Project 2

Design Optimization

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Abstract:

A disk break is to be optimized to achieve the following objectives: (1) minimize the overall volume of the component, (2) minimize the maximum stress in the rotor, (3) maximize the 1st deformation frequency response of the break, (4) Minimize the maximum temperature of the brake rotor. Ansys is used to simulate brake pads applying a pressure onto the brake rotor to extract mechanical, thermal, and harmonic responses of the system.

Model:

Model of the braking pads and rotors were provided, and materials were specified as Gray Cast Iron for the rotor and structural steel at the brake pads.

- Brake pad material: Structural Steel
- Brake rotor: Gray Cast Iron

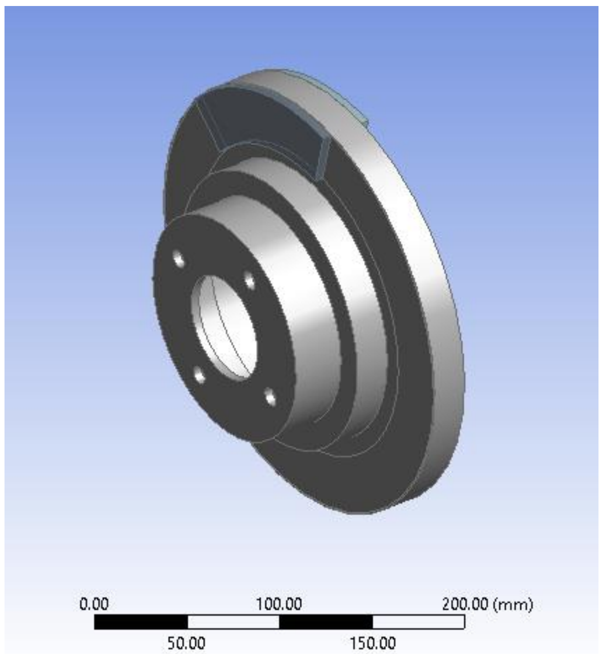


Figure 1: System Geometry

Mesh:

A patch conforming tetrahedron method was implemented to mesh the rotor geometry. Mesh sizing refinement was implemented at the face-face contact region of the brake pads and brake rotor. Figure2 and figure3 illustrate the meshed brake system.

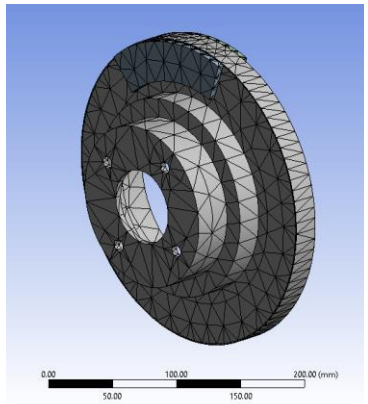


Figure 2:

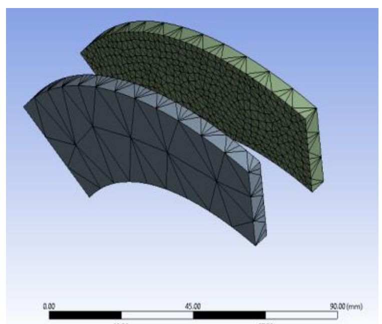


Figure 3

Static Structural:

A Static Structural simulation was implemented to extract both the maximum von-misses stress and total system volume. System boundary conditions were set as:

1. rotational velocity: 250 rad/s at the y-axis
2. Revolute Joint: Body to ground connection type at the inner diameter interface
3. Displacement of the system was fixed in the x-axis and z-axis
4. Frictional contact points at the break bad and brake rotor interface. A coefficient of frication of .22 was set for both components

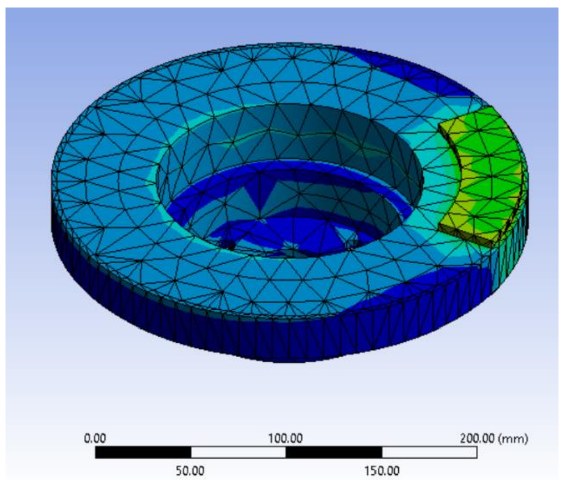


Figure 4

Modal:

A modal analysis was implemented to extract the first frequency of deformation. Ten modes were extracted, and the 7th mode was determined to be the first frequency of deformation and was set the output.

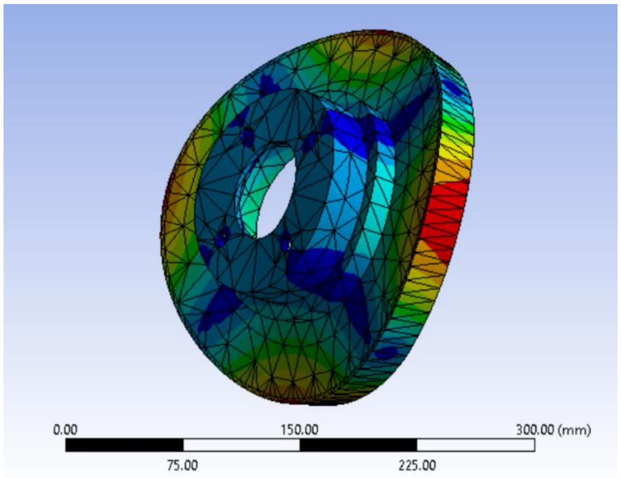


Figure 5

Transient Thermal:

A 5 second transient thermal analysis was run to extract the maximum temperature experience at the brake rotor. The following condition were set for the simulation:

1. Initial temperature:35c
2. Convection: 5. W/m^2
3. Heat Flux: Defined at the contact face = 1.5395 W/m^2

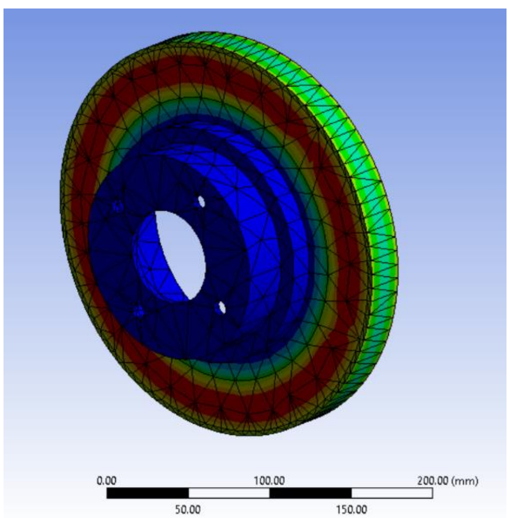


Figure 6

Optimization:

The applied design optimization considered: total volume, maximum Von-Misses stress, maximum temperature, and the first frequency of modal deformation. The respective system characteristic objectives are listed in (table 1). Table 2 detail the parameterization of the brake rotor geometry. For this optimization the brake parameters were limited to a dimensional range that would eliminate any geometric conflict. Furthermore the system parameters were each defined in increments of .5mm by implementing a snap to feature in Ansys optimization tool.

Table 1

Volume Total	Minimize
Equivalent Stress Maximum	Minimize
Total Deformation Reported Frequency	Maximize
Temperature Maximum	Minimize
rotor_thickness	Bounded
rotor_OD	Bounded
rotor_ID	Bounded

Table 2

Input Parameter	Lower Bound (mm)	Upper Bound (mm)	Incriment Delta (mm)	Objective:
Rotor Thickness	10	27	.5	Minimize
Inside Diameter	72	88	.5	Maximize
Outside Rotor Diameter	123	138	.5	Minimize

Due to the multiple objectives defined in the project instructions an Adaptive Multi Objective Direct optimization was implemented using and Ansys recommended automated configuration with a run time index of “5”. The optimization routine was run until convergence for a total number of 69 samples.

Optimization Results and Discussion:

As expected, the many defined objectives resulted in trade-off in optimizations of the system. This problem requires a practical analysis of the brake system and its application to better understand the trade off's so that objectives can be characterized by criticalness. This was accomplished by making assumptions on the needs of the system and are detailed and table 3.

Table 3

Objective criticality table:		
Objective:	Criticality:	Notes:
Thermal:	High	Thermal expansion, fowling, and other..
Modal deformation:	Neutral	Simulated freq. << Experienced RPM
Von Misses stress:	Neutral – High	Simulated values << Tensile strength, Ultimate
Volume	High	material and weight savings, form factor

Sensitivities and Trade-off's:

Investigating the system sensitivities generated through direct optimization show the following:

1. Rotor thickness has the largest impact on equivalent stress, rotor temperature, and total system volume.
2. Rotor inside diameter has a large impact on equivalent stress and modal deformation frequency onset
3. Rotor outside diameter has a large impact on modal deformation frequency onset

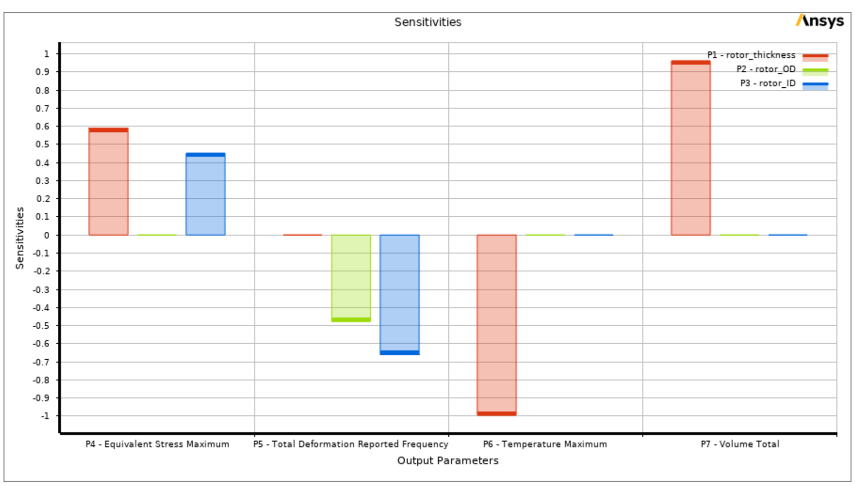
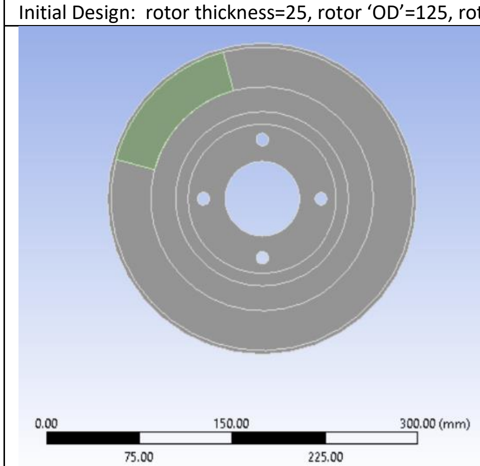


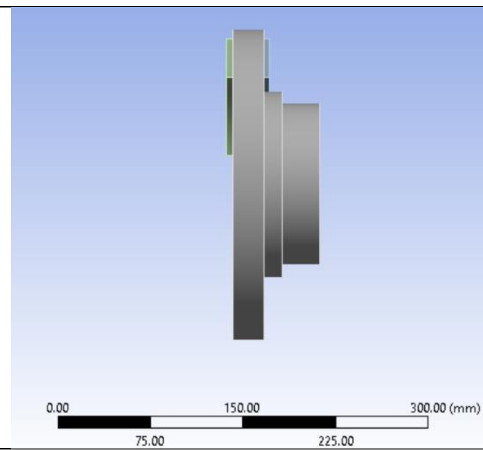
Figure 7

	rotor_thickness (mm)	rotor_OD (mm)	rotor_ID (mm)	Equivalent Stress Maximum (MPa)		Total Deformation Reported Frequency (Hz)		Temperature Maximum (C)		Volume Total (m^3)	
	value:	value:	value:	value:	Ref. Δ:	value:	Ref. Δ:	value:	Ref. Δ:	value:	Ref. Δ:
Candidate Point 1	21	123.5	82	13.41388899	-20.15%	1424.817076	-11.81%	355.3607178	4.37%	0.000834398	-19.16%
Candidate Point 2	15.5	124	86.5	11.6796132	-30.47%	1257.329788	-22.18%	405.5568237	19.12%	0.000672999	-34.80%
Candidate Point 3	11	125	77.5	10.89576816	-35.14%	1403.39965	-13.14%	501.3153076	47.24%	0.000587932	-43.04%
Reference Geometry	25	125	75	16.79858173	0.00%	1615.686627	0.00%	340.4679871	0.00%	0.001032196	0.00%

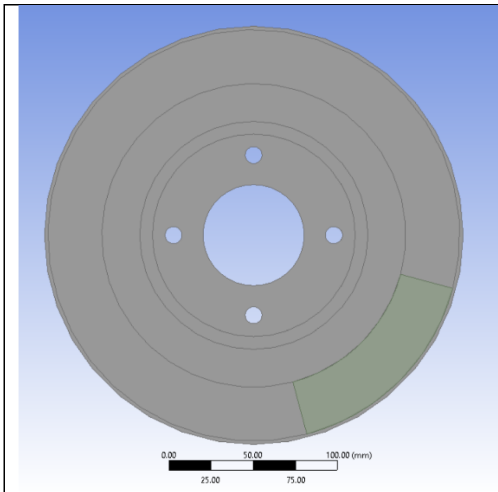
Optimal Design:

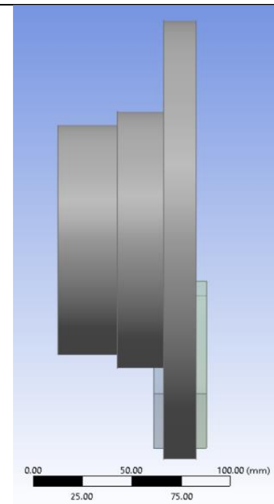
Initial Design: rotor thickness=25, rotor 'OD'=125, rotor 'ID'=75





Optimal Design: rotor thickness=11, rotor 'OD'=125, rotor 'OD'=77.5


0.00
50.00
100.00 (mm)
25.00
75.00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