BICYCLE FRONT DRIVETRAIN

An informal report prepared for
MechEng 370

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Written By

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Contents

1 Project Description

For the project, the group chose to model a basic bicycle drive train, consisting of the chain, front single chain ring, crank arm, pedal axle, and the pedal. These are crucial parts in any bicycle because all of these parts take abuse from any type of ride being stressed by both the pedaling action and the weight of the rider. The focus of the analysis performed on the assembly was to analyze how to minimize the weight of the assembly, while increasing the strength where needed. Bikers try to ride the lightest bike possible so that most of the energy goes into propelling themselves faster, not having to work against the weight of the bike. Furthermore, riders really push the limits of the bikes depending on the type of riding being done so strength is an important factor. Another goal for the analysis was to keep displacement values at a minimum because you dont want your pedals, crank, and sprockets bending due to the forces of riding which in turn would affect stability.

2 Analyses Performed

2.1 Pedal Axle

The first analysis done was for the axle of the pedal. It is cylindrical and goes through the entire pedal and threads into the crank arm, holding the two parts together and allowing the pedal to spin freely. The model was analyzed as a solid and it was analyzed as steel. It was constrained from the bigger diameter part of the cylinder, which is the part that would be threaded into the crank arm. A 100 kg bearing load was placed in the negative y direction to simulate the weight and force of a person being on the pedal to make sure that it was strong enough to hold the weight without failing in any situation. Also, since the shaft is cylindrical, the force could be applied in any direction without failure. This is helpful when the piece is in the real world and the pedal might get hit or pushed by an outside object like a rock. For original drawings of the pedal axle, refer to Appendix A.

2.2 Crank Optimization

The crank arm translates the downward force applied by the rider into rotational motion to the chainring. We chose to focus on the crank arm due to its relatively high mass compared to the other parts, and due to the importance of this part being able to withstand force from the rider. The crank model was also analyzed as a solid, with the material of choice being aluminum 2014-T6 with a yield strenght of 414 MPa. The first analysis we performed on the crank arm was to find any issues with the initial design. We performed both an initial static analysis, constraining the crank at each chainring bolt hole, and an optimization study to minimize the mass of the crank. For the optimization study, we varied the thickness of the crank from 5mm to 15mm at the end portion of the arm, and 10mm - 15mm at the base portion of the arm. Both analysis used a 100kg bearing load at the pedal hole, acting downward simulating the power stroke from a rider. To stay within a factor of safety of 1.5, the max von mises stress at any location would have to stay below 276 MPa. For original drawings of the crank, refer to Appendix A.

3 Analyses Results

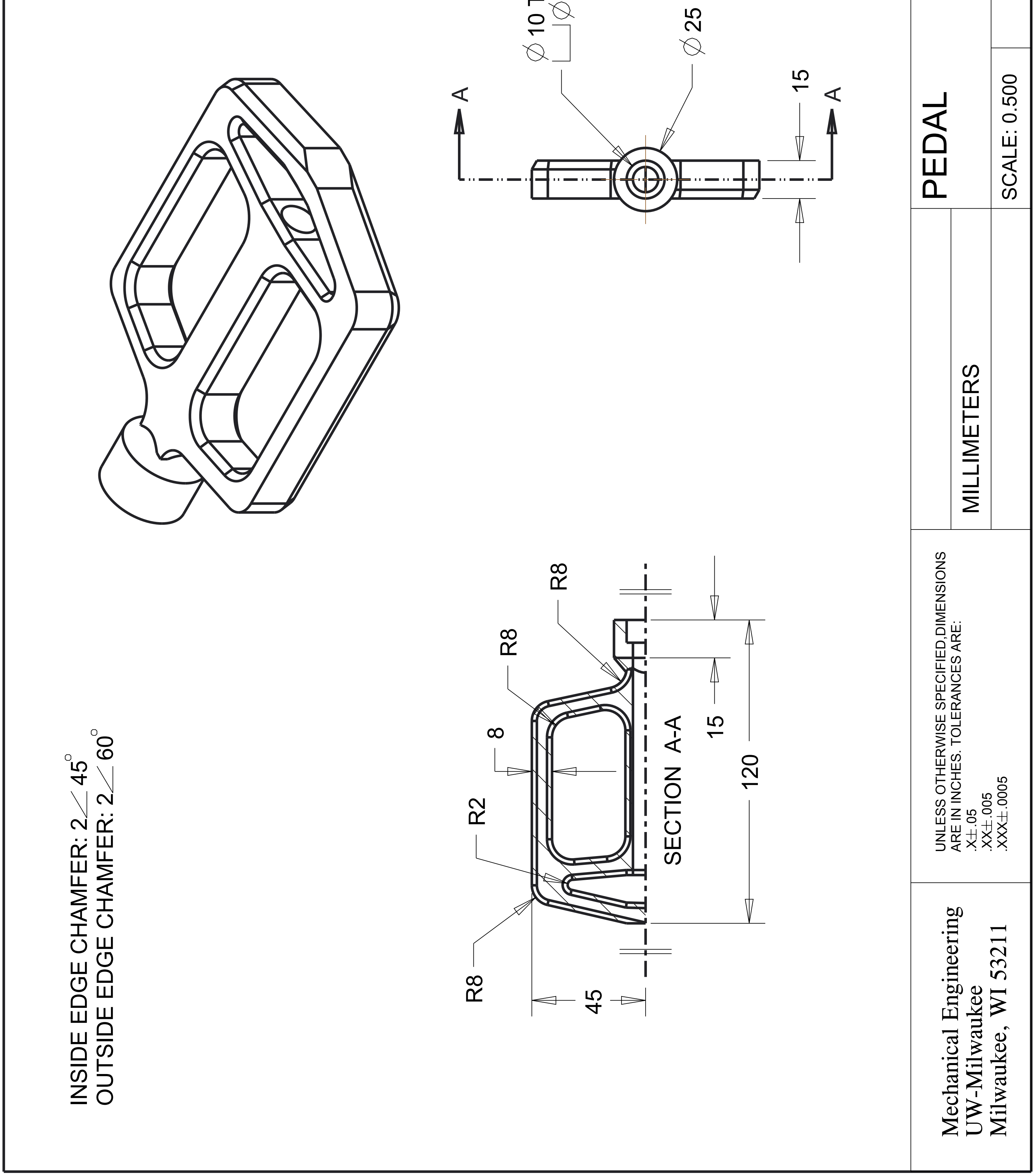
3.1 Pedal Axle

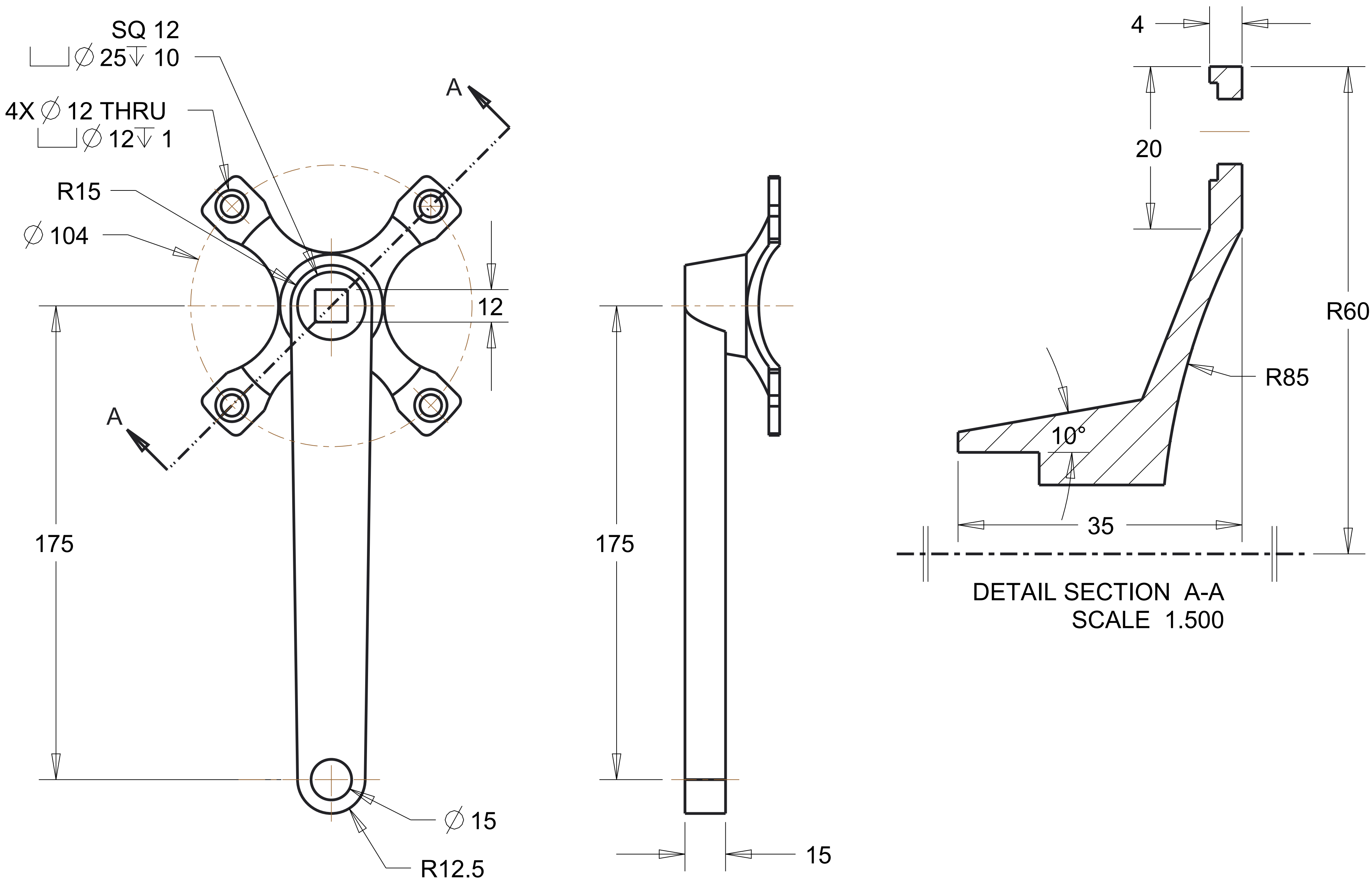
The first analysis on the original axis gave a max von Mises stress of 127.5 kPa and a displacement of 1.610e-04 mm. However, looking at the results it was clear that there was a major stress concentration going from the big diameter down to the smaller diameter because it was just a ninety degree drop off. To try and eliminate this stress concentration the axle was redesigned with a gradual taper from the larger diameter to the smaller diameter. By doing that and retesting the axle it showed a big difference in von Mises stress and displacement. The new von Mises stress was 47.64 kPa and the new displacement was 1.435e-04 mm. That is more than 10% less displacement and almost one third of the stress as the original design. Furthermore, with the new tapered design the stress got spread over a wider area. There was still a stress concentration where the taper met the smaller diameter but it was a big improvement over the original design. The displacement was so small it would go unnoticed and would not effect the use of the axle. For fringe plots and FEA data for the axle, refer to Appendicies B.1-B.3.

3.2 Crank

The static analysis of the initial crank design showed stress concentrations at the origin of the crank arm, and at the chainring bolt holes. To fix these issues, we increased the thickness at the chainring holes from 4mm to 6mm, and at the base of the crankarm, we added a 6mm fillet to distribute the stress more evenly. After that, we went on to optimize the crank arm thickness to minimize the total mass. The material of the crank is aluminum 2014 and has a yeild strength of 414MPa. The optimization was set up to vary the thickness of the crank arm from each end while staying below the prescribed max von mises stress. The initial mass of the crank arm was 0.264 kg. After the optimization study, the final design gave us a mass reduction of 35%, bringing the total mass down to 0.172 kg. See appendicies B.4-B.6 for the stress and displacement fringe plots and FEA data. For the final optimized design drawings of the crank and axle, refer to Appendix C.

A Orginal Drawings





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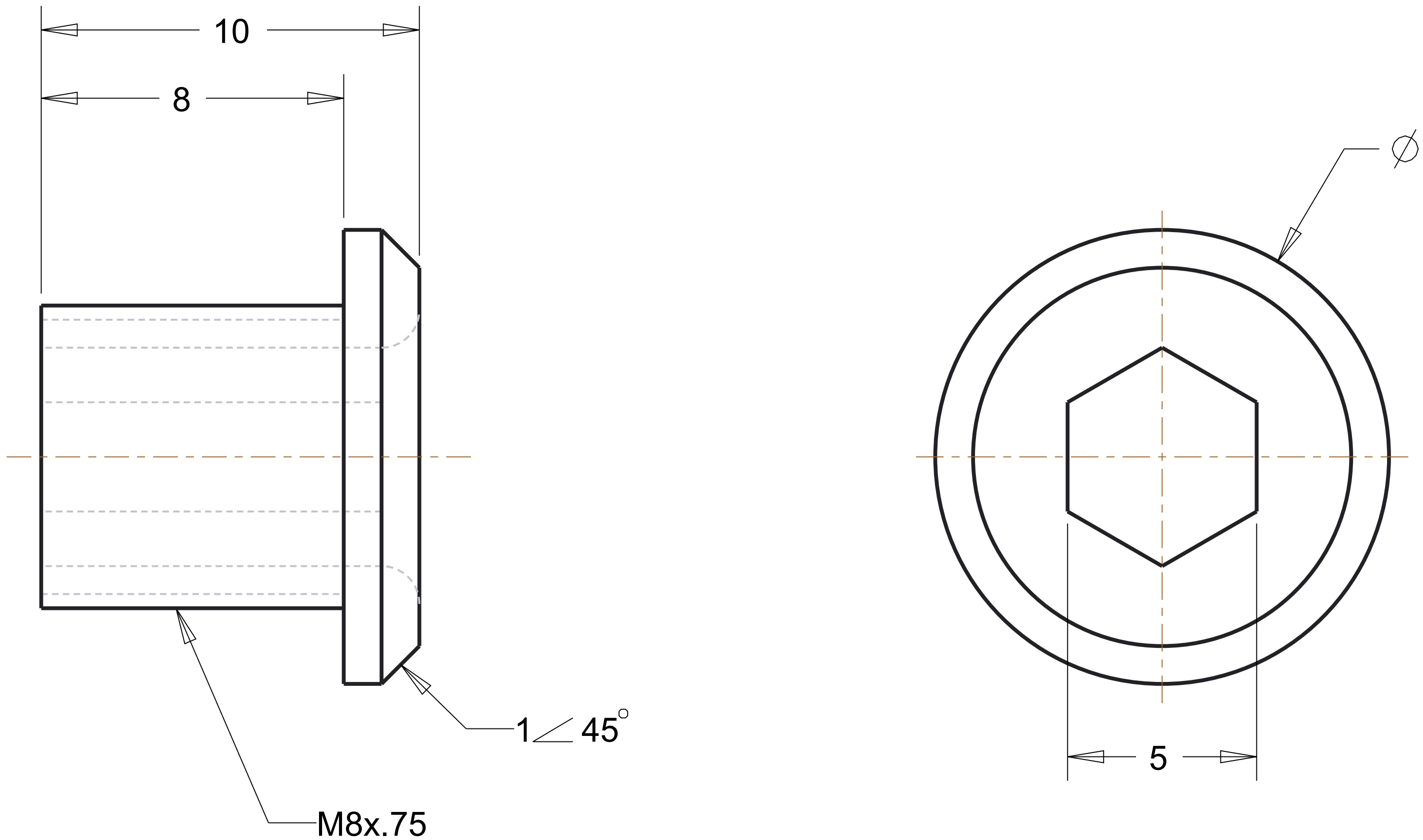

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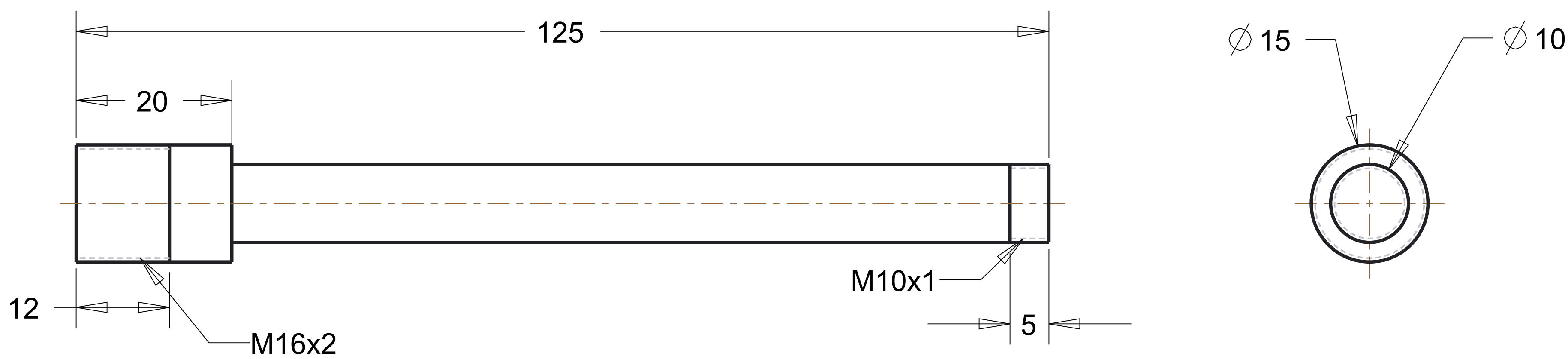

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ARE IN INCHES. TOLERANCES ARE:
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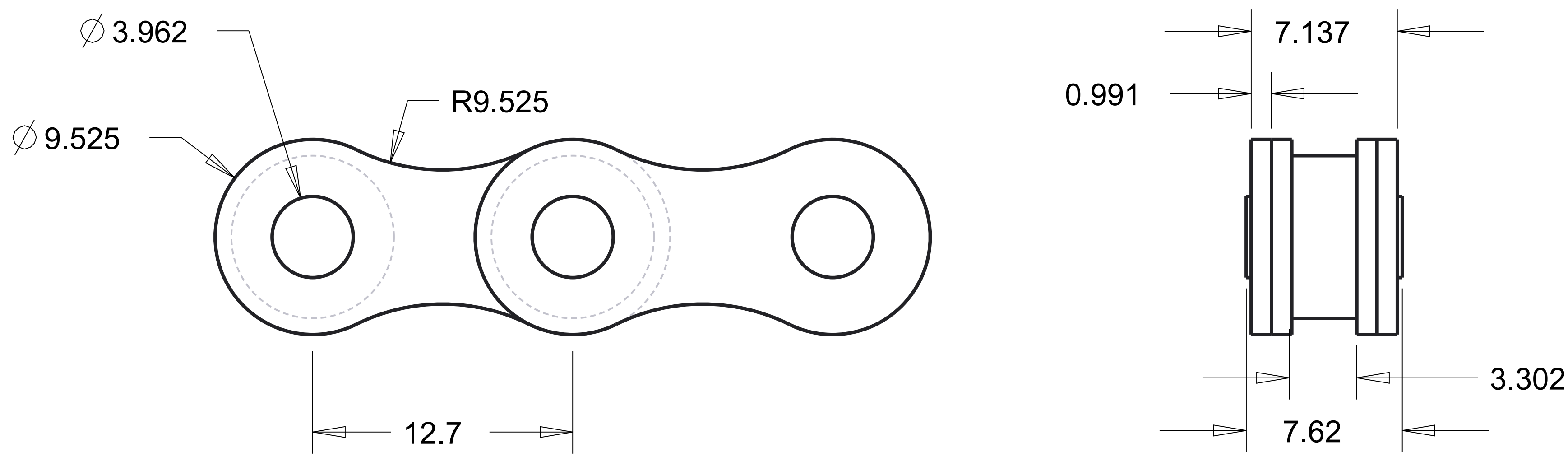
MILLIMETERS

AXLE

SCALE: 1.200



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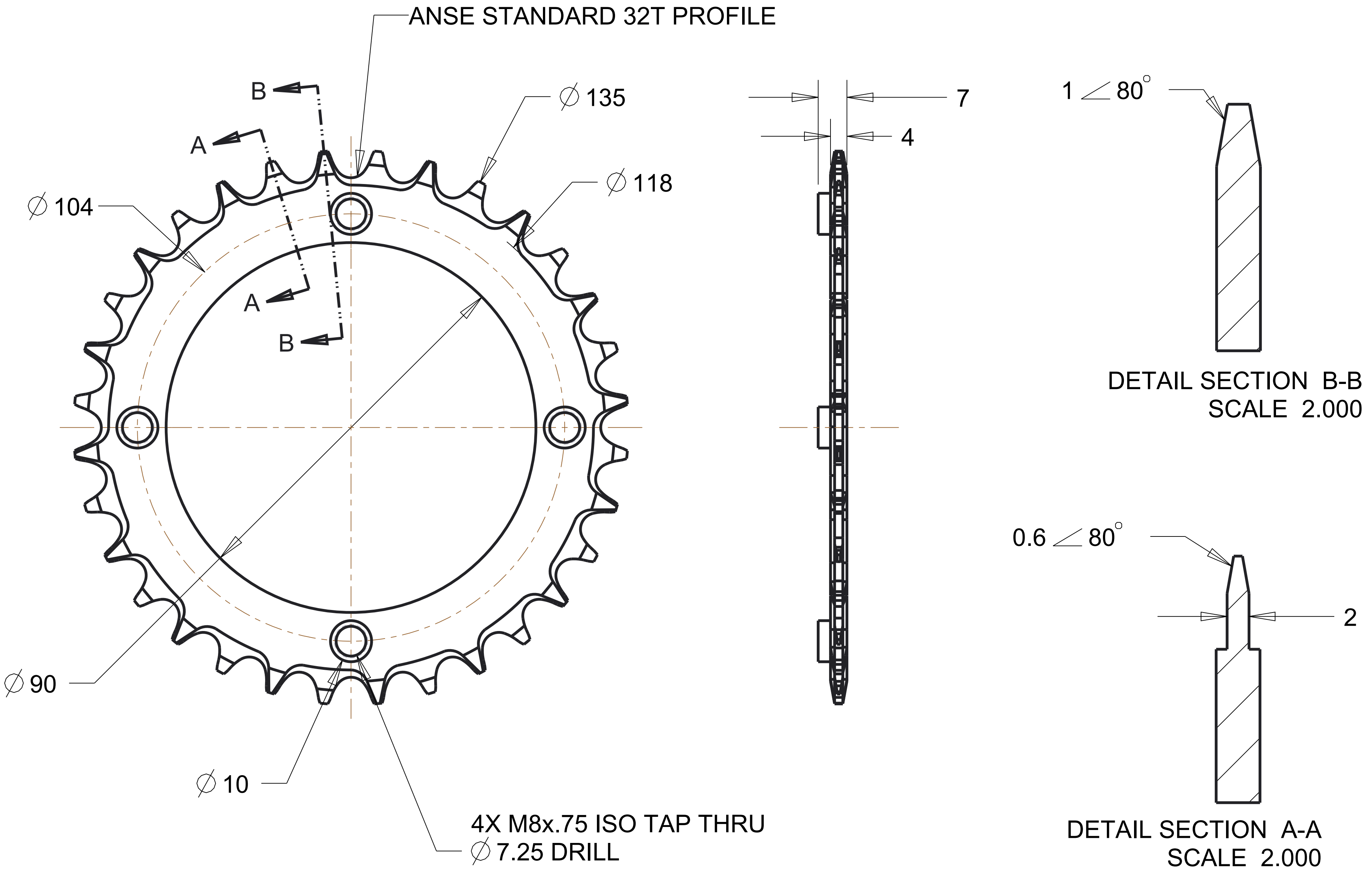

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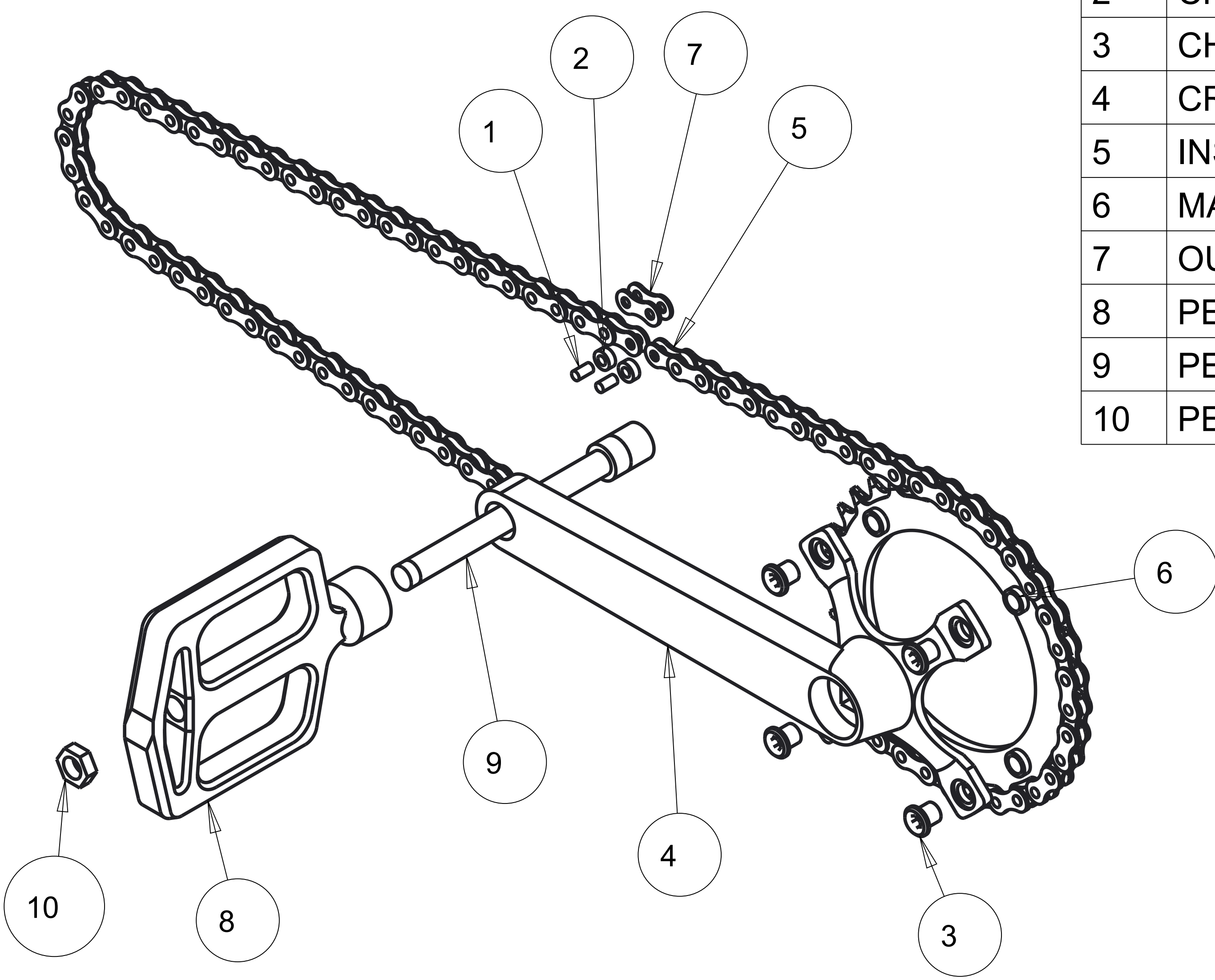

No.	Part Name	Qty
1	CHAIN PIN	92
2	CHAIN ROLLER	92
3	CHAINRING BOLT	4
4	CRANK ARM	1
5	INSIDE LINK PAIR	46
6	MAIN SPROCKET	1
7	OUTSIDE LINK PAIR	46
8	PEDAL	1
9	PEDAL AXLE	1
10	PEDAL NUT	1

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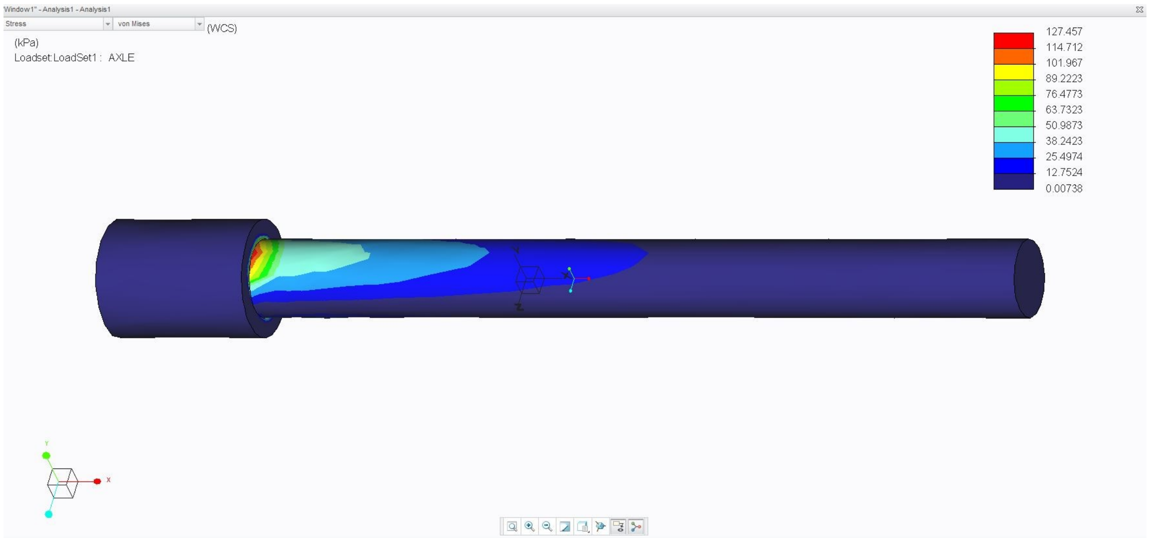
.XX±.005
.XXX±.0005

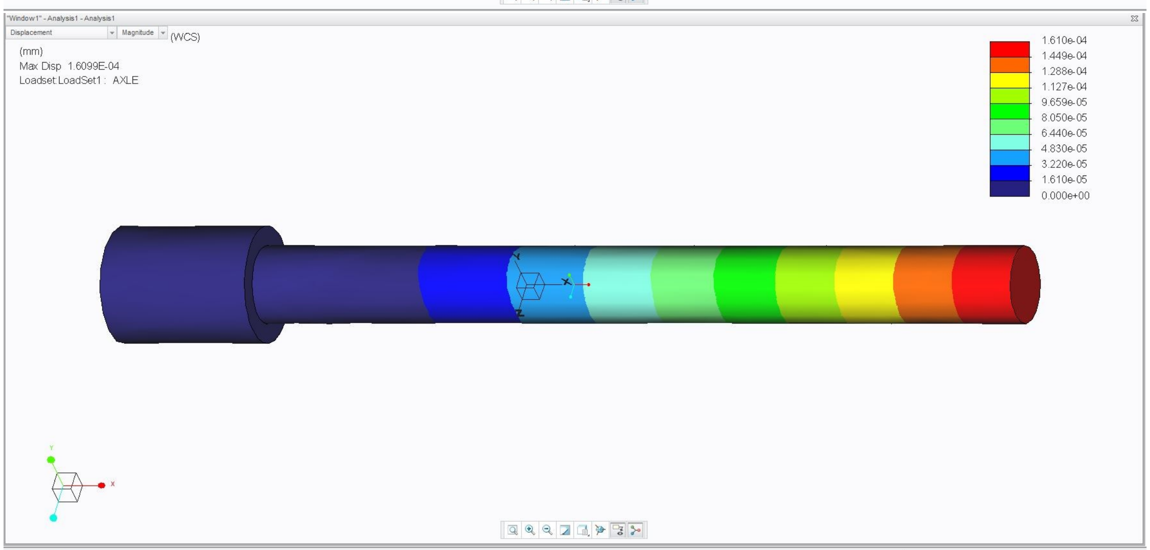
FULLASSEMBLY

SCALE: 0.400

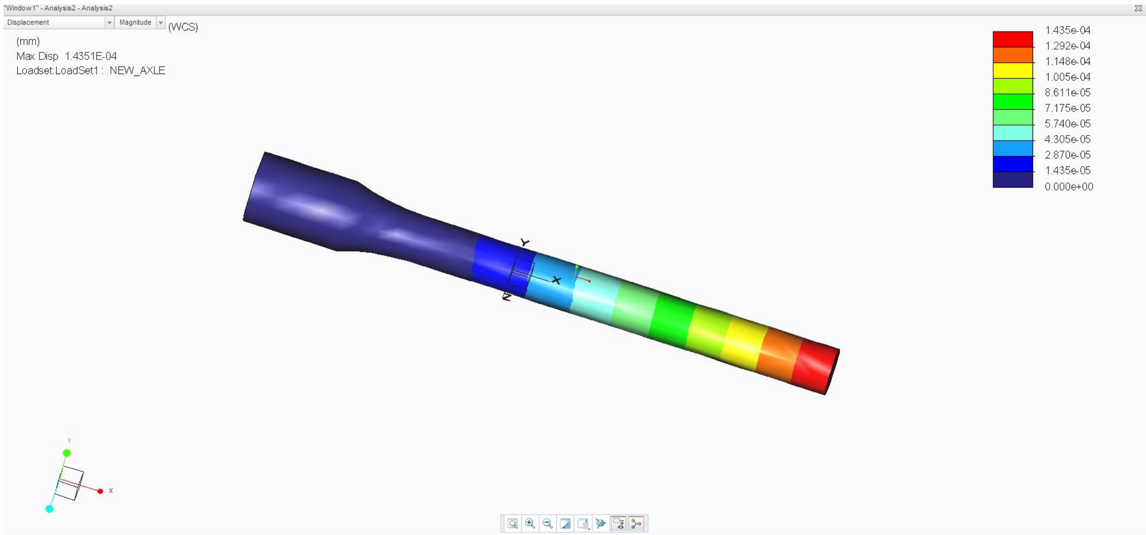
B FEA Data & Fringe Plots

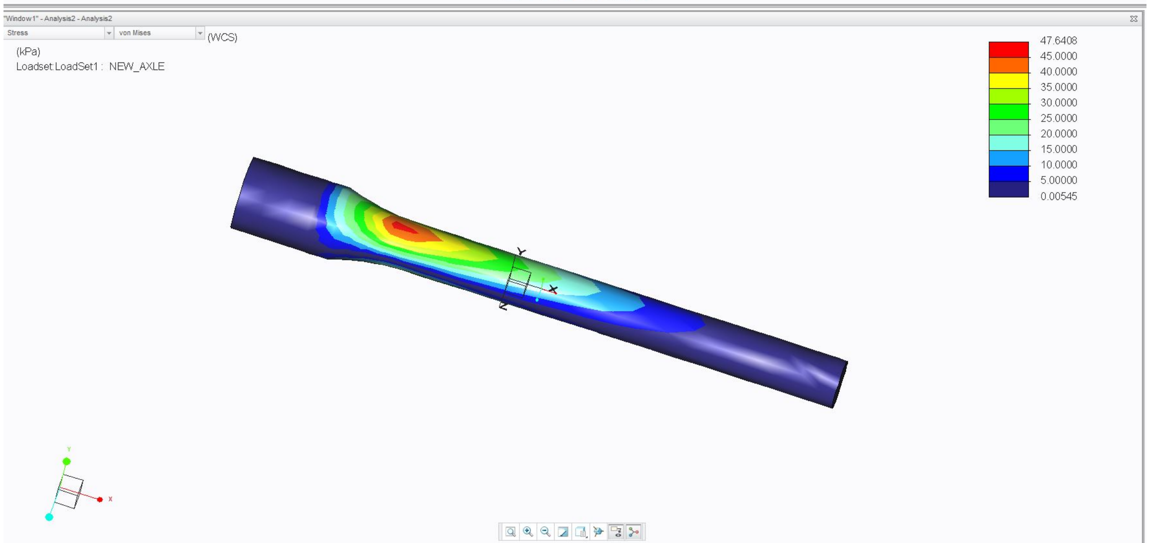
B.1 Original Pedal Axle





B.2 Modified Pedal Axle





B.3 Pedal Axle Results

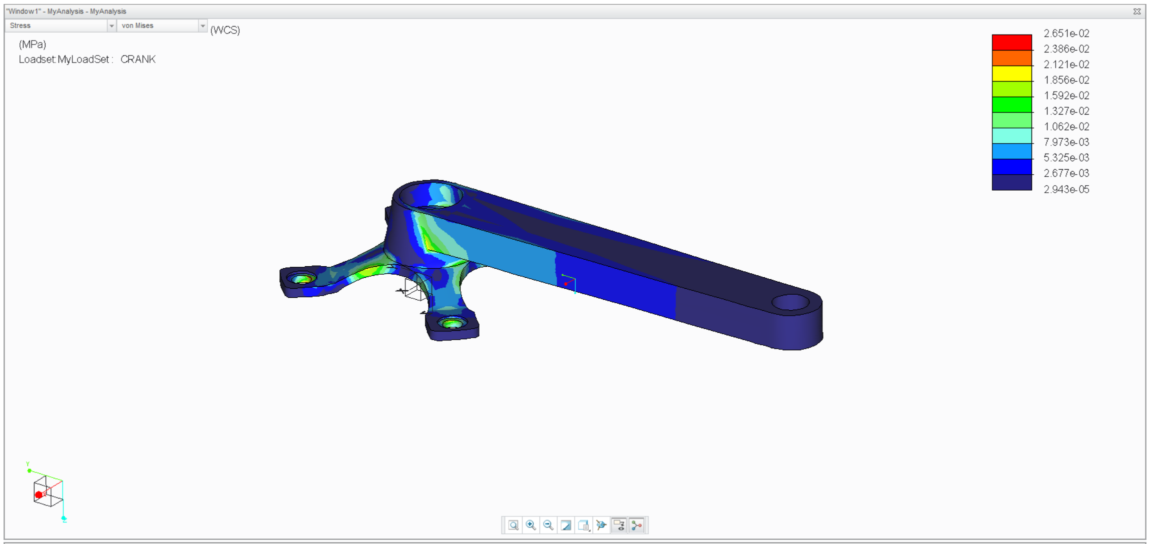
ORIGINAL AXLE RESULTS:

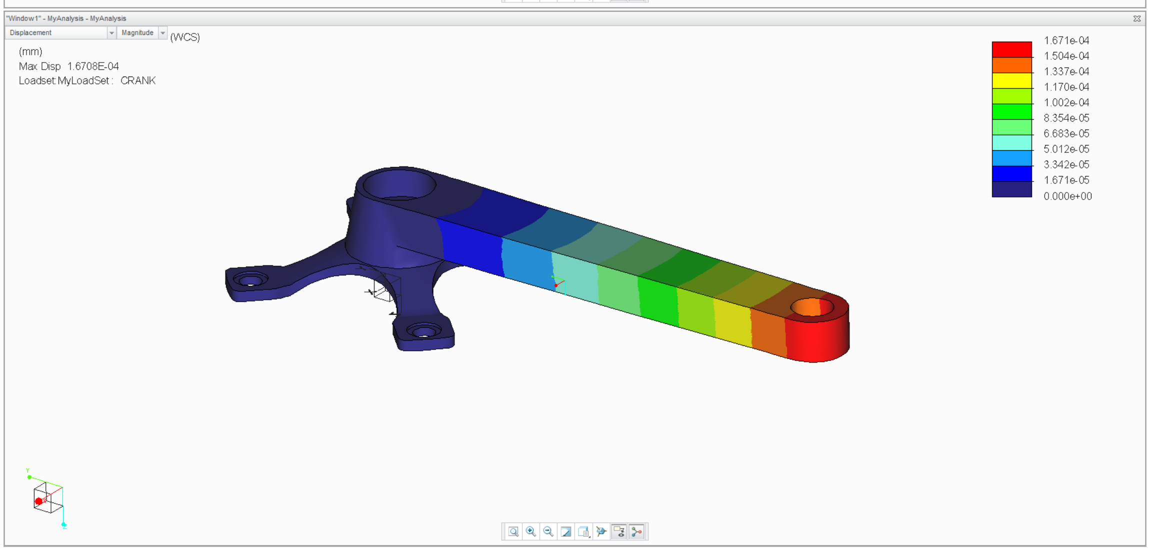
Name	Value	Convergence
max_beam_bending:	0.000000e+00	0.0%
max_beam_tensile:	0.000000e+00	0.0%
max_beam_torsion:	0.000000e+00	0.0%
max_beam_total:	0.000000e+00	0.0%
max_disp_mag:	1.611565e-04	0.1%
max_disp_x:	9.965192e-06	0.1%
max_disp_y:	-1.608487e-04	0.1%
max_disp_z:	-1.593920e-07	0.5%
max_prin_mag*:	1.641834e+02	9.0%
max_stress_prin*:	1.641834e+02	9.0%
max_stress_vm*:	1.275910e+02	8.4%
max_stress_xx*:	1.205100e+02	8.3%
max_stress_xy*:	-6.397185e+01	9.1%
max_stress_xz*:	3.507433e+01	8.6%
max_stress_yy*:	7.044935e+01	11.1%
max_stress_yz*:	-6.395624e+00	10.3%
max_stress_zz*:	4.946879e+01	10.6%
min_stress_prin*:	-1.198423e+02	8.2%
strain_energy:	3.290248e-03	0.1%

MODIFIED AXLE RESULTS:

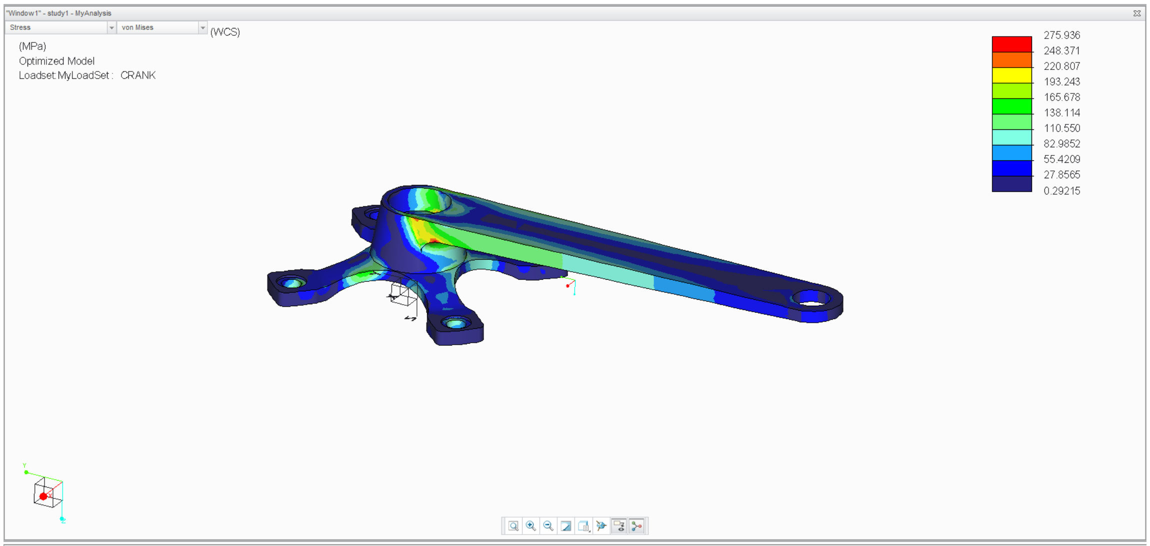
Name	Value	Convergence
max_beam_bending:	0.000000e+00	0.0%
max_beam_tensile:	0.000000e+00	0.0%
max_beam_torsion:	0.000000e+00	0.0%
max_beam_total:	0.000000e+00	0.0%
max_disp_mag:	1.431762e-04	0.2%
max_disp_x:	9.452736e-06	0.2%
max_disp_y:	-1.428649e-04	0.2%
max_disp_z:	1.538590e-07	3.0%
max_prin_mag:	-4.736418e+01	0.9%
max_stress_prin:	4.712106e+01	1.2%
max_stress_vm:	4.675884e+01	0.4%
max_stress_xx:	-4.698179e+01	0.0%
max_stress_xy:	-1.205514e+01	20.6%
max_stress_xz:	6.405616e+00	6.0%
max_stress_yy:	5.684232e+00	20.0%
max_stress_yz:	-2.246886e+00	4.6%
max_stress_zz:	-5.199779e+00	22.6%
min_stress_prin:	-4.736418e+01	0.9%
strain_energy:	3.194914e-03	0.3%

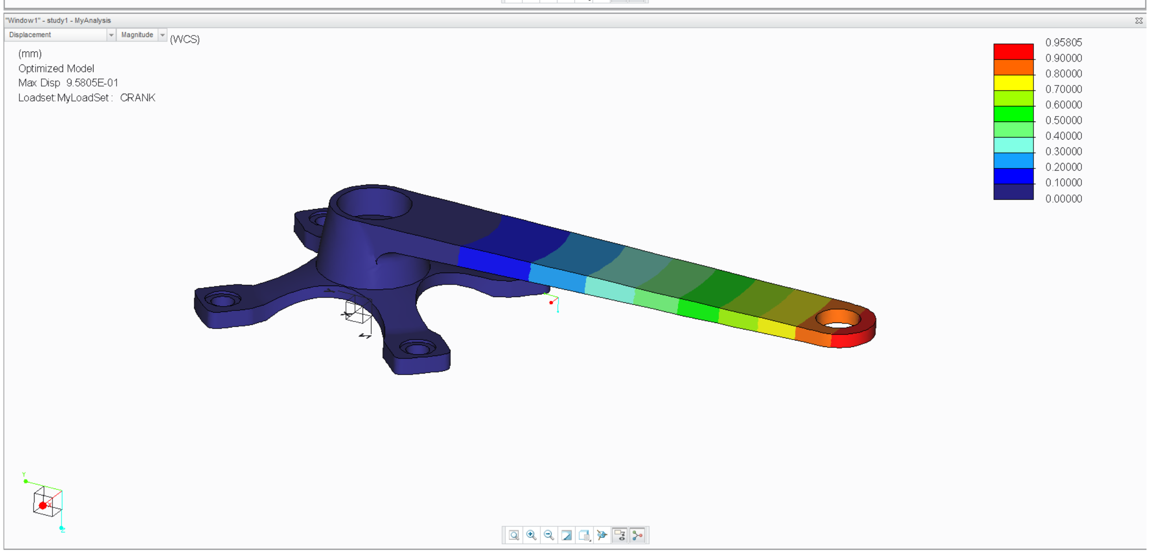
B.4 Original Crank Arm





B.5 Optimized Crank Arm





B.6 Crank Results

ORIGINAL CRANK RESULTS:

```
     Name              Value       Convergence
--------------     -------------  -----------
max_beam_bending:   0.000000e+00      0.0%
max_beam_tensile:   0.000000e+00      0.0%
max_beam_torsion:   0.000000e+00      0.0%
max_beam_total:     0.000000e+00      0.0%
max_disp_mag:       6.056095e-02      0.1%
max_disp_x:         6.055857e-02      0.1%
max_disp_y:         5.204540e-03      0.1%
max_disp_z:        -1.613569e-03      0.1%
max_prin_mag*:      3.085243e+01      2.7%
max_stress_prin*:   3.085243e+01      2.7%
max_stress_vm*:     2.585291e+01      2.3%
max_stress_xx*:     2.840310e+01      4.7%
max_stress_xy*:    -1.224368e+01      1.2%
max_stress_xz*:    -9.050020e+00      8.4%
max_stress_yy*:    -2.097990e+01      0.1%
max_stress_yz*:     8.745988e+00      7.2%
max_stress_zz:      1.087165e+01     12.3%
min_stress_prin*:  -3.056946e+01      3.7%
strain_energy:      2.759196e+00      0.1%
```

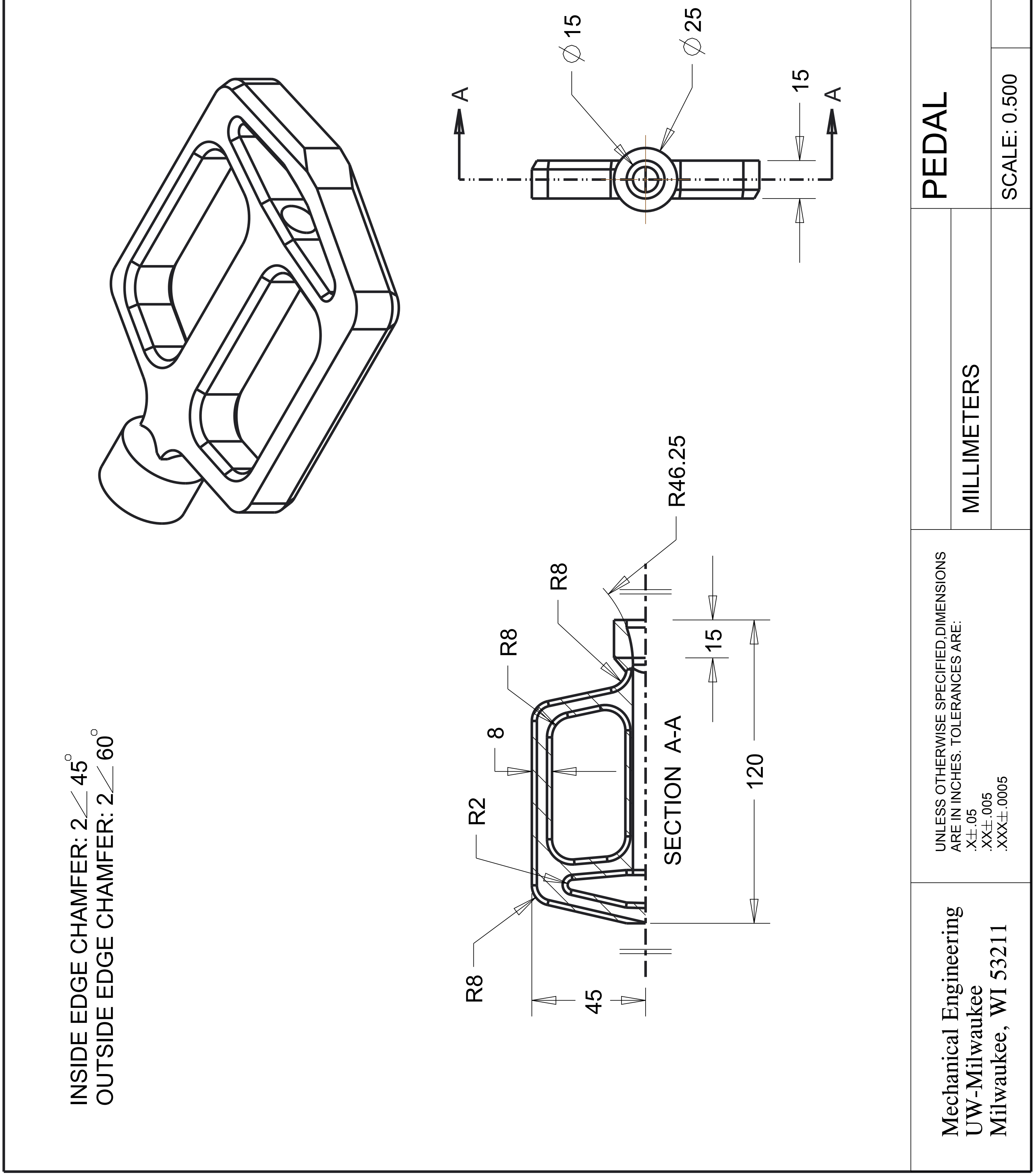
RESULTS OF CRANK OPTIMZATION

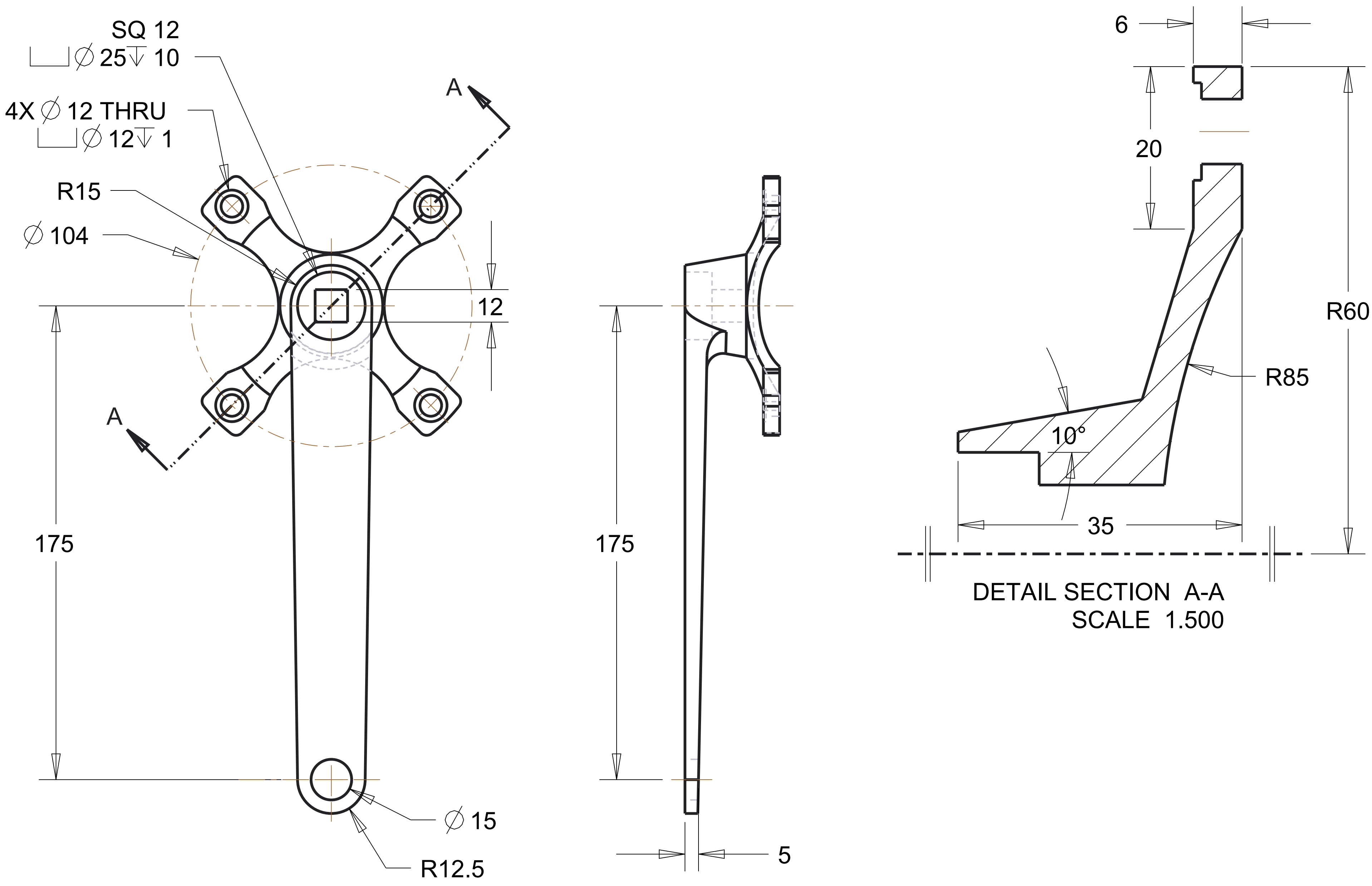
```
Status of Optimization Limits:
1. max_stress_vm     2.7594e+02 <  2.7600e+02 (satisfied within tolerance)

Resource Check                                     (19:56:39)
   Elapsed Time     (sec):     600.17
   CPU Time         (sec):     648.43
   Memory Usage      (kb):     989275
   Wrk Dir Dsk Usage (kb):         16
Begin Optimization Iteration 5                     (19:56:39)
Converged to optimum design.
Best Design Found:
Parameters:
   endthick                     5
   thickness              8.49334
Goal:  4.7970e-04 TONNE
```

OPTIMIZED CRANK RESULTS:

Name	Value	Convergence
max_beam_bending:	0.000000e+00	0.0%
max_beam_tensile:	0.000000e+00	0.0%
max_beam_torsion:	0.000000e+00	0.0%
max_beam_total:	0.000000e+00	0.0%
max_disp_mag:	5.270900e-01	0.0%
max_disp_x:	5.270899e-01	0.0%
max_disp_y:	4.680954e-02	0.0%
max_disp_z:	-1.096470e-02	0.1%
max_prin_mag:	-2.532370e+02	8.5%
max_rot_mag:	0.000000e+00	0.0%
max_stress_prin*:	2.146001e+02	8.5%
max_stress_vm:	2.327086e+02	8.0%
max_stress_xx*:	1.633215e+02	9.5%
max_stress_xy:	-7.773699e+01	1.0%
max_stress_xz*:	-1.021555e+02	7.8%
max_stress_yy:	-2.205660e+02	8.8%
max_stress_yz*:	6.571469e+01	10.2%
max_stress_zz*:	-9.474305e+01	12.5%
min_stress_prin:	-2.532370e+02	8.5%
strain_energy:	2.352179e+02	0.0%

C Optimzied Drawings





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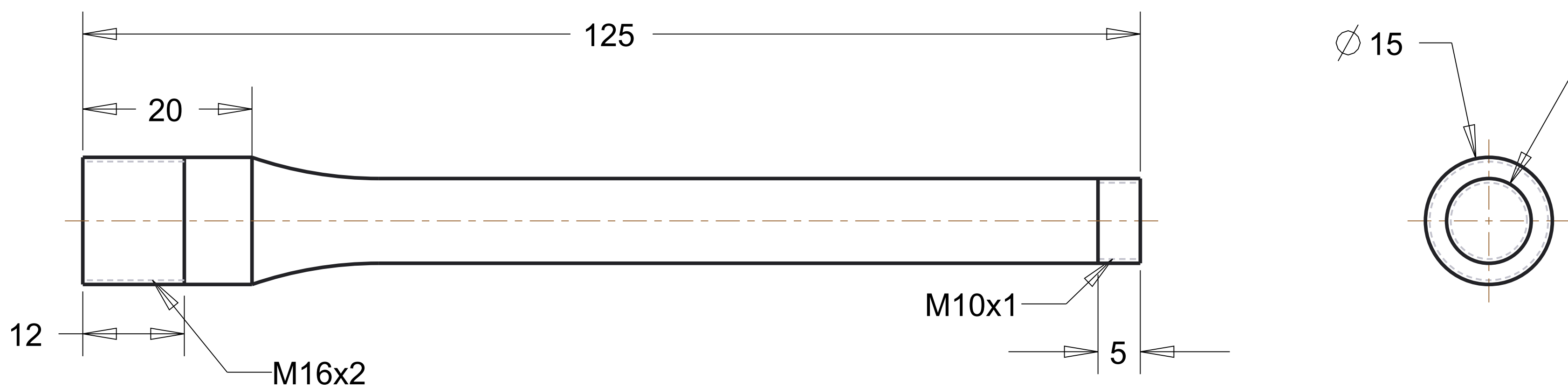

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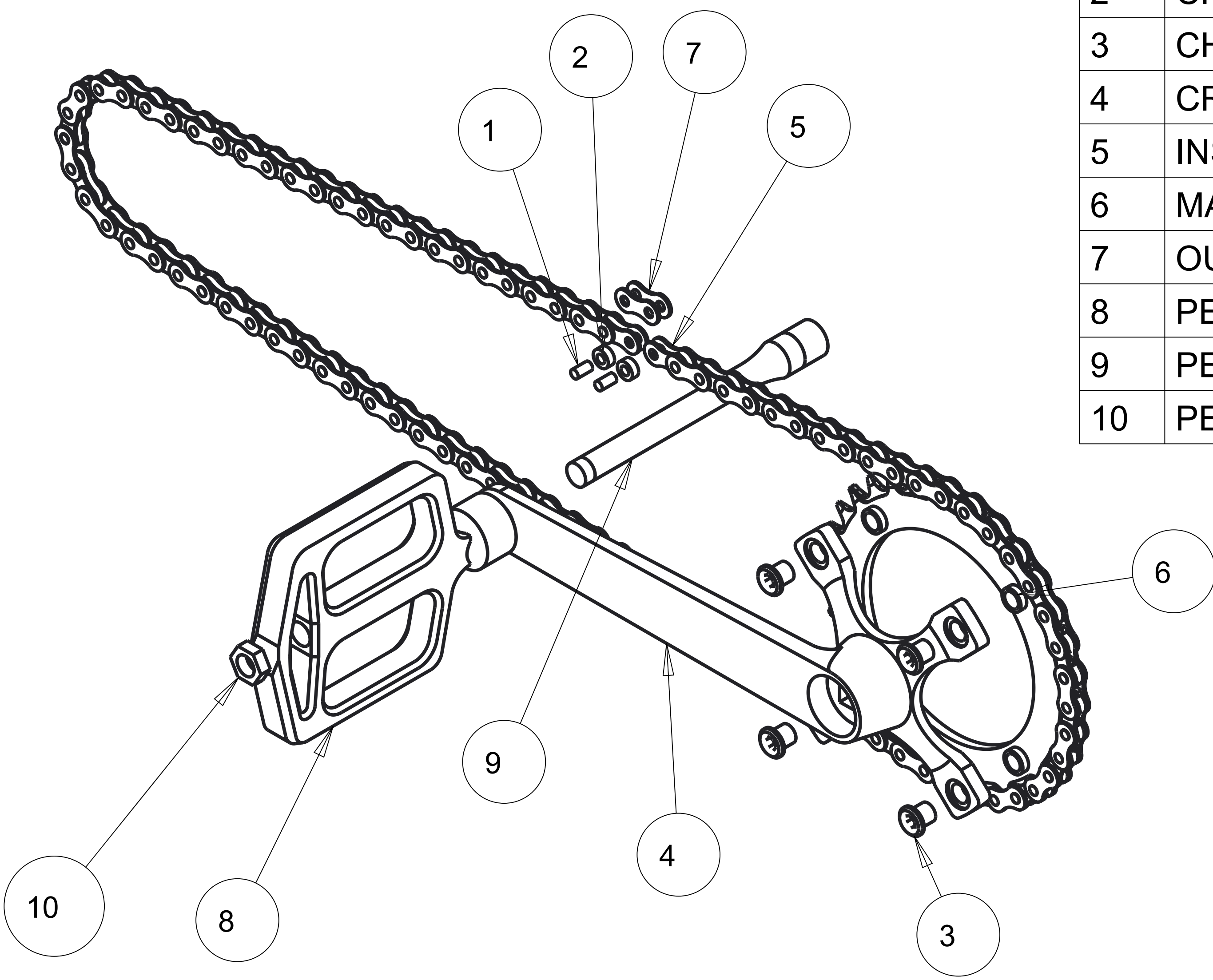

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.XXX±.0005

FULLASSEMBLY

SCALE: 0.400