

Executive Summary

This project involves designing a motorcycle frame with pre-manufactured joints, as well as investigation into production methods and cost. The design process began by consolidating our load cases into five possible loading situations on the frame. Using Altair Inspire for optimization, the frame design was refined to reduce the number of joints and members while maintaining high stiffness, resulting in a line model suitable for production. A cost analysis was conducted comparing welding, machining, investment casting, and additive manufacturing for joint fabrication. Additive manufacturing proved cost-prohibitive for high-volume production, with high material and machine costs that do not decrease significantly with scale.

Background

- Thailand's large motorcycle market, combined with government incentives for electric vehicles, presents a significant opportunity for a company to expand into pre-assembled electric motorcycles.
- With over 44 million motor vehicles, and half of them being motorcycles, Thailand is a major market for automotive companies.
- Manufacturing a fully optimized frame using 3d printing is very expensive, but its benefits in repeatability and low labor costs may outweigh the current manufacturing methods



Figure 1. Common Electric Motorbike in Thailand

Experimental Setup

To create a design, we first had to understand the conditions of our product, we were given a basic design space with specified locations for the load applications, mounting points and stay out zones, seen below.

After receiving the design specifications, we developed free body diagrams that represent our potential load cases on the frame. The load cases include, turning, front and rear braking, front and rear impulse, static, and cargo. An example free body diagram of the static case can be seen below.

After our first round of analysis, we found that the cost to produce the initial design was too high, so we repeated this process with a simplified 3 joint frame.

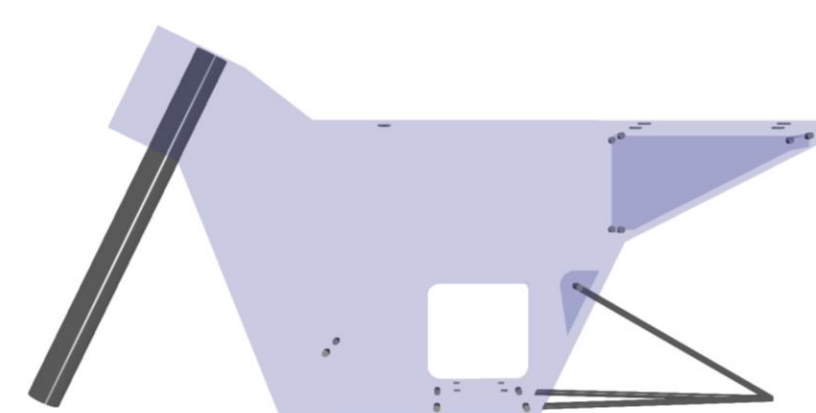


Figure 2. Design space

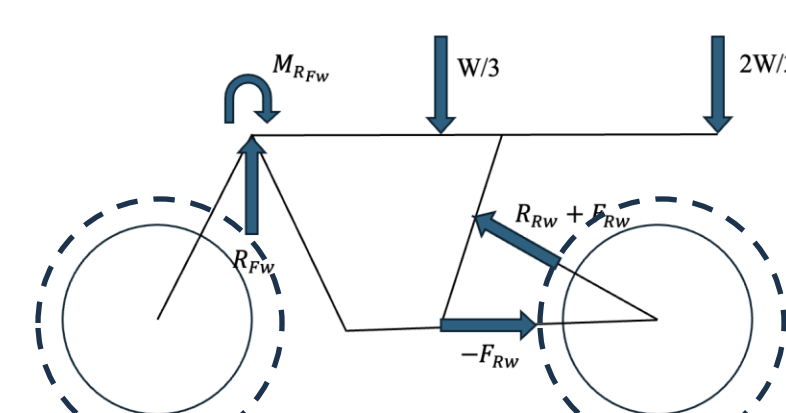


Figure 3. Static FBD

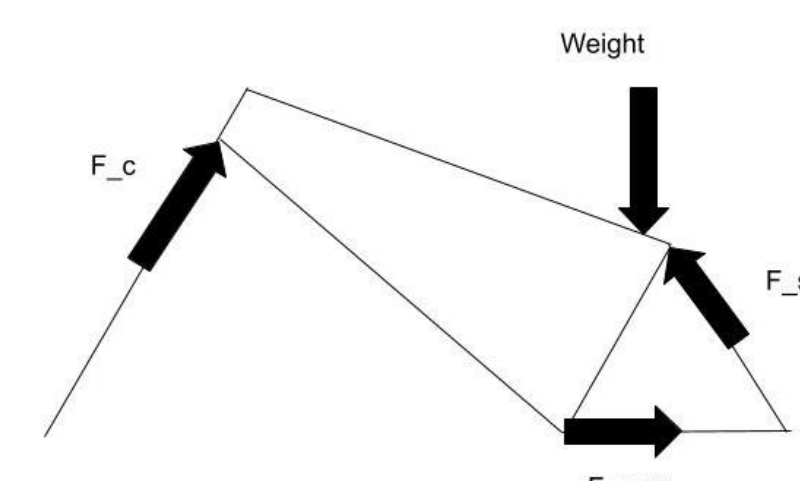


Figure 4. Static 3 joint FBD

Experimental Test Plan

After gathering our free body diagrams of our load cases, we can then move on to the analysis process. This begins with applying our magnitude loads to a truss approximation of the frame as seen in the free body diagrams, this will give us our reaction forces and moments at each attachment point.

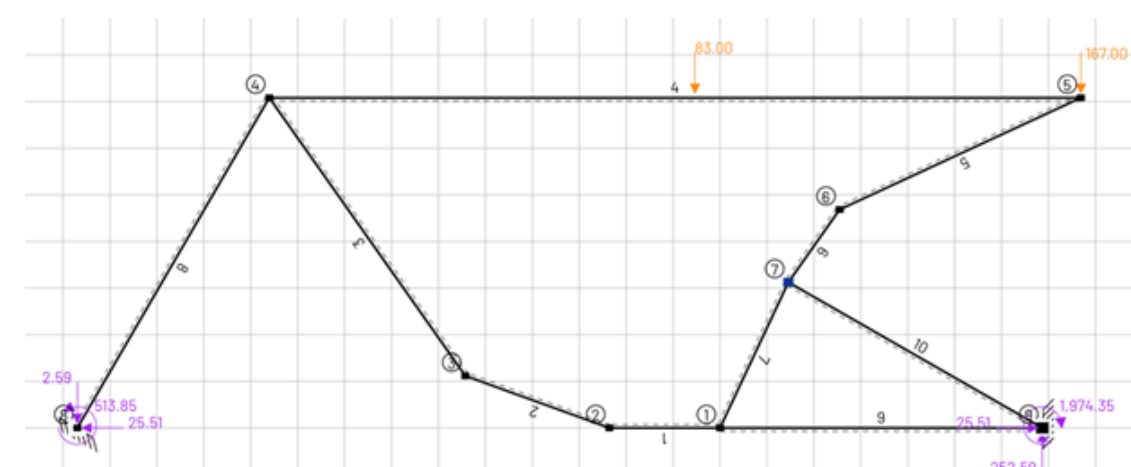


Figure 4. Frame calculations - edubeam.com

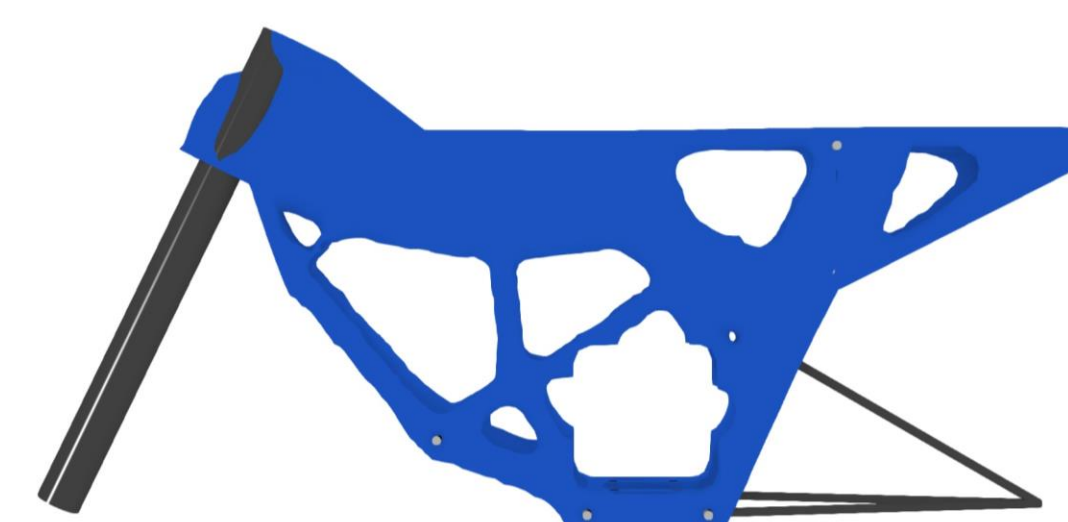


Figure 5. Optimized frame using Ansys

These force values are imported into Ansys, where we can apply all the load conditions on the design space, allowing us to generate an optimized material path that will give the highest stiffness possible with our design specifications. When repeating this process for the 3 joint simplified, we did not need to use Ansys because the new line model is 2 dimensional.

The connections between beams are our weak points; to increase strength, we are also optimizing the joints, in the same way we saw previously.

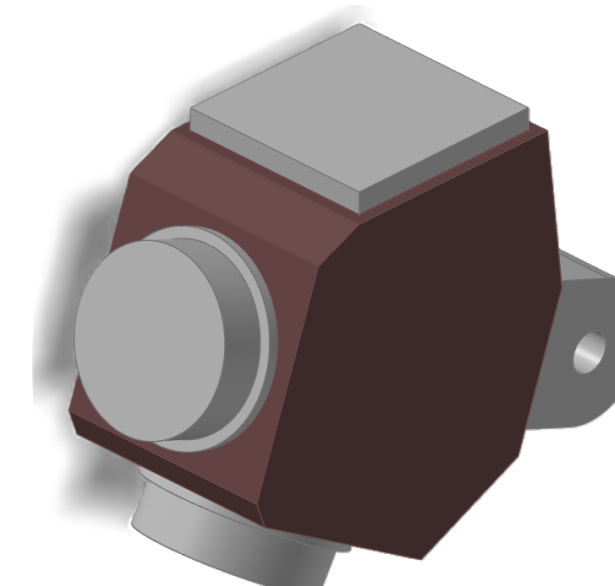


Figure 5. Joint Design Space

Experimental Results

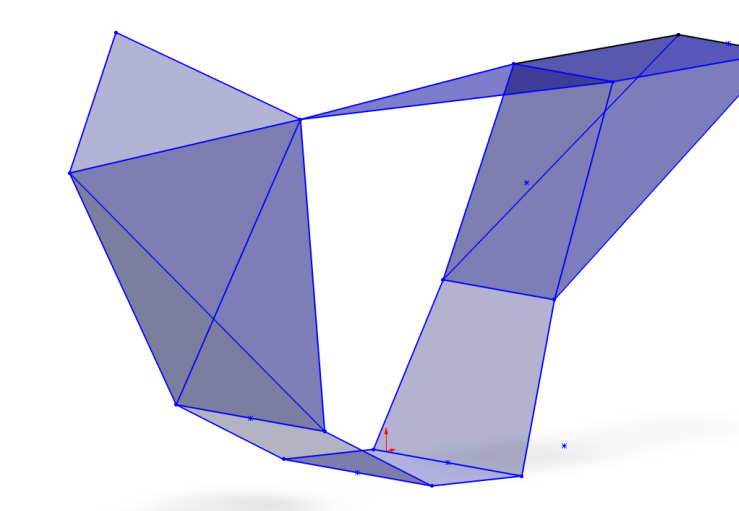


Figure 6. Line Model from optimization

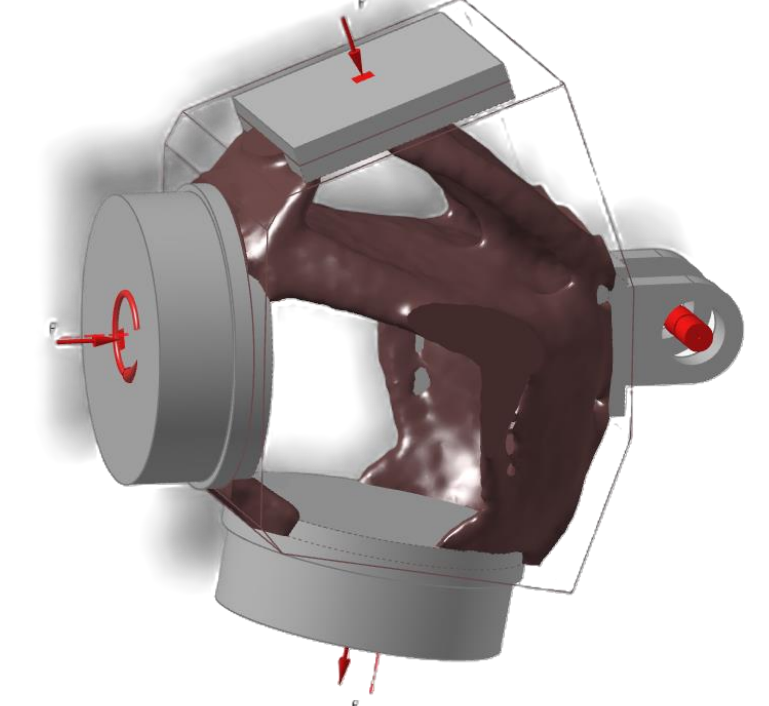


Figure 7. Optimized joint example



Figure 8. Simplified 3 joint CAD

- To reduce the cost of the frame, we follow the main material paths to generate a basic line model, which we will in theory use those basic lines as standard tube stock, then generate joints to connect the lines.
- After analyzing our frame, we found that our product was still too expensive to produce, therefore we decided to pivot to a 3 joint frame with larger joints and tubes

Conclusions

- Our three joint frame will provide a much simpler to manufacture and produce comparatively to traditional frames in the market

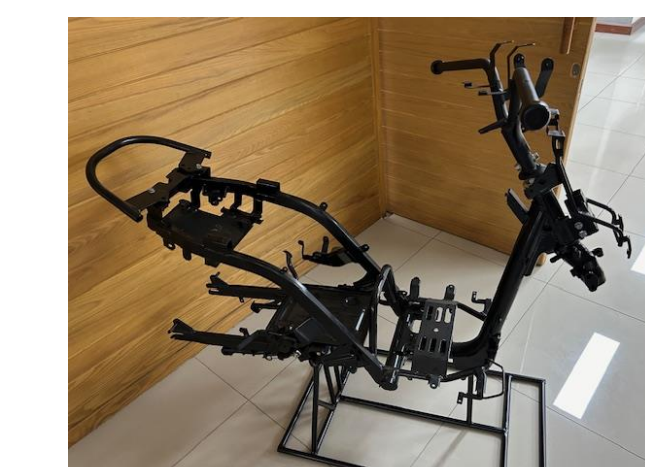


Figure 9. Traditional frame using welded tabs and joints

- Cost analysis shows as we replace welds with 3d printed components our cost per frame is much lower than traditional manufacturing costs at a low volume
- Our cost data was confirmed by real company quotes of many differing manufacturing methods such as Powder bed fusion and Investment casting, showing that cost per joint is on average \$700 per part, much too high to compete if we have a lot of joints
- Cost at high volumes could be found to be cheaper given the proper printing processes, but this is still yet to be found

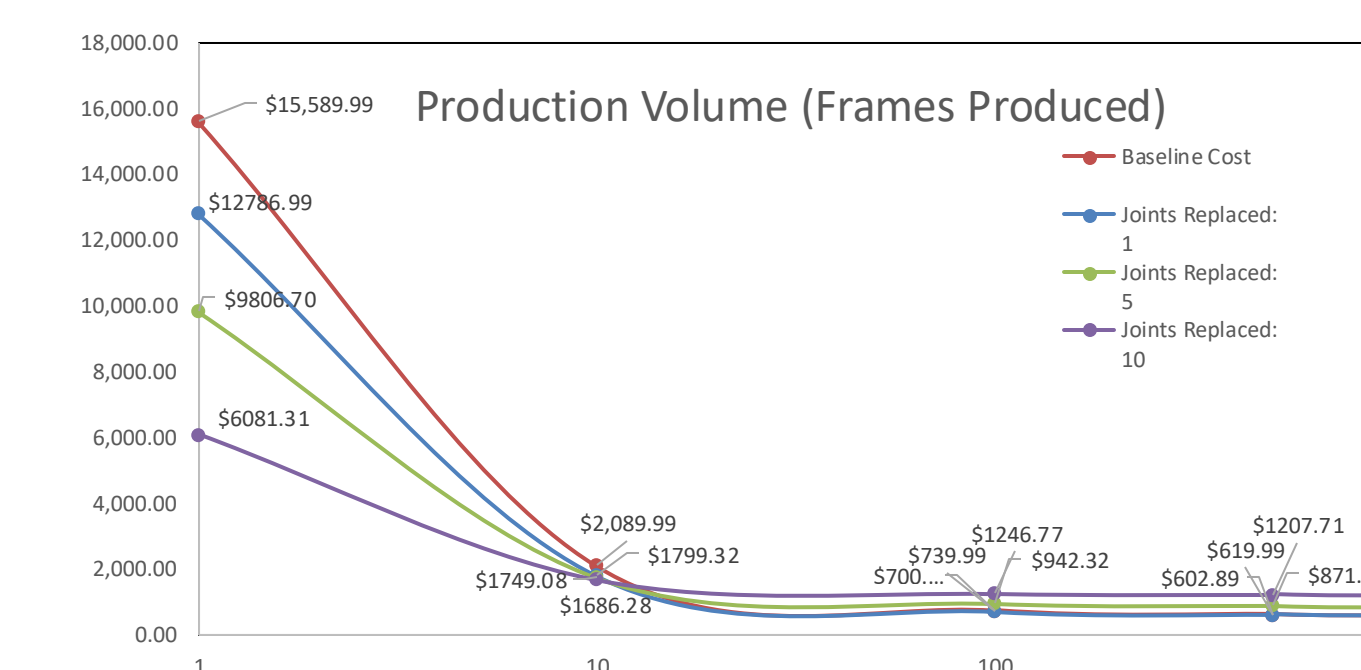


Figure 10. Frame Cost vs Production Volume: \$100 per Joint

References

- News, B. (2022, July 6). Five electric motorcycles you must know now. <https://www.bangkokpost.com>. <https://www.bangkokpost.com/business/motoring/2340967/these-are-the-five-electric-motorcycles-you-need-to-know-now>