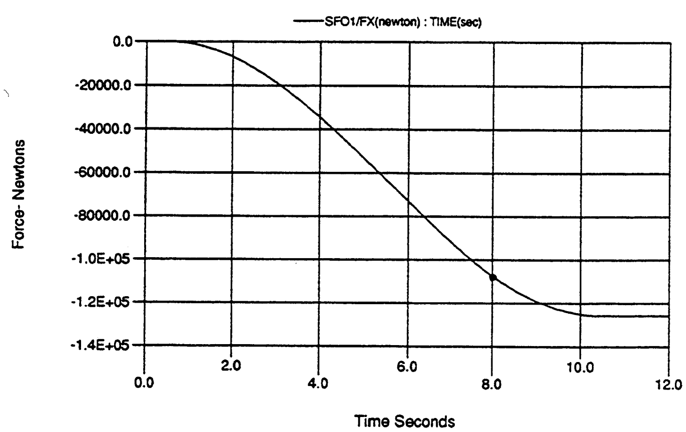
One of the commonly used methods for determining system stability is to compute the complex eigenvalues or poles of a linearize model. These eigenvalues can then be plotted on a pole plot with the real part of the complex eigenvalue on the horizontal axis and the imaginary part on the vertical axis. If any of the poles lie in the right half plane(RHP), i.e., the eigenvalue has a positive real part, the model is deemed to have unstable modes. If all the poles of the system are in the left half plane(LHP) the system is deemed to be stable.

To apply this methodology to the present application, a 3 degree-of-freedom 4WD tractor model with accurate representation of the tire dynamics is setup in ADAMS. The tractor is simulated accelerating from rest for 10 seconds. During this time the draw bar pull is increased from 0 to 1.26E+5 newtons as shown in figure 2. The total 10 second duration for the simulation is split into 10 simulations of 1 second duration each. After each of the 1 second duration of simulations the model eigenvalues are computed. The ADAMS command file for this simulation is given as

```
4wd.adm
4wd
sim/stat
linear/eigen
sim/transient, end=1,step=100
linear/eigen
sim/transient, end=2,step=100
linear/eigen
        .....
        .....
        .....
stop
```

On completion of the simulation the results plotted as complex scattering is ADAMS/View.

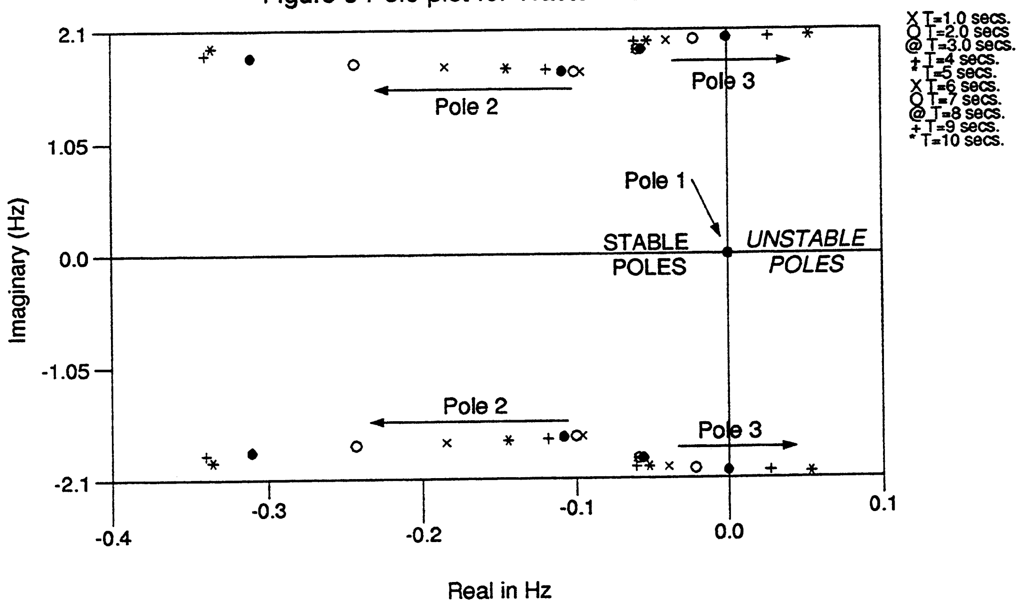
Figure 2 Draw Bar Pull



Simulation Results

Figure 3 shows the pole plot of the 4WD. The poles are plotted as a function of time. As expected in the 3 dof model there are 3 pairs of poles. One pair of poles stays on the real axis. The second conjugate pair of poles starts in the LHP at the beginning of the simulation and stays in the LHP for the duration of the simulation. In fact this pole becomes more stable as it moves further left of the imaginary axis. The third conjugate pair of poles starts in the LHP but moves toward and crossed into the RHP as time progresses. Thus increasing the draw bar pull on the tractor causes this pole to become unstable. From the pole plot it can be observed that the 3rd pair of poles just crosses into the RHP at 8 seconds. From figure 2 the draw bar pull at 8 seconds is given as 1.0735E+5 Newtons.

Figure 3 Pole plot for Tractor Model



Conclusion

It can be concluded that the maximum draw bar pull allowed for stable operation of this 4WD tractor in the given soil and setup condition is 1.0735E+5 Newtons. Exceeding this drawbar pull level will cause onset of the power hop instability resulting in reduced operating efficiency for the tractor.

References

1. Wiley, J.C, B.E. Romig, L.V. Anderson, F.M Zoz, 'Optimizing Dynamic Stability and Performance of Tractors with Radial Tires', 1992 International Winter Meeting of The American Society of Agricultural Engineers, Nashville, TN, 15-18 Dec. 1992.