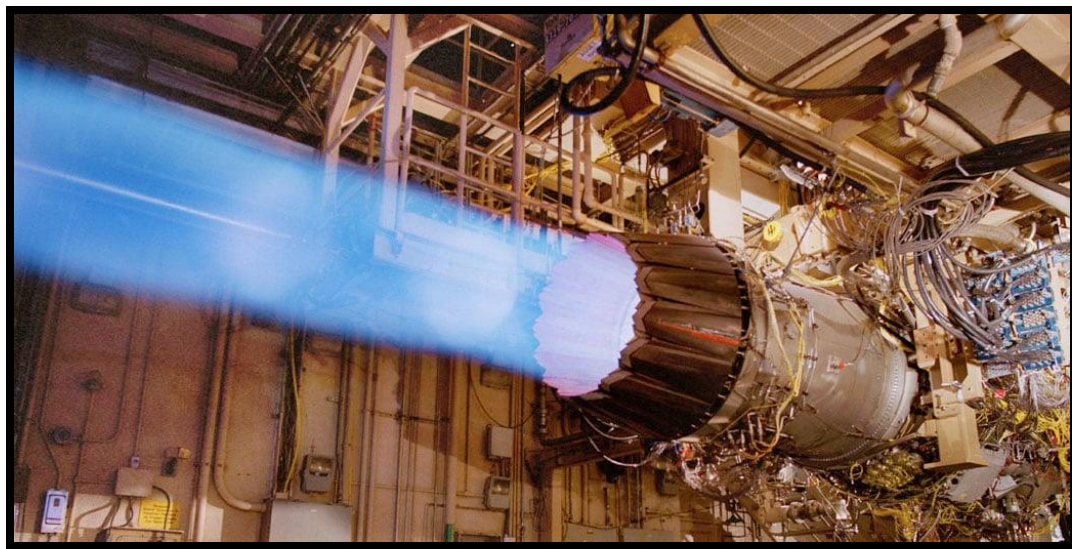


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The Application

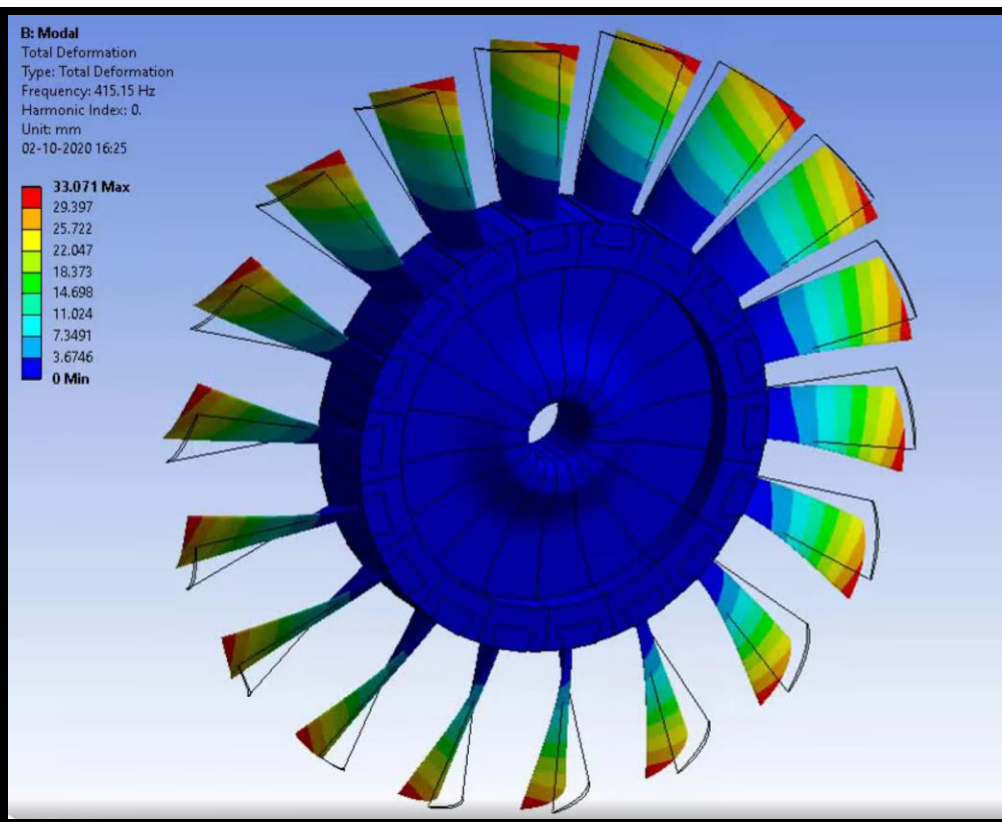
Turbine Disks

- A jet engine compresses air, mixes it with fuel, and ignites it to generate thrust. Turbine disks connect the blades to the shaft, spinning at 10,000 – 15,000 RPM under extreme stress.
- As turbine disks must withstand extreme heat, high rotational stress, and long-term exposure to creep and fatigue, we’ve chosen Inconel 718 in turbine disks as our application.



Design Constraints

- Turbine disks are subjected to high temperatures, large centrifugal stresses, and repeated thermal cycling, simultaneously. These high temperatures exponentially accelerate creep, increasing risk of failure.
- The material selected must maintain its structural integrity at these extreme conditions, while also remaining commercially practical, considering its cost and weight, so that intricate shapes can be reliably manufactured.



The Material Selected

Inconel 718

- Inconel 718 has been the industry standard for turbine disks for decades, particularly due to its exceptional tensile strength and reliable performances at moderate to severe temperatures.
- Its primary drawback is the coarsening of its γ'' strengthening phase above 650 °C, which gradually reduces creep resistance and mechanical performance under sustained high temperatures. However, most commercial jet engines operate below this threshold, keeping Inconel within its reliable performance range.

Composition Table:

Element	Wt.%	Element	Wt.%
<i>Ni</i>	51.49	<i>Si</i>	0.07
<i>Cr</i>	18.31	<i>Mn</i>	0.07
<i>Fe</i>	Bal	<i>C</i>	0.043
<i>Cb</i>	5.03	<i>P</i>	0.007
<i>Mo</i>	2.93	<i>Cu</i>	0.039
<i>Ti</i>	1.04	<i>B</i>	0.002
<i>Al</i>	0.54	<i>Ta</i>	0.001

- Each element plays a specific role in Inconel 718’s performance. Nickel provides the base corrosion resistance, chromium adds oxidation resistance, and niobium enables the γ'' hardening.



Fabricating the material

- Nickel, chromium, iron, and other elements are carefully measured and prepared.
- The material goes through a vacuum induction melting, (VIM) process to keep them clean and free from contamination.
- The melted metal is refined again by a process called vacuum arc remelting, (VAR) to make it more uniform and remove any defects after the initial melt.
- The metal is formed into useful shapes like sheets, bars, tubes, or wires.



- The metal is heated, then cooled, so it becomes softer and easier to machine or shape
- Optional phase: If higher strength is needed, the metal goes through another heating process:
 - Heat for several hours
 - Slowly cool it down
 - Hold at a lower temperature
 - Cool it in air
- Inconel 718 is primarily characterized by a face-centered cubic (FCC) austenite matrix (γ -phase).
- Its high strength is from precipitation hardening, containing a high-volume fraction of body-centered tetragonal (BCT) γ'' precipitates, along with smaller amounts of FCC γ'



Origin of desirable properties

- Inconel 718 has exceptional resistance to creep (the slow deformation of a material under stress at high temperature). In jet engines, turbine disks operate under extreme rotational stress and temperatures (~800–900 K), conditions in which creep can degrade performance and cause failure over time.
- Creep becomes significant at ~30–50% of a material’s melting temperature. Although Inconel 718 operates at ~50–60% of its melting temperature (1533–1609 K), it maintains structural integrity.
- This resistance originates from its precipitation-hardening (aging) treatment. During this process, fine precipitates form throughout the alloy. These particles are obstacles to dislocation motion, and thus they reduce atomic movement and slowing creep.
- Unlike most materials, these precipitates remain stable at high temperatures, allowing Inconel 718 to retain strength and resist long-term deformation.

Conclusion

- Inconel 718 is expensive, heavy, and hard to manufacture, however in aerospace applications such as turbine disks, where components experience extreme heat, stress, and repeated thermal cycling, these trade-offs are necessary .
- Our research has proven that choosing a material is not about a particular property. It’s about how the material performs across various real-world conditions, with reliability and human safety, prioritized above all else.

