A characterisation of bicycle powertrain losses due to chainring deflection

T.H.A. Davis[1], D.T. Asquith[1,2]
[1] *Department of Engineering and Mathematics, Sheffield Hallam University, Sheffield, UK*
[2] *Materials and Engineering Research Institute, Sheffield Hallam University, Sheffield, UK*

Abstract
The engineering of a modern road racing bicycle is ever increasing in complexity, one component that does not see many major improvements is the chainset. This study is to focus on the chainset, specifically the amount of displacement of the chainring's and therefore the amount of strain energy lost into the chainset. The calculated data can be used to lighten or decrease the power losses in future chainset designs.

Introduction
There have been many studies into the elastic deformation of bicycle chainsets [1,2,3], however these studies were focussed the planar deflection and did not consider the deformation on the chainring. Due to the geometry of the samples the main expected displacement of the chainring is in the Z direction (out of plane). The out of plane displacements of the chainset requires the use of 3D DIC, using binocular-stereovision to provide the Z displacements. The displacement data is converted into strain energy values which correspond to power losses into the chainset. The two samples under comparison are a Shimano 105 4 arm asymmetric chainset and an FSA Gossamer 5 arm symmetric chainset.

Completed Work
The previous studies have only considered the planar displacement of the chainset with the displacement being measured at the pedal axle and chainset being fixed by the chain. The experimental set-up of this study is very similar, the chain is fixing the chainset and there is a load applied at an offset at the pedal axle. A tensioner must be used to ensure that there is no slippage of the chain.

A commercially available DIC system, from LaVision, has been used to take displacement measurements, with the use of a StrainMaster DIC controller and DaVis software. The Surface height and deformation field within DaVis has been utilised to obtain the average maximum non-planar displacement over the region of maximum displacement for each of the two samples. The data shown in Figure 1 & Figure 2 has been collected under the maximum loading condition.

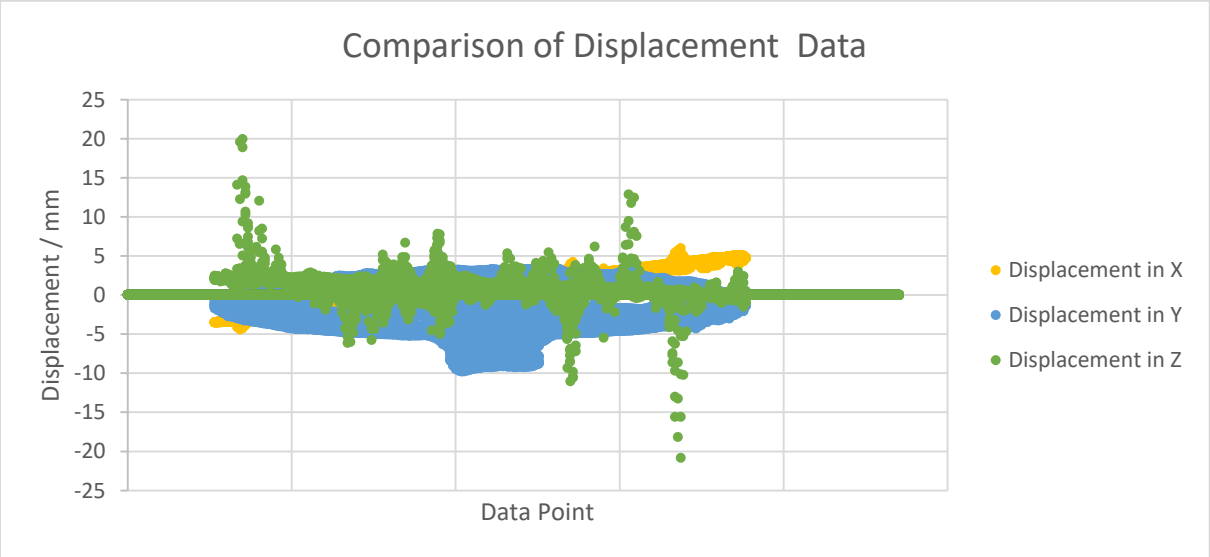

Figure 1: 105 Chainset strain value comparisons

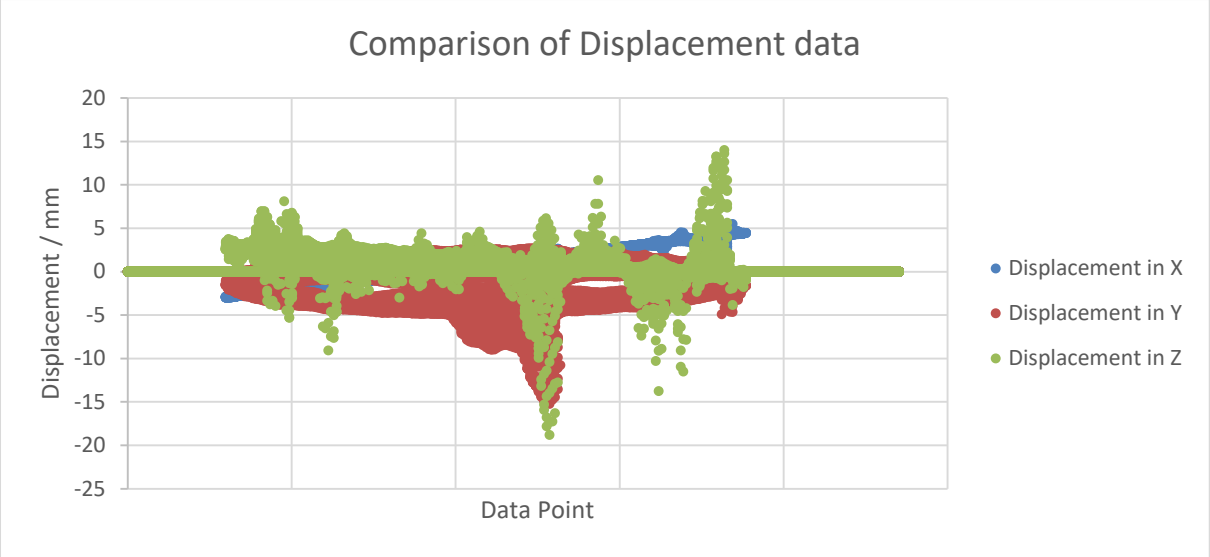

Figure 2: FSA chainset strain value comparison

Figure 1 & Figure 2 allow for a comparison between the two different geometries, whereby the difference in maximum displacement is shown by the location of the peak of the displacement values on the x axis (as the Data Point value relates to a specific location on the sample). It must be noted that the strain values for the Z displacements are greater than for X or Y displacements as the initial length is much lower.

The focus of the study is the Z displacement and strain energy losses of the chainset, however the comparison of the planar displacement data to published data, [1,2], is used for validation.

The maximal loading condition used in this study is equivalent to $3\ kW$ of power produced by the rider. This is far greater than even the most powerful track sprinter; however, it should highlight the performance of the chainset under load.

The displacement data has been imported into MATLAB to allow for the calculation of the calculation of the specific strain energy of a 3D stress system, which is in turn transformed into a strain energy value. As the strain energy is equal to the work done onto the system, the power loss through the chainset can be measured.

Conclusion

The application of 3D DIC to calculate the Z displacement of chainsets under load allows for the performance of different chainsets to be quantifiably compared, with the displacement data relating to a power loss into the chainsets. Further work is to include investigating the effect of chain angle (different cogs on the cassette) on the Z displacement, and to relate the strain data to a power loss through the chainset. With the collected data allowing for an improvement to the current chainset designs.

References

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