Approximating Loads in Kick Scooters with Measured Strain

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Overview

Kick scooters are rapidly becoming a mainstream mode of urban transport that reduces inner-city congestion and pollution. They also receive widespread recreational use. Despite comprising a multi-billion-dollar industry, there is no published research on the loading of kick scooters. Understanding the loads scooters face in real-world use can help design lighter and stronger scooters. This research investigates the loading scooters face and uses this information to optimize their design. There are three main components to the load investigation. First, appropriate experimental equipment must be built to capture strain data. The data acquisition system is lightweight and capable of capturing eight channels of data at 62.5 kHz. A model drawing from both FE simulations and experimental results has been verified. It is used to approximate the input loads from the measured strain. Loads are measured, analysed and then used to help optimize scooter component geometry. Future work will involve experimental tests on components to further verify the performance improvement. The research presented has applicability to other sports equipment, such as skateboards.

Building experimental equipment

A data acquisition system (DAQ) has been constructed from amplifiers, Wheatstone bridges, an existing data logger and other components to measure strain. Its size is approximately 75 x 75 x 40 mm without the battery. It is small enough to be mounted on a scooter with little impact on the performance of riding. Requirements exceed the needed data-logging rate to obtain an accurate strain history of the scooter, making it suitable for use in real-world applications.

Approximating scooter loads with strain measurements

A model has been developed utilizing FEA and experimental measurement that can approximate the loading the scooter faces from measured strains. The loading uses approaches similar to some of those found in [1].

In the case of static loads, as in Fig 1., the possible basis loads must be assumed, and their strain output can be simulated with FE analysis and confirmed with experimental measurement. Each basis load will produce a unique strain distribution that results in a measured strain at each strain measurement point. These basis loads go to form an orthonormal set such that any set of measured strains can be approximated by the basis loads. without any constraints, the results will be ill-conditioned (very sensitive to experimental noise, or imperfect representation of the basis loads). This can be solved by putting suitable restrictions on the allowed values of the basis loads.

The total force applied to the scooter will be a linear sum of the basis loads:

$$\boldsymbol{F} = \sum_{x=1}^{n} c_x \boldsymbol{f}_x \tag{1}$$

Where c_x is the weighting of each basis load, and the weighting of the basis loads will be the solution to the equation:

$$[\boldsymbol{\varepsilon}_t]\boldsymbol{c} = \boldsymbol{\varepsilon}_m \tag{2}$$

Where $\boldsymbol{\varepsilon}_t$ is the matrix that relates the measured strain to the basis loads, **c** is the vector of weighted forces, and ε_m is the measured strain.

1. R. Adams and J. F Doyle – Multiple Force Identification for Complex Structures, Experimental Mechanics (2002)

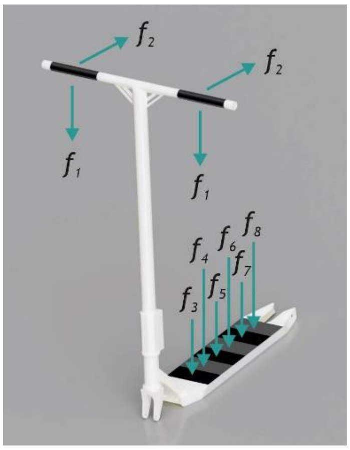

Figure 1. Figure 4.4: An example of the assumed possible loads on a model scooter. Black and grey regions are to highlight the area over which the basis operate. In this model, symmetry is assumed on forces applied from the hands on the handlebars, thus the basis load for $\boldsymbol{f}_1$ *and* $\boldsymbol{f}_2$ *are equally distributed across each side of the crossbar.*

The approach can be extended to the dynamic case, where instead of basis loads, basis impulses are used, and the strain history is used, rather than strain measurements at one instance in time. Each basis impulse will produce a strain at distribution that varies with time. Damping characteristics need to be measured to accurately describe the strain evolution of a basis impulse. As dynamic analysis enables a more realistic approximation of the applied loads and their effects, such an impulse based model is used for scooters.

Results

The variation in the magnitude and distribution of the loads the scooter faces will be discussed. This information will inform improvements in scooter design. New geometries will be compared with existing scooter components. Geometries that reduce the stress that scooter components face whilst also minimising the component weight will be shown. The manufacturability of such components will also briefly be considered. Topology optimization and shape optimization techniques will help achieve improved geometries.