Designing a Topology Optimised Guitar for Matthew Bellamy

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Introduction

Matthew Bellamy is the eccentric lead singer of the rock band Muse. The band is known for their elaborate shows, each one bigger than the one before. Matthew is especially known to use new innovative instruments on stage. On top of that, he has developed his own guitar, which is fully adapted to his own playing preferences. Combining his preferences plus love for innovative instruments, we propose a Topology Optimisation (TO) of his most used instrument: the guitar. More specifically the Manson Meta Series MBM-1 [1].

Objectives

Siemens NX Topology Optimisation will be used to create a personalised guitar for Matthew Bellamy. To reach this goal, various objectives have been set, to guide towards the final result. These objectives are as followed:

- Analysis of Matthew Bellamy and how he uses his guitar;
- Create and compare topology optimisations and generative designs based on use case analysis;
- Analysis of various materials based on material properties of original guitar, including stress and displacement analysis;
- Fully realised topology optimised guitar including all electrical components.

Design process

1. **Create design space**
   A 3D model of the body the guitar Matthew normally uses was made, based on pictures and available information about the guitar [1]. For other components, such as the neck [2] and the bridge [3], already existing models were used.
2. **Define printing materials**
   The MBM-1 is made of basswood, a type of wood which is widely available, relatively soft and has a balanced tonal characteristics [4]. As TO'ed body cannot be made with basswood, four other materials have been identified that have similar properties to basswood and can be used for Additive Manufacturing as well. These materials include Polypropylene (PP) [5], Wood-filled PLA [6], Glass-fibre reinforced nylon (PA-CF) [7] and Carbon-fibre reinforced nylon (PA-GF) [8].
3. **Requirements**
   - Leave in surface areas of the guitar which are frequently used by Matthew;
   - Body of the guitar should not weight less than the neck of the guitar (0,6 kg) to keep balance;
   - Study maximize stiffness with a safety factor of 1.3 with regards to the yield strength of the material.
4. **Calculate forces**
   Since the analysis is focussed on stage performance the main forces acting on the guitar are from the strap holding the guitar up to the body and the string tension.
   The forces of the strap are simulated at their respective connection point. The string tension is simulated by defining the forces put on the screw points of the bridge. These forces were found by a FEM simulation on the bridge, putting the forces of the strings [9] in their respective places and then extracting the reaction forces at the screw holes.
5. **Simulations**
   Based on the defined forces and chosen materials. exploratory studies were done, to confirm if forces had been set correctly. Based on these studies, forces were redefined and fixed points were changed, resulting in step 4 and 5 being done multiple times. The final set up is explained down below.
   To explore different iterations a final simulation setup was made. The standard simulation parameters would not change as different iterations were made based on material and form.
   Non-changing parameters were: forces, fixtures, construction bodies, minimum member size, maximum mass limit and the optimization was set to maximize stiffness.
   Iterations that were made are based on: Design space, Centre Of Gravity (COG) placement, Guitar border/contact surfaces to the player, and material.
6. **Comparison**
   Based on the outcomes of various simulations, a comparison study was set up in which all the results were compared. Based on this comparison, a final design was chosen in which the electrical components would be placed.

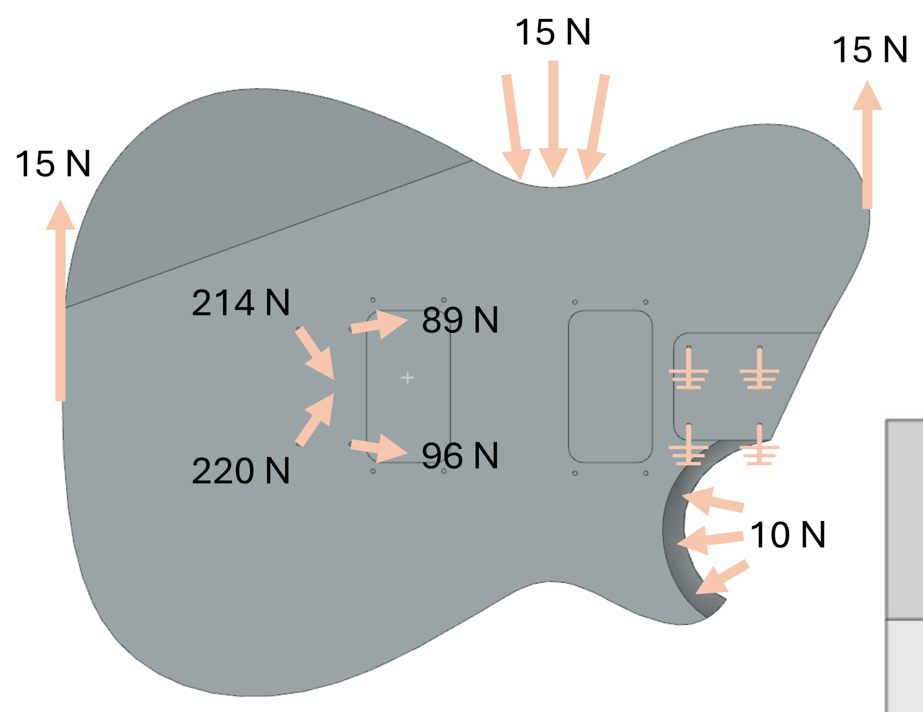
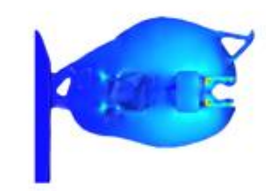
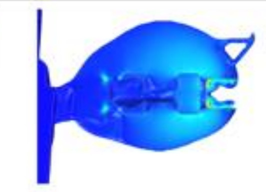
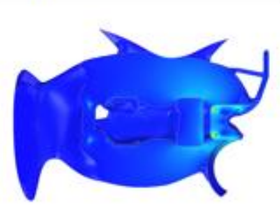


Figure 1 (left): final forces on the guitar for simulations
Table 1 (down): Simulations of the guitar with different and settings

Pre-liminary results

The different iterative studies that were done can be seen in the table. From these different iterations the final direction was chosen based on the highest stiffness achieved and most available space to place the electrical components. The iteration with the highest stiffness is the material Polypropylene with border.

	No border	No border No-COG	Generative	Generative No-COG	Border
Poly-Propylene					
Wood-Filled PLA					
Glass-Fiber Reinforced Nylon					
Carbon-Fiber Reinforced Nylon					

Final design

To finalize the chosen design, space for the routing and attachment of the electrical components was added [10,11,12,13]. Furthermore, the weight of the design was further reduced to 1 kg resulting in the guitar that can be seen here. The final achieved safety factor is 1.4 (yield strength / stress).

Reference list:

Conclusion and Discussion

This project explored the creation of a topology optimised guitar for Matthew Bellamy. This was done analysing Matthew's guitar usage and keeping in surfaces needed to keep playing the guitar. The final does copy the original shape, as it generated the highest stiffness, while reducing the most weight. Through this process it became clear that Siemens NX does not allow for generative design, as it still needs a pre-defined design space, something . Furthermore, it is not capable of producing multiple outcomes. Simulations show that adding a COG to the simulations results in a lot of material being added to the back of the guitar. This is most likely to keep the guitar in balance. Because similar materials were used for the simulations, the results did not differ much, making it difficult to draw clear conclusions on what material is most suitable. For future studies, materials with more property differences could be chosen, to generate results with greater variance. Lastly, more iterations could have been done on the final design, as Siemens NX allows for more variables being added, such as maximum member size or a print direction, optimising the guitar even further.