**Blue – make more concise**

**Red – make into own words**

**Key points to mention:**

**Show code working for synthesised data**

**Show the likelihood**

**Explanation as to why the stiffness was lower**

**Writing this paper:**

**Abstract, Mathematics and code, Experiment, Defining the models/ methodology, Results, Conclusion**

**My problems with this paper:**

We have made an assumption that our deflections were Independent, identically distributed- well yes they are but they all have a deviation from the model by an amount, mu. Check this assumption in the book.

**Abstract:**

We use mathematical models to predict the behaviour of physical systems, whether it be structural beams, bridges, cells or circuits. This short paper aims to use how a Bayesian approach to assess quantitatively how well two different beam models, namely Euler-Bernolli beam theory and Finite Element Analysis (FEA), predict the deflection of a thin shelled structure.

**Introduction**

Mathematical models of physical and natural systems have long been employed to investigate the underlying mechanisms leading to the form and function of such processes being studied, with Partial Differential Equations (PDE) being almost ubiquitous in such scientific enquiry. These mathematical models and associated computer simulations are in many cases simplifications of the actual system, for example making assumptions about the nonlinearity of certain system processes or model parameters, thus introducing possible model misspecification (Kennedy and O’Hagan, 2001). In addition to this, computer simulations of these models are often extremely computationally expensive to run. It is because of this that such models are seldom used as the only component in the overall modelling procedure; data observed from the actual physical system, obtained as measurements from sensors, is often utilised as well. The mathematical models can be calibrated, tuned and combined with this observed data. In most cases, this data is used to infer information about the undefined parameters in the model (Stuart, 2010; Grafe, 1998). In order to train our model with data, the first step might be to asses quantitively how well the model in question fits the data.

**Maths**

**Models**

**Application to the Mechanics of Thin Shell Structures**

In this section we demonstrate the application of the proposed methodology to the deflection of thin shell structures. Thin shells are curved solids with one dimension significantly smaller than the other two. They are prevalent in nature, e.g., as insect wings or biological membranes and in engineering, most prominently in aerospace and automotive. Carefully designed curved thin shells have a load carrying capacity which is usually significantly higher than comparable flat structures.\\

**Problem Description**

We consider the composite beam shown in Figure 1 consisting of a gyroid core and two face plates. The gyroid is a triply periodic minimal surface with zero mean curvature and has recently been extensively explored in additive manufacturing applications, see e.g. Hussein et al. (2013); Abueidda et al. (2017). As known, cellular solids like the gyroid core can have mechanical properties that are orders of magnitude different from their constituent materials (Fleck et al., 2010). The length of the beam is $0.243m$, its height, i.e. distance between the top and bottom plates, is $0.1$ and its width is $0.1$. The gyroid core is described by the algebraic function\\

$algebraic function$

with $\lambda = 20\pi$. The core and the two plates are modelled as thin shells and have a thickness of $t = 0.901mm$.

The beam is clamped at its left end, and at its right end the bottom plate is simply supported at a

distance $0.025$ away from the boundary. The Young’s modulus and the Poisson’s ratio are $E = 2.30GPa$

and $\nu = 0.3$. The top plate is subjected to a uniform pressure $f(x) = 3$ acting in the negative z

direction.

\subsection{Getting data}

**Euler- Bernoulli beam model**

The gyroid structure’s deflections can be estimated by an Euler-Bernoulli beam model, assuming that bending moment is proportional to curvature. To estimate the stiffness of our beam we need to know its Youngs modulus, which from lab tests was taken to be 2.30GPa, and the second moment of area. The second moment of area changes as the cross section of the beam changes. It can be crudely approximated by smearing all the material between the flanges into a central web, so that it looks like an I beam. The second moment of area was taken to be 19,560mm^4.

**Finite Element Model**

This model of the beam was compared to a thin-shell finite element model. The young’s Modulus of the material was taken to be 2.30GPa

**Problems with our formulation**

The Euler-Bernoulli model underestimated the deflections of the beam. This could be explained by the fact that the Euler-Bernoulli model does not take into account shear deflections, which are most prominent in short, fat beams, furthermore, the crude calculation of the Young’s Modulus of the beam by smearing the material to the central web, which contributes to about a third of the total value of the young’s modulus, may have been an over-estimate. The finite element model overestimated the deflections of the beam.

It follows that our assumption that the data is normally distributed about the model is wrong, for both our models. The I-beam model underestimates the deflections because it does not take into account shear deflections, and the second-moment of area is likely to have been overestimated. However, it is still a good comparison between the models, as the likelihood will be lower for a model that deviates from the mean.

**Taking measurements**

The gyroid beam is a complex geometry that can only be manufactured via additive methods, such as 3D printing. The gyroid beam was 3D printed using the facilities in the Dyson Centre for Engineering Design and tested using the instron machines at the Fatigue Lab at Cambridge University Engineering Department.\\

A laser system and reflective tape were used to measure the deflection of the beam across the span. The laser system measured the distance between two reflective tapes, once attached to the beam, and one attached to the intron machine, as pictured. The distances were subtracted from initial distances to get a deflection measurement, which was taken multiple times and averaged.

FIGURE\_XX diagram of the instron testing, labelled.

The laser was swung round on a tripod to point it at each set of tapes. This introduced some error in the deflection measurements as the act of rotating the laser on the tripod may have moved the tripod slightly in the direction of deflection.

The deflections were measured at loads of 200N, 250N and 300N.

A plot of the deflections at the different loads can be shown below. The 200N data can be seen to be quite noisy. This can be explained by the fact that the relative magnitude of the noise versus deflection is higher at lower deflections, and the noise had lowered for the 250N as we had taken more care with the measurements as we got used to the apparatus. It should be noted that the 300N load caused a small amount of plastic deformation, as deflection was outside of the linear-elastic regime.

FIGURE\_XX the displacement graphs, plotted in matplotlib