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Delay Induced Canards

We consider a model for regenerative chatter in a drilling process. The model is a nonlinear delay differential equation where the delay arises from the fact that the cutting tool passes over the metal surface repeatedly. For any fixed value of the delay, a large enough increase in the width of the chip being cut results a Hopf bifurcation from the steady state, which is the origin of the chatter vibration. We show that for zero delay the Hopf bifurcation is degenerate and that for small delays this leads to a canard explosion. That is, as the chip width is increased beyond the Hopf bifurcation value, there is a rapid transition from a small amplitude limit cycle to a large relaxation cycle. Our analysis relies on perturbation techniques and a small delay approximation of the DDE model. We use numerical simulations and numerical continuation to support our analysis and to determine when the small delay approximation fails. We discuss how our results may apply to other systems with time delays. This is joint work with Emily Stone and Thomas Erneux.