An Application of Bifurcation Analysis to Automotive Windscreen Wipers

Bradley Graham*, James Knowles* and Georgios Mavros *
**Department of Aeronautical and Automotive Engineering, Loughborough University, UK*

Abstract. In this work we study the effects of automotive windscreen wiper design variables on the dynamics. To do this we utilise a lumped parameter model and numerical bifurcation analysis to determine operational regions of instability. This is achieved through an iterative two continuation calculation to produce surfaces of both the Hopf and Saddle node bifurcations. The continuation results agree well with known bounds of stable wiper operation.

Introduction

Whilst the purpose of windscreen wipers is well-defined, the non-linear contact and sliding mechanisms which govern the operation are complex. However, unlike almost every other aspect of vehicle development, empirical data is relied upon as oppose to predictive models to inform design decisions. This reliance on empirical data places constraints of questionable necessity on design criteria, the result of which can restrict both the vehicle designers and wash-wipe engineers producing the optimum product. This work presents an analysis of the impact that a selection of wiper design criteria has on the dynamic stability of a windscreen wiper system.

Approach

We consider a contact distribution that is calculated by finite element analysis at the park position of a commercially available screen. A mathematical expression for the distribution is subsequently derived to allow for precise manipulation of contact distribution shaping. In order to study the impact that a selection of wiper design criteria has on the dynamic stability of the system, a reduced complexity mechanical model is established. The contact distribution along with a continuously differentiable Stribeck curve which features six constants and the angular velocity of the wiper blade is used to capture the transient friction characteristics[1]. Bifurcation analysis is then applied to determine Hopf bifurcations, the subsequent periodic orbits and associated saddle node bifurcations.

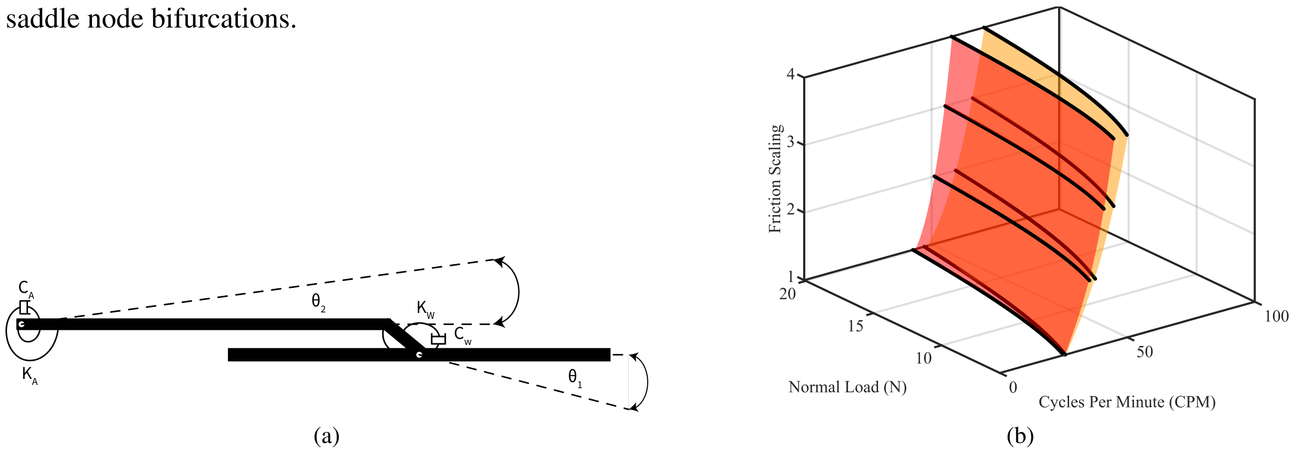

Figure 1: (a) Reduced Complexity Lump Parameter Model of an Automotive Wiper, (b) Three Parameter Continuation Diagram tracing the Hopf and Saddle Node Bifucations

Figure 1a shows a schematic of the wiper system used throughout the study. Figure 1b shows a three parameter continuation diagram tracing the Hopf (red surface) and Saddle node (amber surface) bifurcations. The results are interpolated using three parameters to construct a surface of bifurcations. Such a surface can be used to determine optimum regions of operation for wiper blades. The results of our work agree well with known operational regions of automotive wiper blades.

Conclusions

The non-linear complexities and current reliance on empirical data associated to windscreen wipers necessitate the development of models and analyses such as presented above. The work presented shows calculated regions of instability associated to the manipulation of windscreen wiper design parameters. These results can be used by vehicle designers and wash-wipe engineers to efficiently study the impact of design decisions on the stable areas of operation of automotive windscreen wipers. Thus providing valuable insight into the relationship between vehicle design and wipe quality.

References

[1] Makkar C., Dixon W. E., Sawyer W. G., Hu G. (2005) A New Continuously Differentiable Friction Model for Control Systems Design *IEEE/ASME International Conference on Advanced Intelligent Mechatronics.* Monterey, CA, USA, 24-28 July 2005