The Effects of Screen Curvature On The Transient Dynamics Of Automotive Windscreen Wipers

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

Summary. In this paper we study the effects of automotive windscreen curvature on the transient dynamics of a wiper blade. To do this we utilise a finite element (FE) model to obtain contact force distributions for multiple screen curvatures in a single axis. The distributions obtained are directly integrated into a multiple connected mass-spring-damper (MSD) system to analyse the transient dynamics.

Introduction

The primary function of windscreen wipers is to remove water and debris from the windscreen, ensuring the driver has a clear view of the road ahead. The successful operation of windscreen wipers is therefore imperative for the vehicle occupants' safety. Predicting wiper performance at the design stage is important to ensure their safe operation: whilst the purpose of windscreen wipers is simple, the non-linear contact and sliding mechanisms which govern the operation are complex. Because of these complexities, a lot of preliminary design decisions are based on empirical data rather than predictive models. This can present constraints of unknown necessity on other aspects of a vehicle's design (e.g. windscreen curvature). There is hence a need to develop physics-based models of wiper performance that can be used as evaluative tools early in the design stage.

Approach

This work presents an analysis of the impact that the contact distribution has on the transient dynamics of a windscreen wiper blade. We consider the curvature of the screen in a single axis, the y axis. For the purpose of our model we maintain the geometry of the wiper blade used in the FE model. Initially we take a commercially available screen, of curvature G for analysis. We subsequently establish a mathematical expression of the screen to adjust the curvature to $\frac{1}{3}G$ and $\frac{5}{3}G$. We utilise multiple connected mass spring damper systems to represent the full length of the blade, and to allow for direct integration of the distributions computed via a finite element (FE) model. A continuously differentiable Stribeck curve[1] which features six constants is used to capture the transient friction characteristics of the blade. The Stribeck curve is modified to agree with a recognised range of fiction coefficients, $0.1 - 0.6$, associated to wet friction[2]. Additionally, we use experimental values for both the stiffness, K, and damping, C, which were presented by Shigeki Okura and Tohru Sekiguchi[3]. For our study we consider a discretisation that corresponds to a real-life discretisation distance of $2mm$ on a $600mm$ wiper blade, providing much greater resolution than currently offered by experimental measures.

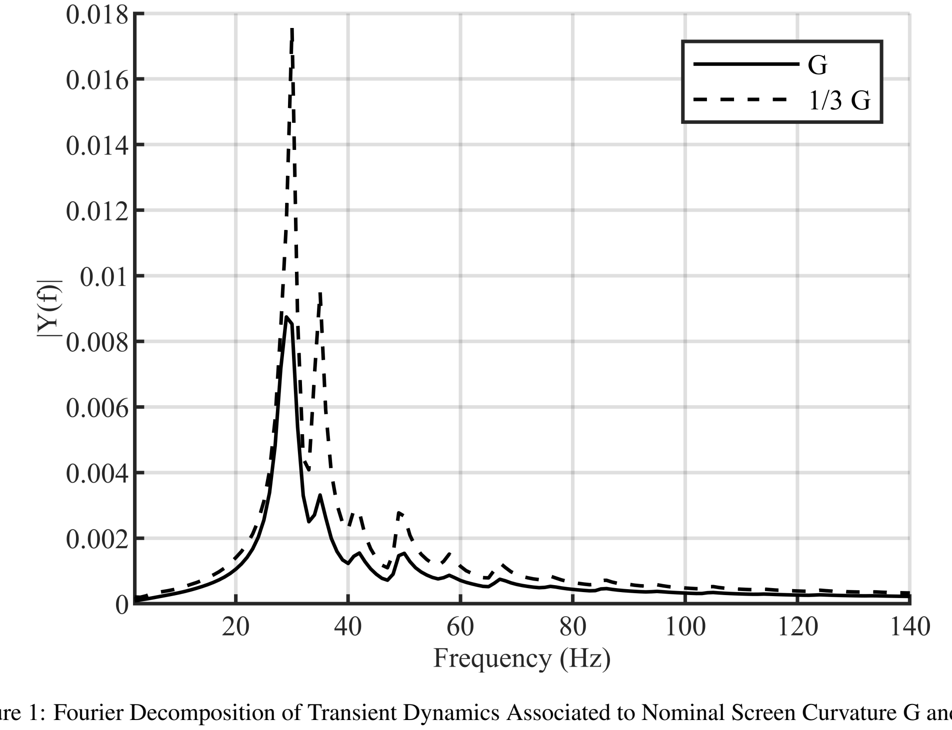

Figure 1: Fourier Decomposition of Transient Dynamics Associated to Nominal Screen Curvature G and $\frac{1}{3}G$

Figure 1 shows the Fourier decomposition of the transient dynamics data for a nominal curvature, G and $\frac{1}{3}G$. In the nominal case, we find a peak in the amplitude of frequency at $30Hz$. Additionally, there are a number of underlying beats with a greater frequency than the peak, but significantly lower amplitude. When considering the a reduced curvature case, we find that the peak frequency remains constant at $30Hz$, but has a much greater amplitude. The underlying beats that were visible in the nominal case are also present in the reduced curvature case. As with the peak frequency, the amplitude of the beat frequencies also increase. However, the increase in amplitude, decreases as we consider higher frequencies. Additionally we find that a uniform distribution does not yield a more desirable dynamic response than the current contact distributions that feature on flat style wiper blades, but in fact a screen of greater curvature can yield reduced amplitudes of the frequencies observed. Throughout our study we observe a dominant peak frequency, $30Hz$, such a frequency is associated to a chatter response of wiper blades[4].

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 how small design decisions such as the curvature of a windscreen, can dramatically affect wiper system performance, and shows how some small design changes can aid in the functional operation of windscreen wipers. These results show the importance of understanding the effects that screen curvature has on not only the transient dynamics but also the frequency response of the blade, providing insight into improving wiper quality.

References

[1] Makkar, C., Dixon, W.E., Sawyer, W.G. and Hu, G., 2005, July. *A new continuously differentiable friction model for control systems design.* In Proceedings, 2005 IEEE/ASME International Conference on Advanced Intelligent Mechatronics. (pp. 600-605). IEEE.

[2] Robert Bosch. *Automotive Handbook.* 8th ed. Plochingen: Bosch, 2011.

[3] Okura, Shigeki, Tohru Sekiguchi, and Takio Oya. *Dynamic analysis of blade reversal behavior in a windshield wiper system*. SAE transactions (2000): 183-192.

[4] Awang, I. M., et al. *Modeling and simulation of automotive wiper noise and vibration using finite element method.* EVALUATION OF AN AUTOMOTIVE WIPER NOISE AND VIBRATION CHARACTERISTICS USING NUMERICAL APPROACH (2009): 13.