MFG119631

Cranking into the Future of Making Things with CXP Racing

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CADPRO Systems

Learning Objectives

- Understand the potential of the product innovation platform
- Learn how to use various toolsets at your disposal to create, validate, and manufacture your own products locally
- Gain some insight into building unique and customizable parametric models, for both design and manufacture
- Understand how upfront design simulation with Fusion 360 can create differentiation for your company in a competitive market

Description

This class will cover 3D modelling for design intent, design ideation, generative design, simulation, rendering, and CAM workflows. Bruno Pfister contacted CADPRO Systems in 2015 to find out about a product called Fusion 360, wondering if it could help him to develop CAM programs for his brand-new Haas computer numerical control (CNC) machine. His goal was to design and manufacture BMX components for New Zealand's competitive grassroots and professional BMXers. This class tells his story about the development of cranks and chain rings used at various international events including the 2016 BMX World Championships in Columbia.

Speaker(s)

Scott Moyse is a Manufacturing, CAM & Data Management Technical Specialist for CADPRO Systems in New Zealand. He previously worked at SMI for over 9 years after moving from the UK while studying Motorsport Engineering. He started out as design support & quickly moved into programming their new CNC machine. Over the next 4 years he worked closely with both manufacturing & design to create & implement automated processes. This provided him with an invaluable insight into both departments operations. In 2008 he moved back into design full-time, resulting in him taking the Design Manager position in 2009. Since then he's implemented & managed Autodesk Vault Professional, improving communication, work allocation, organization & increased control over the design review process. Over the years he has been deeply involved in process formation, implementation & development in an ever changing environment. He also regularly contributes on designandmotion.net

BMX Crank Simulation

First of all, you will need a subscription to Fusion 360 Ultimate to access the tools detailed herein. Depending on the type of subscription you have, you may or may not have an allocation of Cloud Credits to run the simulation studies. However, most of the studies are currently in Preview and as such don't consume any credits.

My experience with FEA so far has been far from plain sailing, I'm not an engineer, I studied engineering at university but all of that knowledge has long since been forgotten in any meaningful detail. So here's the rub… to get this stuff to work reliably, you have to understand how to define a realistic load case, then rationalize the results to have true confidence in the output. This is the primary area where I failed with the first version of this BMX crank I worked on with CXP Racing.

It wasn't until the cranks started failing in real life, and the NASTRAN solver was embedded into Fusion 360 Ultimate, that we were able to properly simulate the load case. So.. how did we set it up?

Calculating the inputs:

These cranks are intended for use by BMX'ers under 55kg, so that's our first input.

Drop height	**1**	**m**
Velocity	**4.429446918**	**m/s**
Deceleration distance	**50**	**mm**
Deceleration	**196.2**	**m/s/s**
Mass	**55**	**kg**
Total Force	**10,791.00**	**N**
Force On each Pedal	**5,395.50**	**N**

In reality the actual loads put through the BMX pedal and crank vary constantly. Having a rider drop from 1m vertically would never happen, however, to simplify the calculations the assumption has been made that the rider will always absorb a lot of the force with their legs. Also, most of the time the rider will be landing on the back side of a ramp, significantly reducing the force. Nevertheless, we wouldn't want the crank snapping if the rider makes a mistake and lands on the front side of a roller while peeling through a rhythm section.

For the sake of making my life easier when setting up the simulation studies, I decided to round up the force to 5500N.

Setting up the studies

To start with I wanted to reproduce the failure of the crank inside Fusion, so I used the original model parameters instead of any of the changes we had made to the model while considering design changes. To do this I used the design history in Fusion's Data Panel to promote the appropriate version to the latest one.

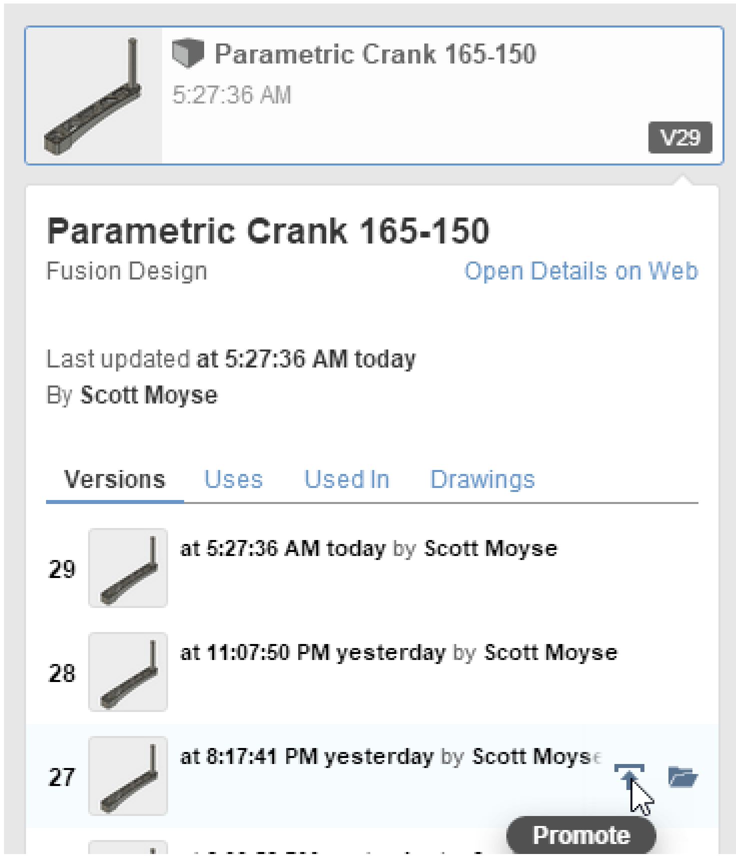

FIGURE 1: PROMOTE PREVIOUS VERSION TO THE LATEST

Linear Static Stress

- Crank Body Material – Aluminium 7075 T651
- 5500N load applied to pedal axle body
- Bonded Contacts
- 2mm Absolute mesh density

Screencast link.

Nonlinear Event Simulation – Impact

- Crank Body Material – Aluminium 7075 T651
- 5500N load applied to pedal axle body
- Bonded Contacts
- 2mm Absolute mesh density

Screencast link.

The Secrets of the Simplify Workspace

The Simplify Workspace within Fusion 360 can currently only be accessed via the Simulation Workspace. Within the Simplify Workspace there are a heap of awesome tools, some of which can't be found anywhere else, and others which are borrowed from the Model Workspace in both History and History-free modes. You can both delete and add features, as well as manipulate existing ones, all while maintaining its own history. The best part though, is being able to create different simulation models. This means you can quickly iterate on your base design without destroying or hacking up your original design while you hunt for solutions to your design and engineering problems. You can then run individual simulation studies on each Simulation model. Ideal!!!

Simplify

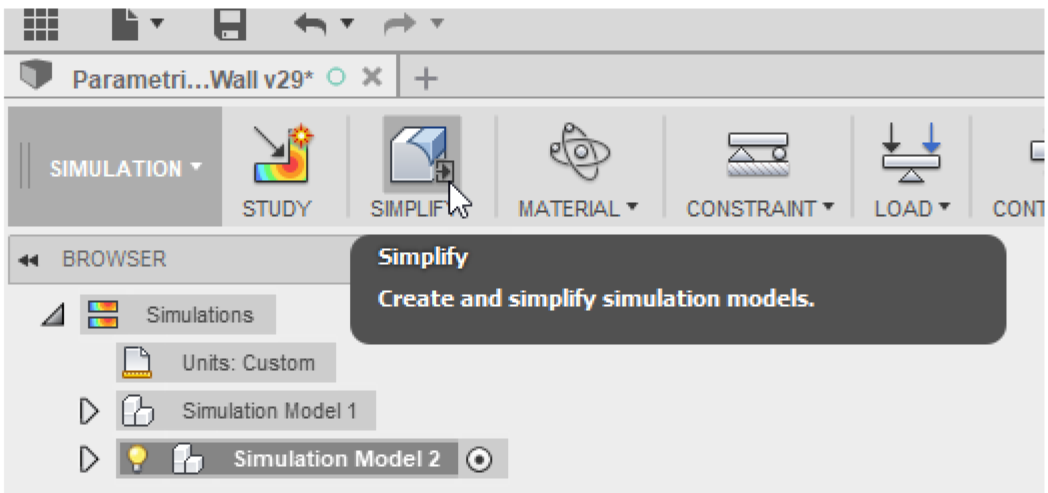

FIGURE 2: ACCESS SIMPLIFICATION TOOLS FROM THE SIMULATION RIBBON TOOLBAR

Screencast link.

Variation Simulation Results

To begin with, I increased the thickness of the walls, and central web running the length of the crank to the cut-out from 3.5 to 4.5mm as a new baseline.

I then repeated the same load case on each of the design variants to see if there was a way to stop the crank from failing so soon. It was counter intuitive that it wasn't failing through the cut-out but instead the pocket in front of it. Clearly the cut-out by itself wasn't the cause. So, I started by removing all the pockets from the outside of the crank, and adding one the full length of the inside face, while retaining the cut-out.

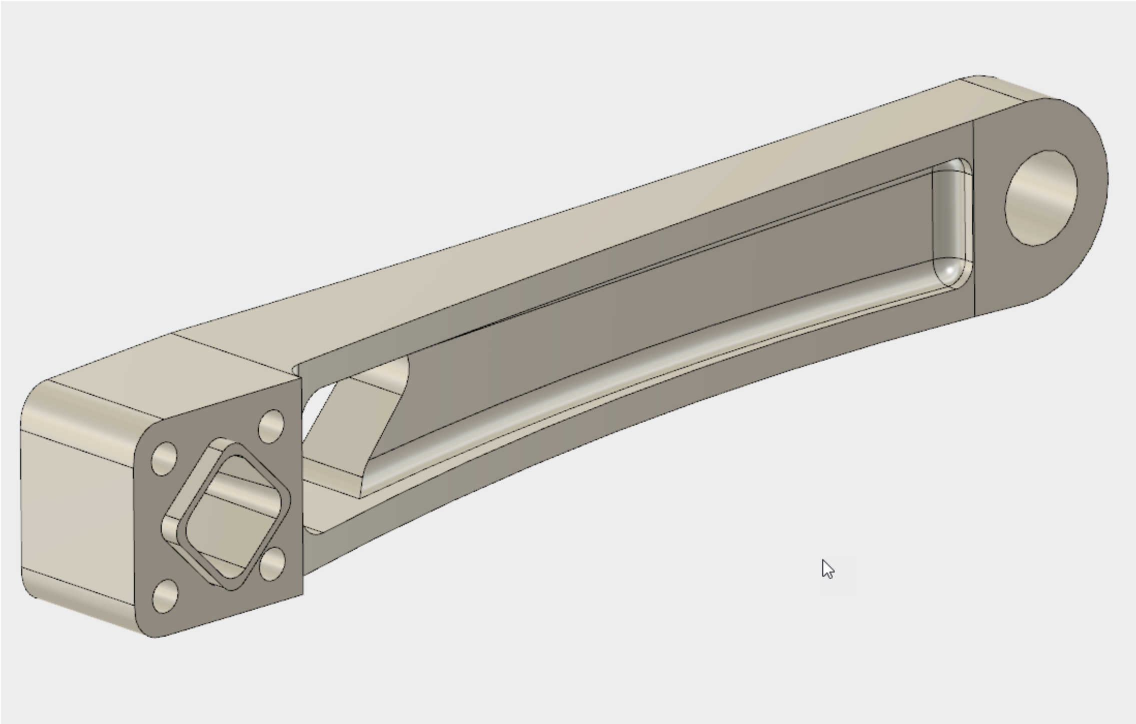

Figure 3: Variation 1, no pockets on the outside face

That failed where you would expect it to.

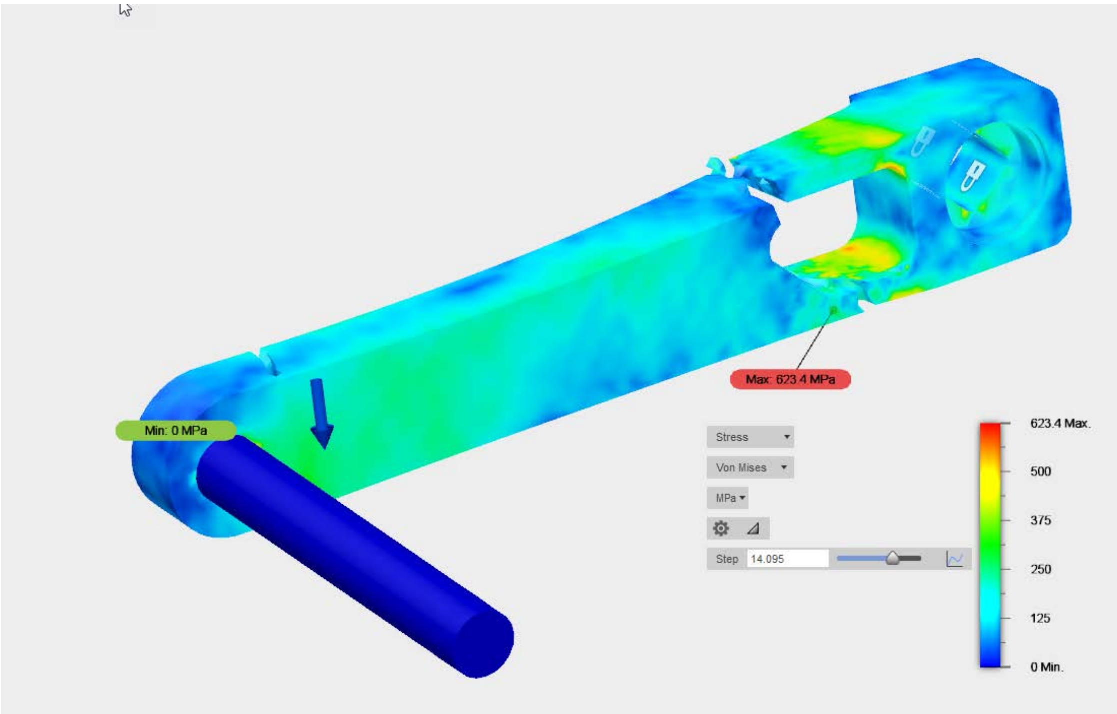

Figure 4: With a 2mm Mesh size & 20 steps

However, the peak stress was far lower than it was in the reference sample. 909MPa versus 1205MPa. The last simulation step prior to failure recorded 503.6MPa, which matches the Yield Strength of 7075 T651.
It still wasn't good enough, so I went back to have pockets on both sides. I had noticed the component performed very differently depending on the direction the load was applied, i.e; was the crank pointing forward or backwards during impact? So my next step was to align the webs from one side of the crank to the other, instead of them alternating their direction relative to one another.

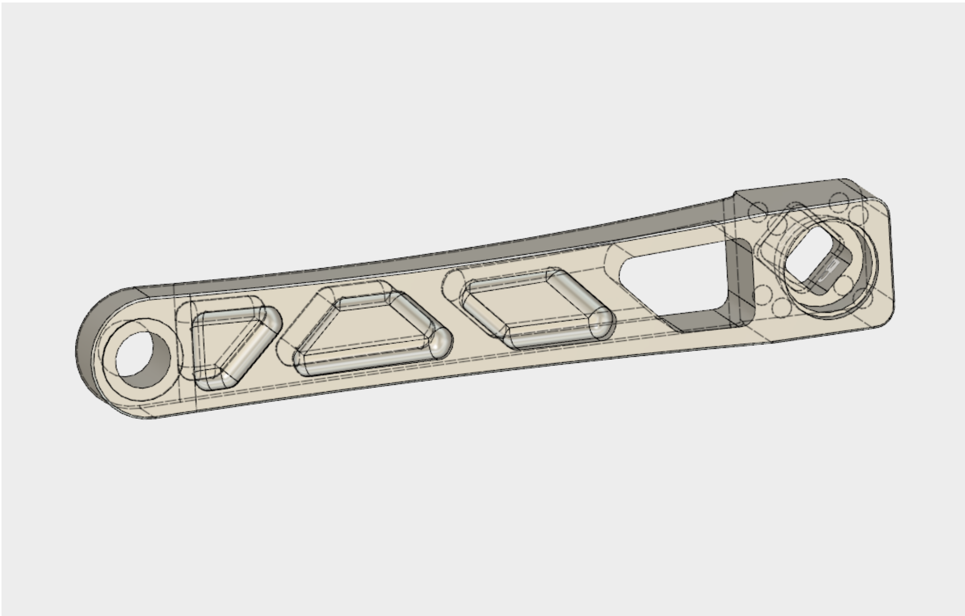

FIGURE 5: WEB STIFFNERS ARE ALIGNED FROM SIDE TO SIDE

And sure enough… the crank didn't fail. However, it reached Yield at the last step.

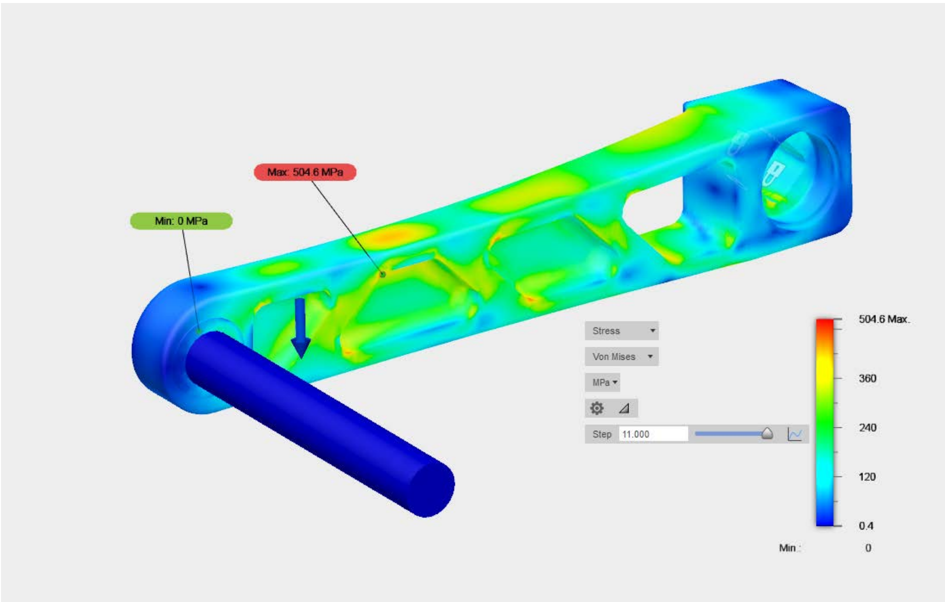

FIGURE 6: WITH A 2MM MESH & 10 STEPS

Although it didn't fail, this isn't a pass. With a safety factor of 1, that just isn't enough. What it does show though, it that the criss-cross structure I created in the original crank, caused premature catastrophic failure. The parts own structure was causing high stress concentrations, whereas by aligning the webs, allowed the stress to spread out more evenly through the part.

The crank I'm simulating is 165mm long pivot to pivot. And the only cranks to fail were any over 150mm in length. So this result is promising for the shorter cranks. Customers loved the look of these cranks. With this new found knowledge we can improve the cranks below 150mm and create a different style for 150mm to 165mm cranks.

So what if the crank stiffener webs weren't angled at 45 degrees and were sitting at 90 instead?

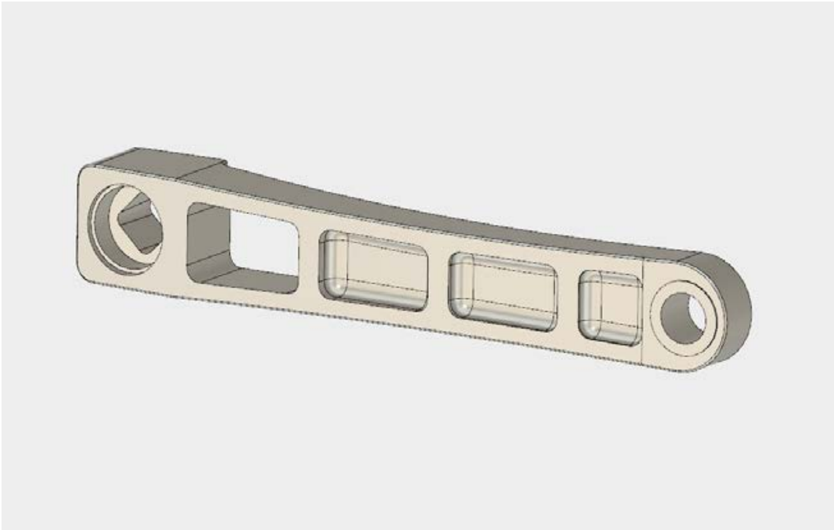

FIGURE 7: PERPENDICULAR WEBS

This one is a complete write off… reaching peak stress of 1730MPa

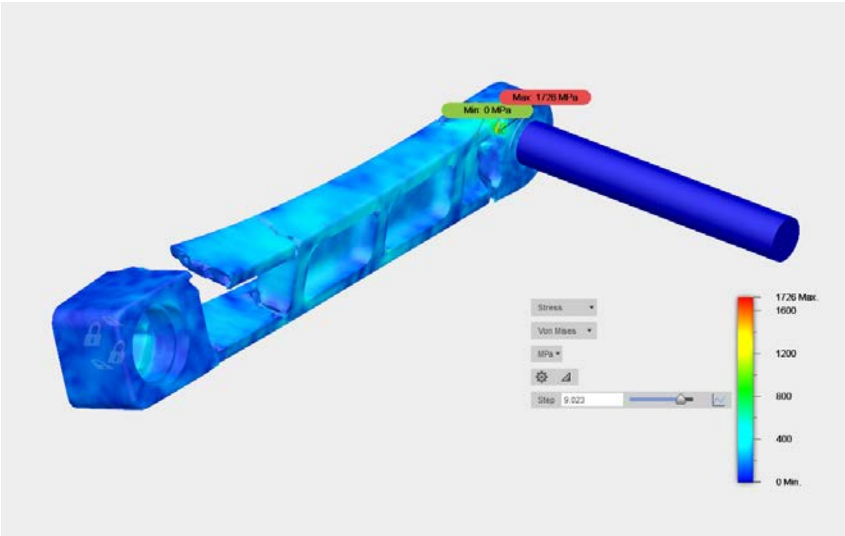

FIGURE 8: WITH A 2MM MESH & 10 STEPS

Shape Optimisation

We know what we have to do to make the sub 150mm length cranks perform satisfactorily, but we still haven't found a viable design for the longer range yet. Going back to basics, let's start with a more 'triangular' profile from the axle to the pedal. I also made the end geometry concentric to the pedal axle again. It was eccentric in the Gen 1 crank based on the results of the original FEA studies in Fusion 360, it showed the material on the end of the crank wasn't contributing anything to the overall structure, so I removed it.

FIGURE 9: THE PEDAL END OF THE CRANK IS NARROWER THEN THE ORIGINAL DESIGN.

With the general aesthetic sorted, it was time to turn it over to Fusion 360's Shape Generation tool. I applied the same load case as I have been with the simulation studies so far. Check out this Screencast to see how to set it up.

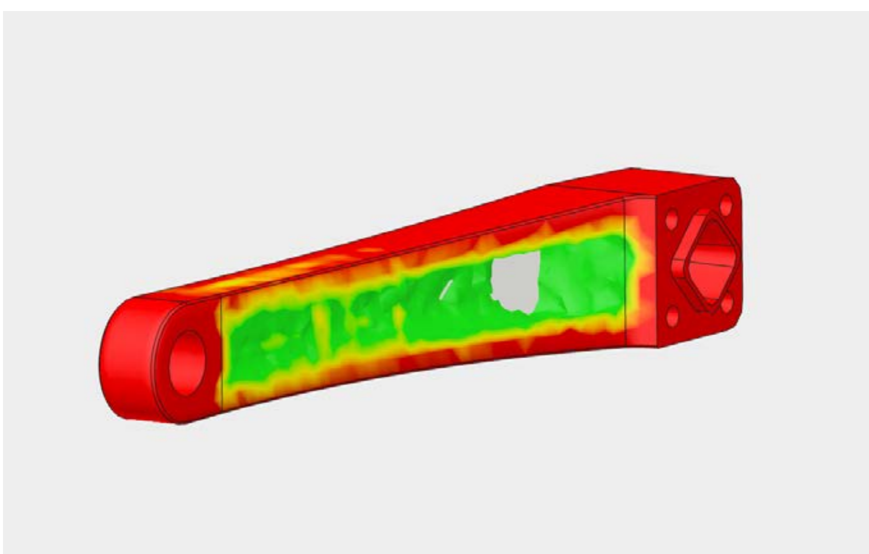

FIGURE 10: SHAPE OPTIMISATION RESULT

The Resulting Model

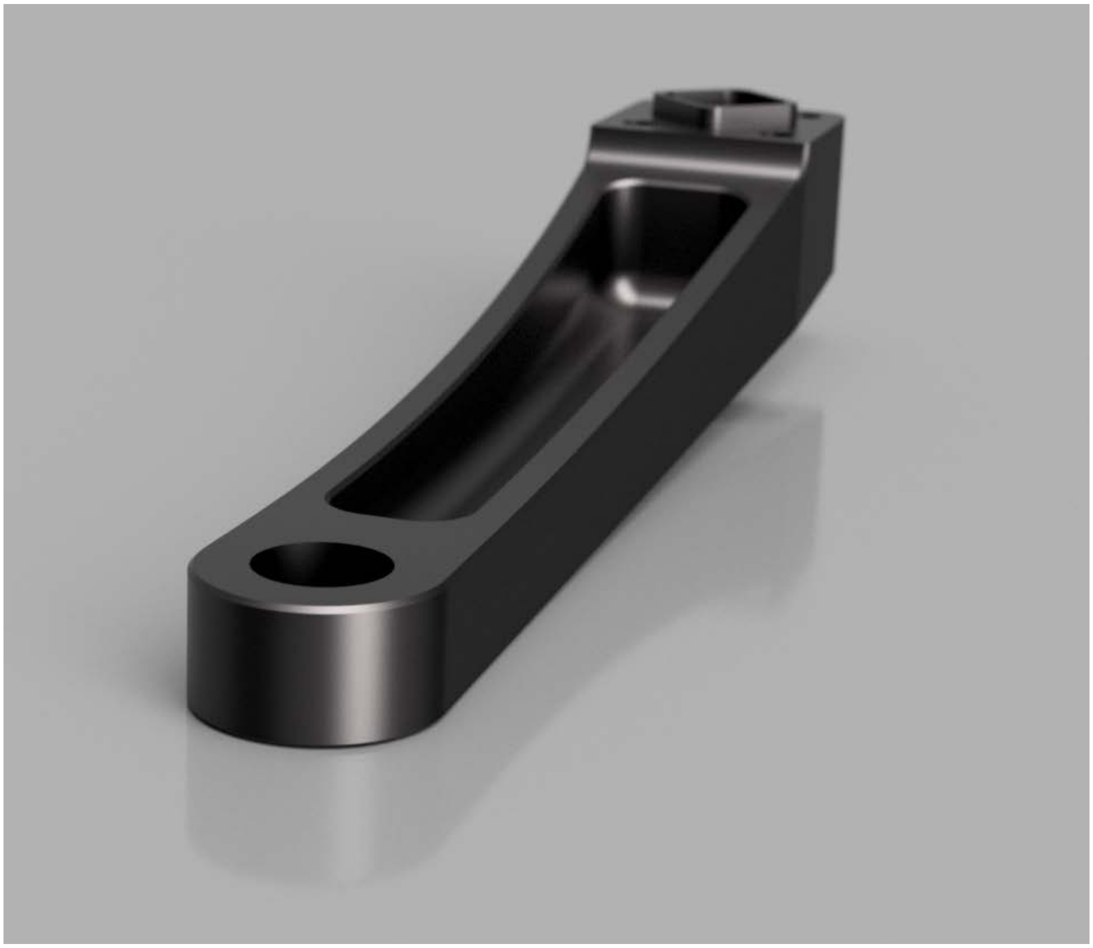

FIGURE 11: SIMPLE BUT CLEAN MODEL BASED ON PRIOR FEA RESULT AND SHAPE OPTIMISATION

So will this version pass the same nonlinear impact event analysis the previous geometry didn't?

Final Simulation

Nonlinear Event Simulation – Impact

- Crank Body Material – Aluminium 7075 T651
- 5500N load applied to pedal axle body
- Bonded Contacts
- 2mm Absolute mesh density
- 10 Steps

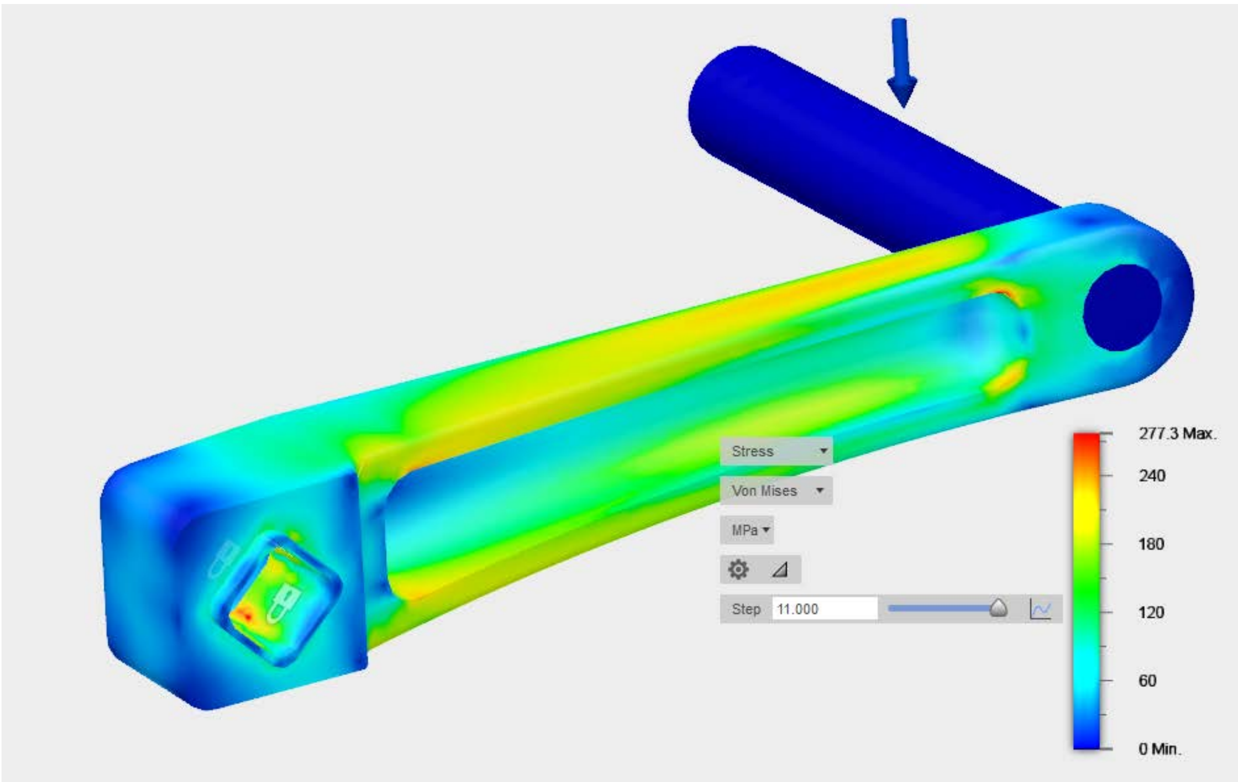

FIGURE 12: PEAK STRESS OF 277MPA

Based on Ultimate Tensile Strength, that's a safety factor of over 2, and 1.81 based on Yield. In reality, these high stress areas are highly localised and drop off very quickly upon analysis. Throughout its core, the crank sees a SF based on yield of more like 3.35.

So that was a resounding success when compared to what we had with the previous generation crank of this length! What if we crank the force up to 10,000N?

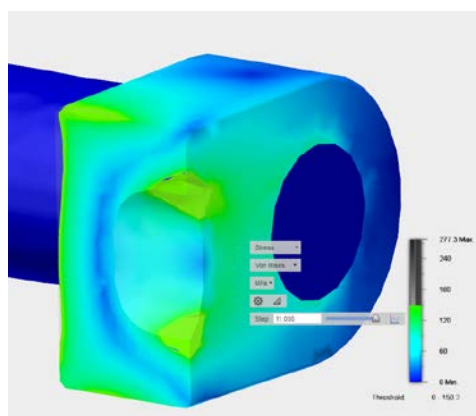

FIGURE 13: CROSS SECTIONAL VON MISES ANALYSIS

- Crank Body Material – Aluminium 7075 T651
- 10,000N load applied to pedal axle body
- Bonded Contacts
- 2mm Absolute mesh density
- 10 Steps

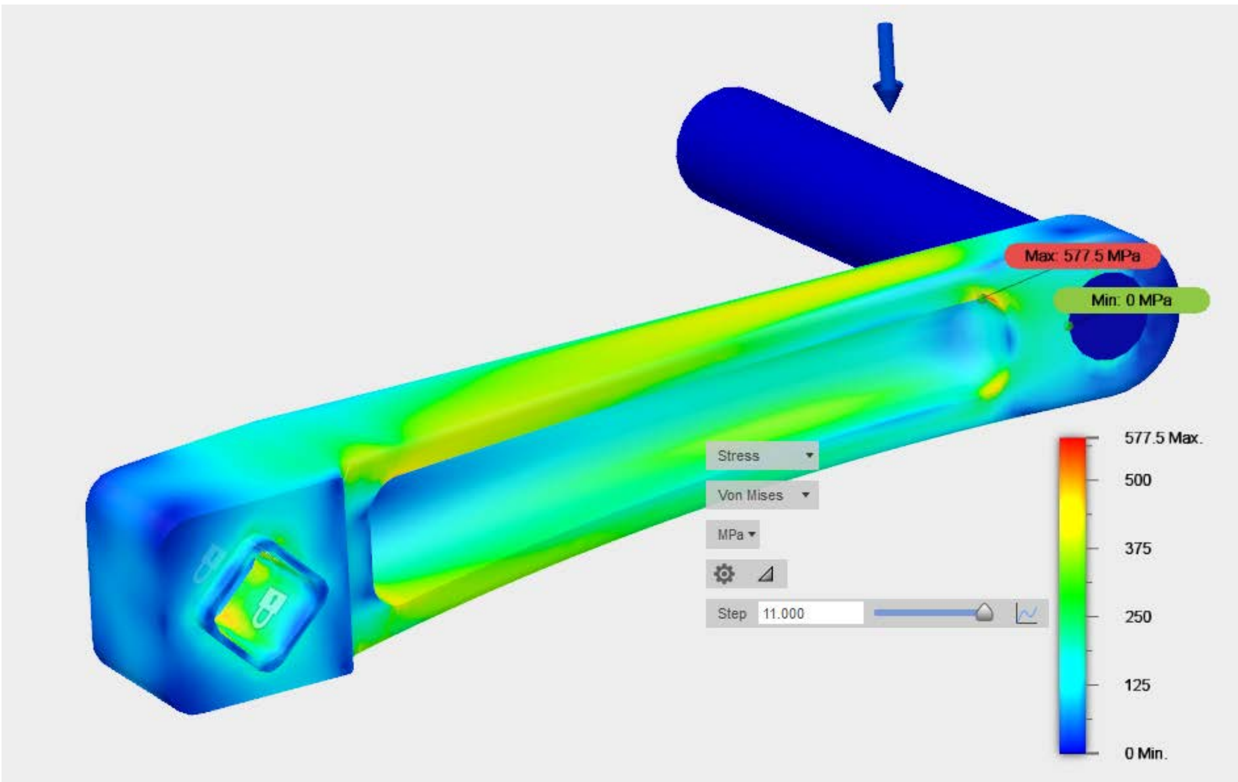

FIGURE 14: PEAK STRESS OF 577.5MPA

With 10,000N of force applied is still intact, it's likely it will have seen some permanent deformation. But at its core, it's still performing at around a SF of 1.65 from yield.

With the peak stress being in a highly localised area and only just surpassing the Ultimate Tensile Strength of 7075 T651, I think this is our winner and the design that should be used for this size crank moving forward.

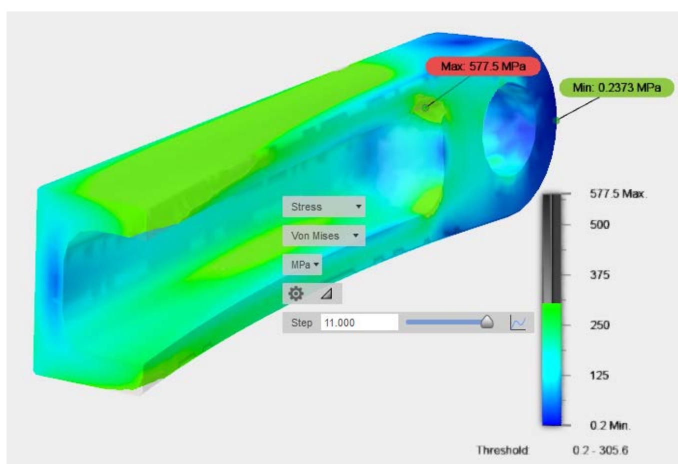

FIGURE 15: CROSS SECTIONAL VON MISES ANALYSIS WITH HIGH STRESS AREAS REMOVED

Parametric Design