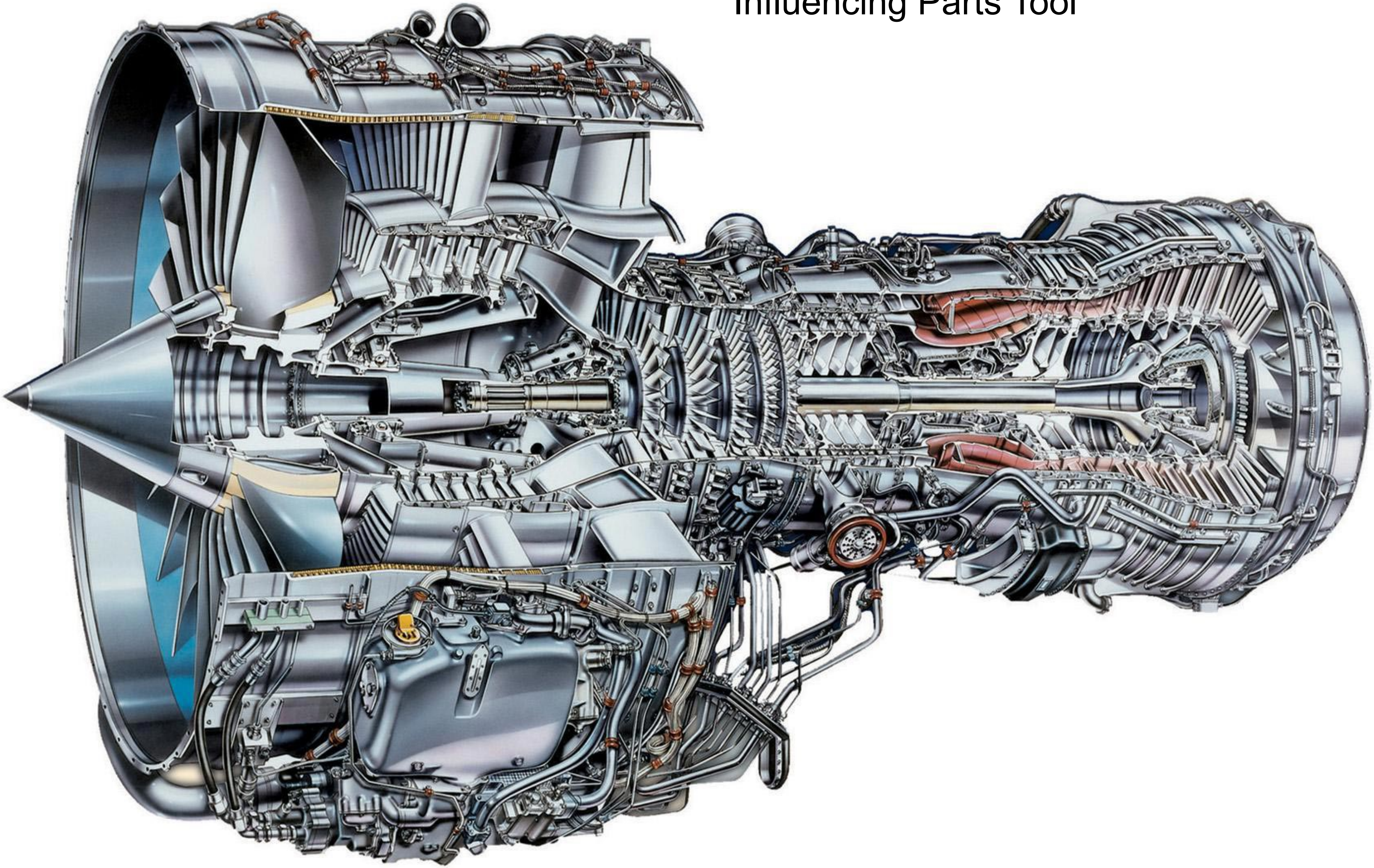
Influencing Parts Tool



What is a life-limited part? (LLP)

A part whose failure could result in a Hazardous Engine Effect as defined by the FAA in 14 Code of Federal Regulations (CFR) §33.75 – Safety Analysis.

What is a life limit?

A life limit specifies the maximum allowable number of flight cycles for which an engine LLP may be operated. (See 14 CFR §33.70 - Engine life-limited parts.) The life limit ensures that each engine life-limited part is withdrawn from service before hazardous engine effects can occur.

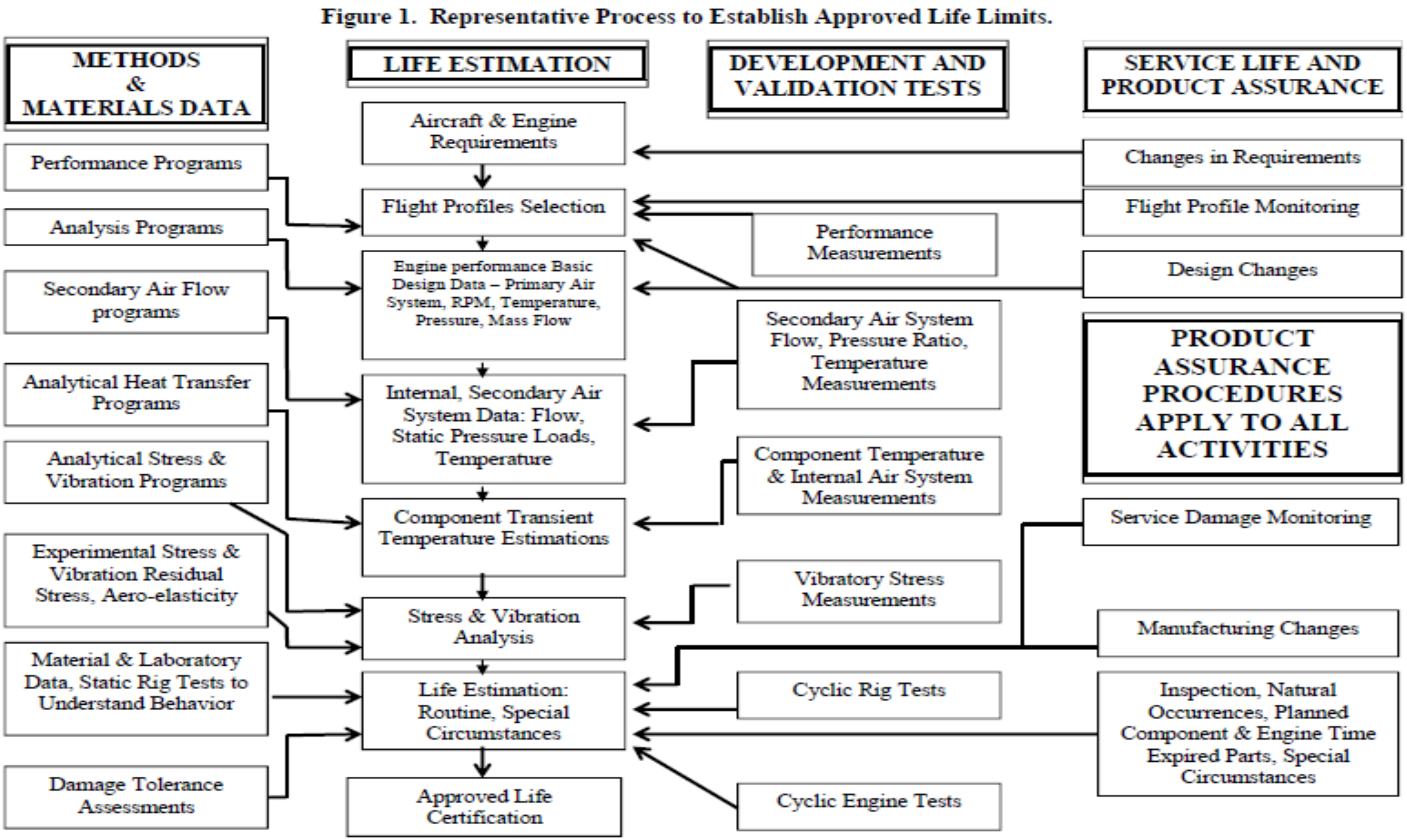
What is an influencing part?

14 CFR §33.70 states that establishing a life limit requires an assessment such that "the combination of loads, material properties, environmental influences and operating conditions, including the effects of other engine parts influencing these parameters, are sufficiently well known and predictable so that the operating limitations can be established and maintained for each engine life-limited part." These "other engine parts influencing these parameters" are commonly called influencing parts.

Refer to https://rgl.faa.gov/ to verify the latest revision of any FAA docs

What factors go into establishing a life limit?

Figure 1 from FAA Advisory Circular 33.70-1 provides a good overview.



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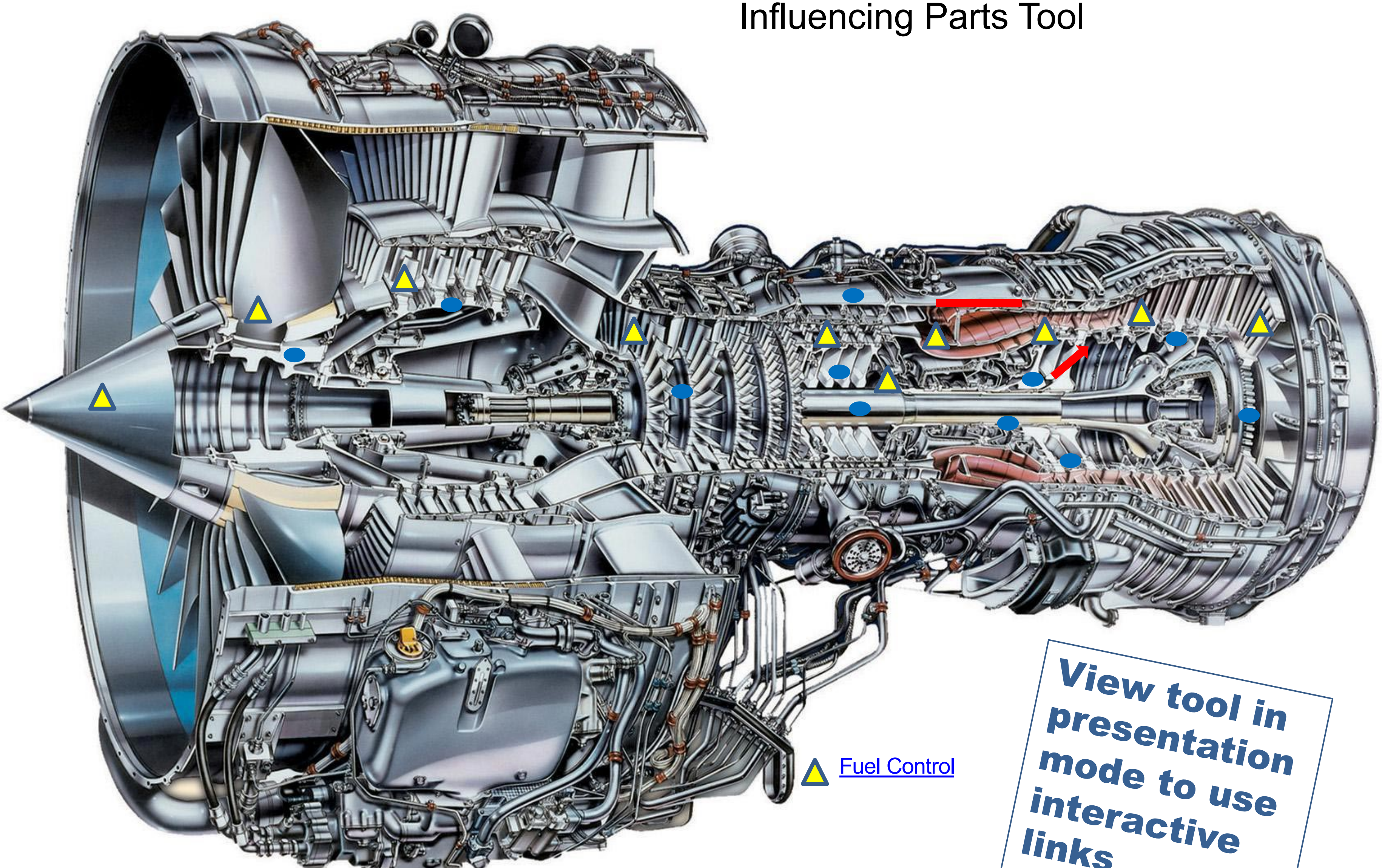
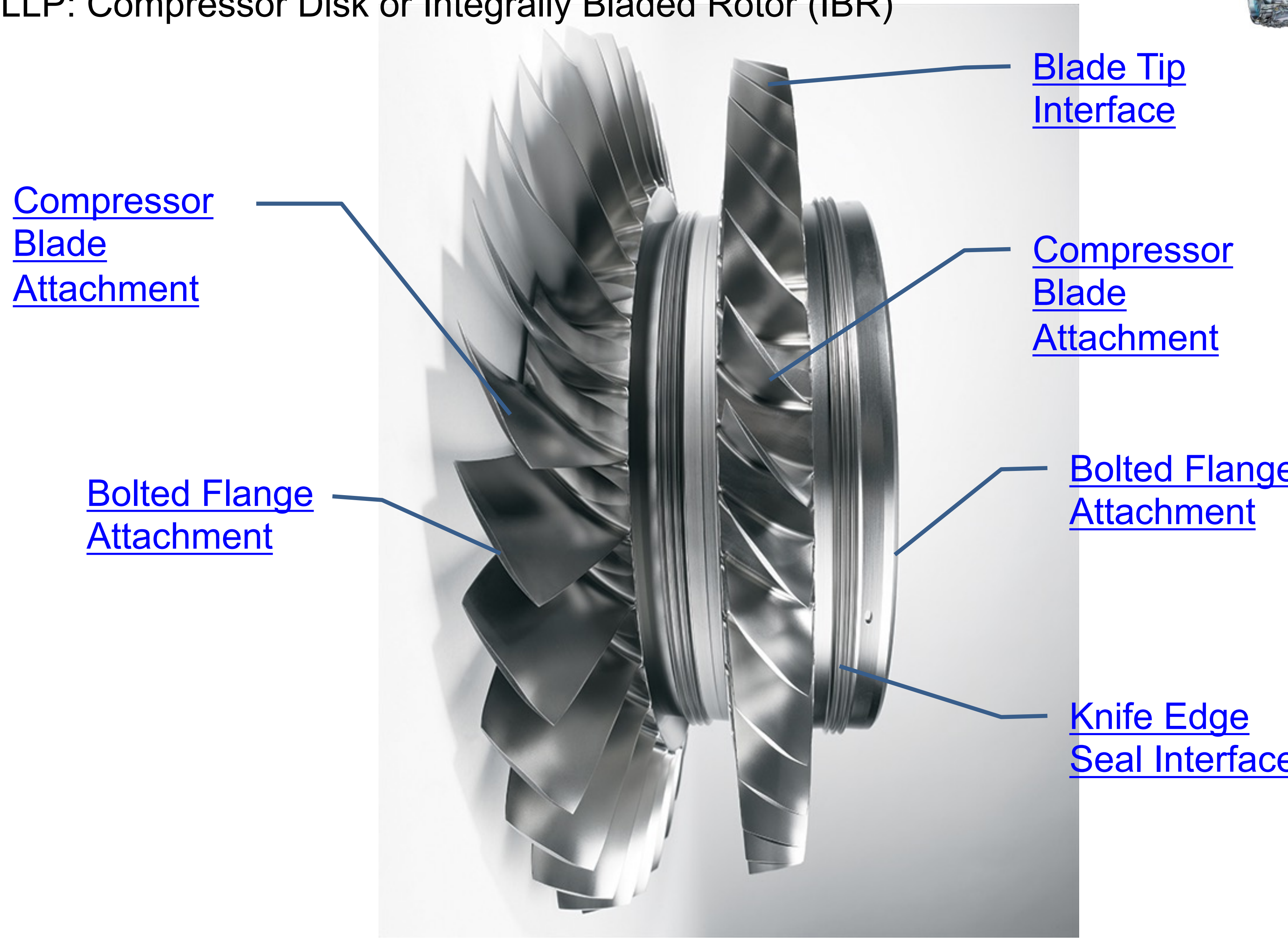
Influencing Parts Tool



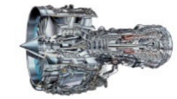
Life Limited Part Section

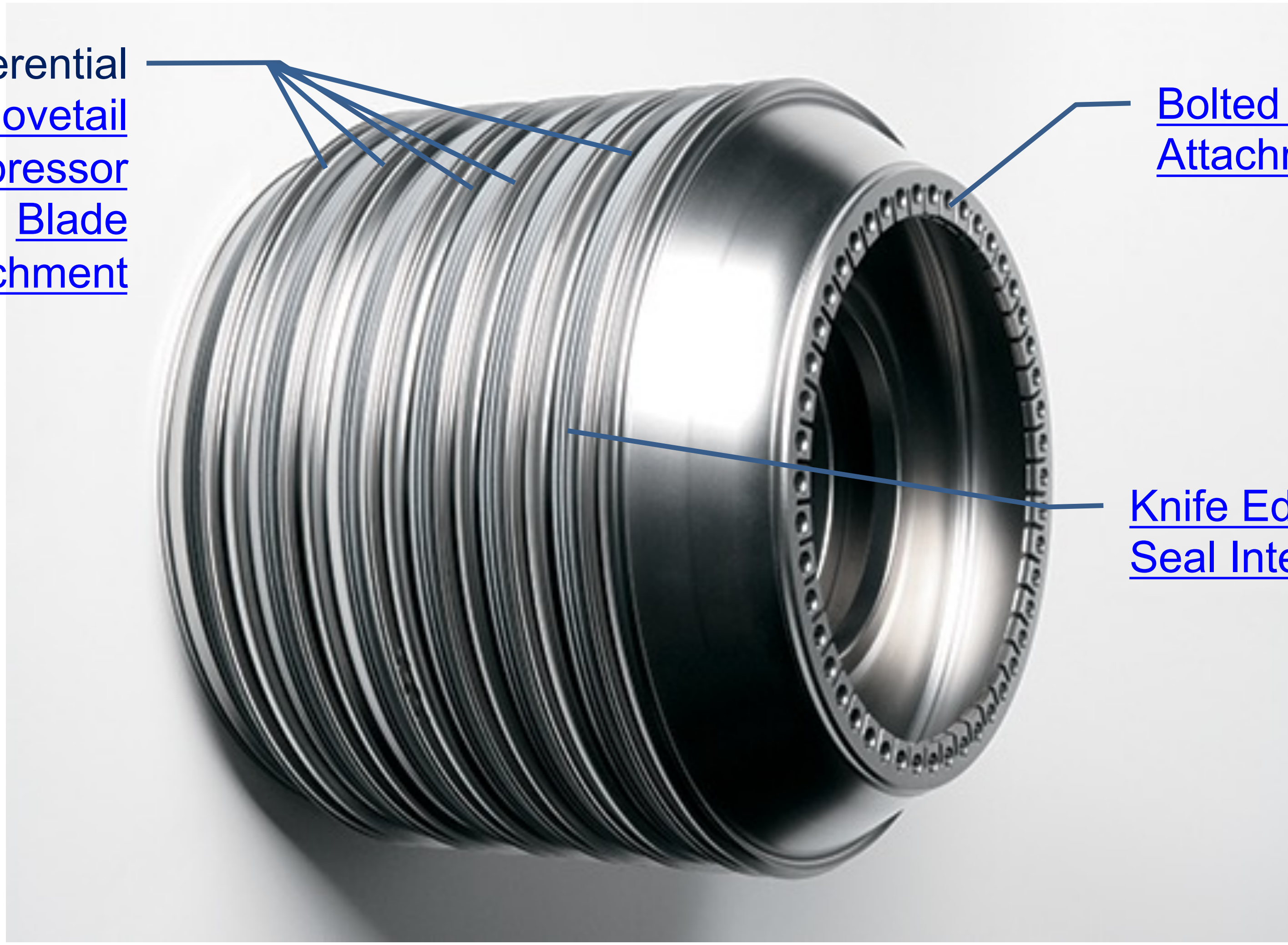
LLP: Fan Hub

LLP: Compressor Disk or Integrally Bladed Rotor (IBR)



LLP: HPC Spool



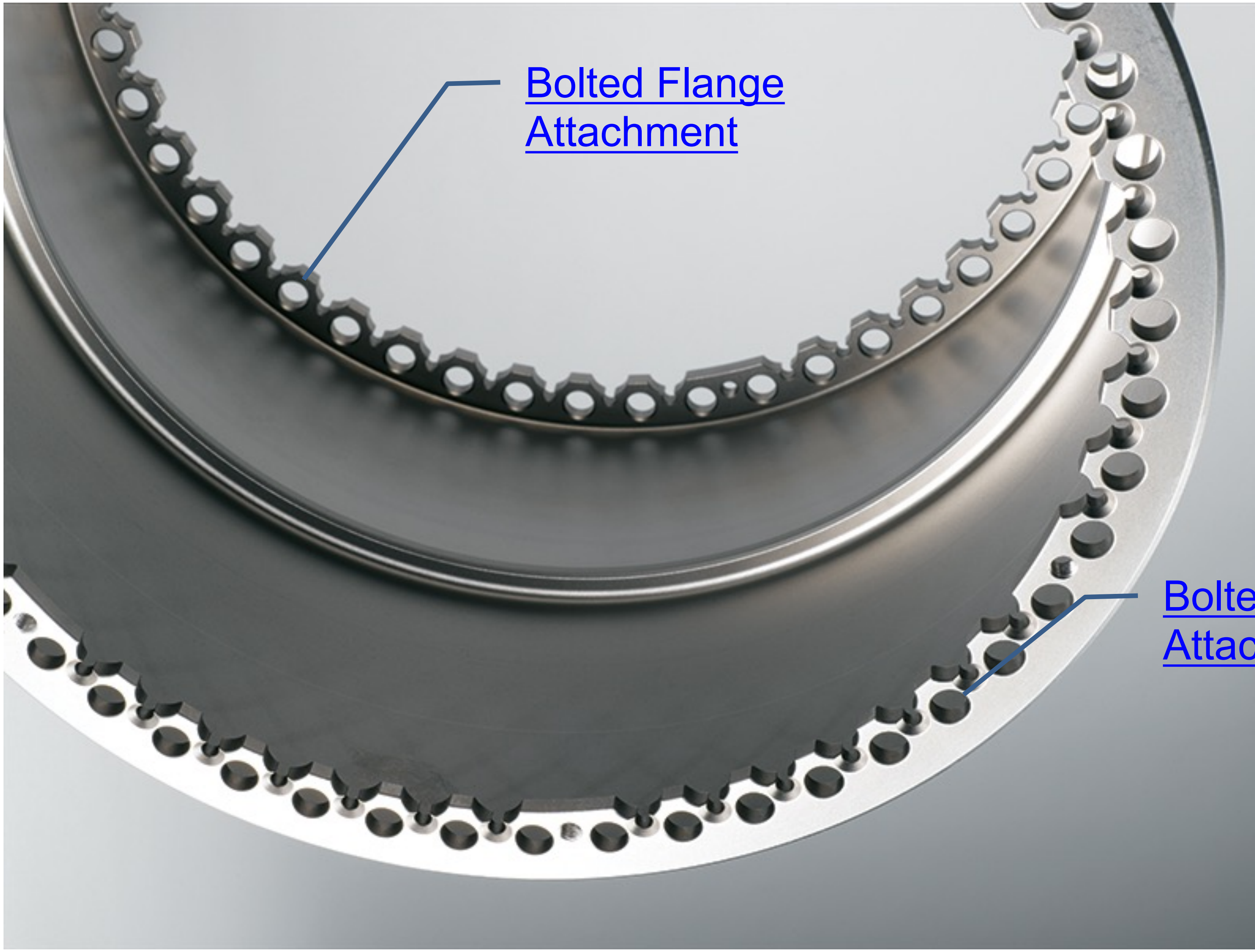


Circumferential Dovetail Compressor Blade Attachment

Bolted Flange Attachment

Knife Edge Seal Interface

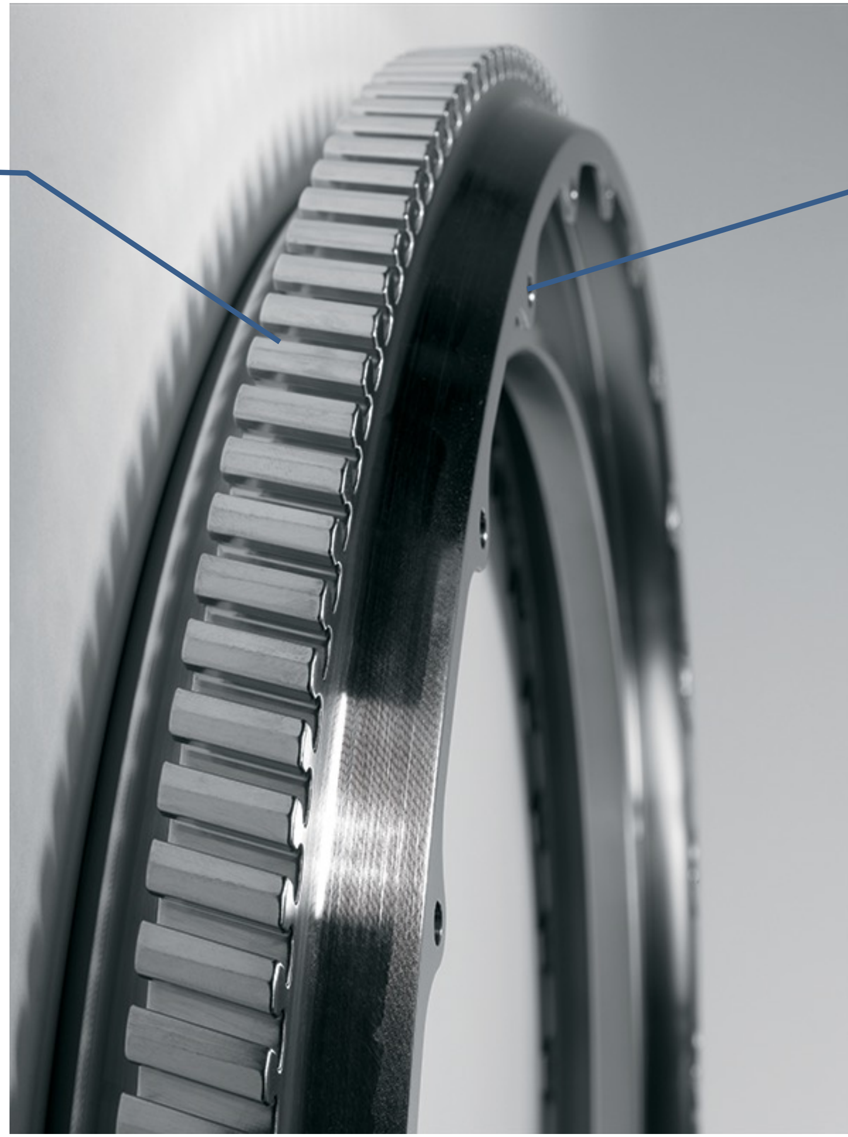
LLP: HPT Shaft



LLP: HPT Seal

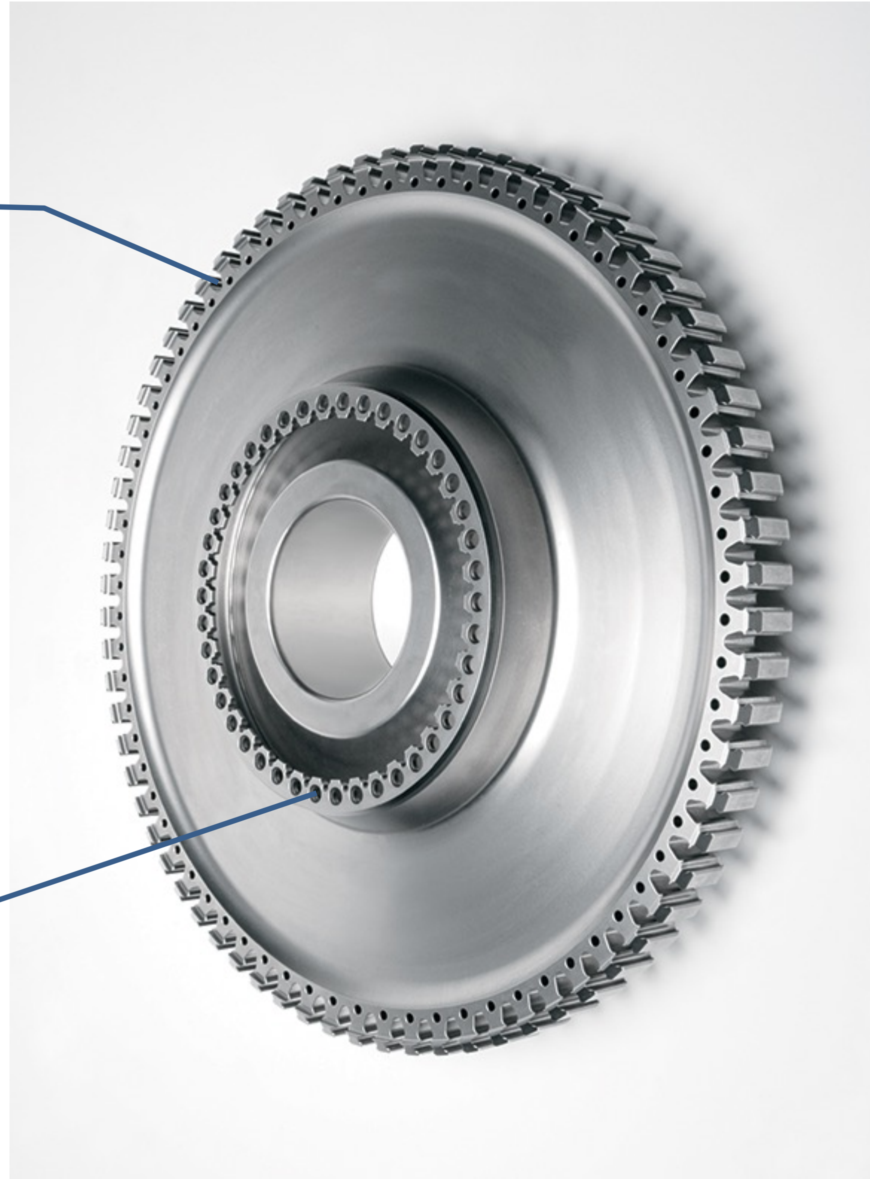

Cooling Flow
Knife Edge
Seal Interface
Knife Edge
Seal Interface

LLP: LPT Disk



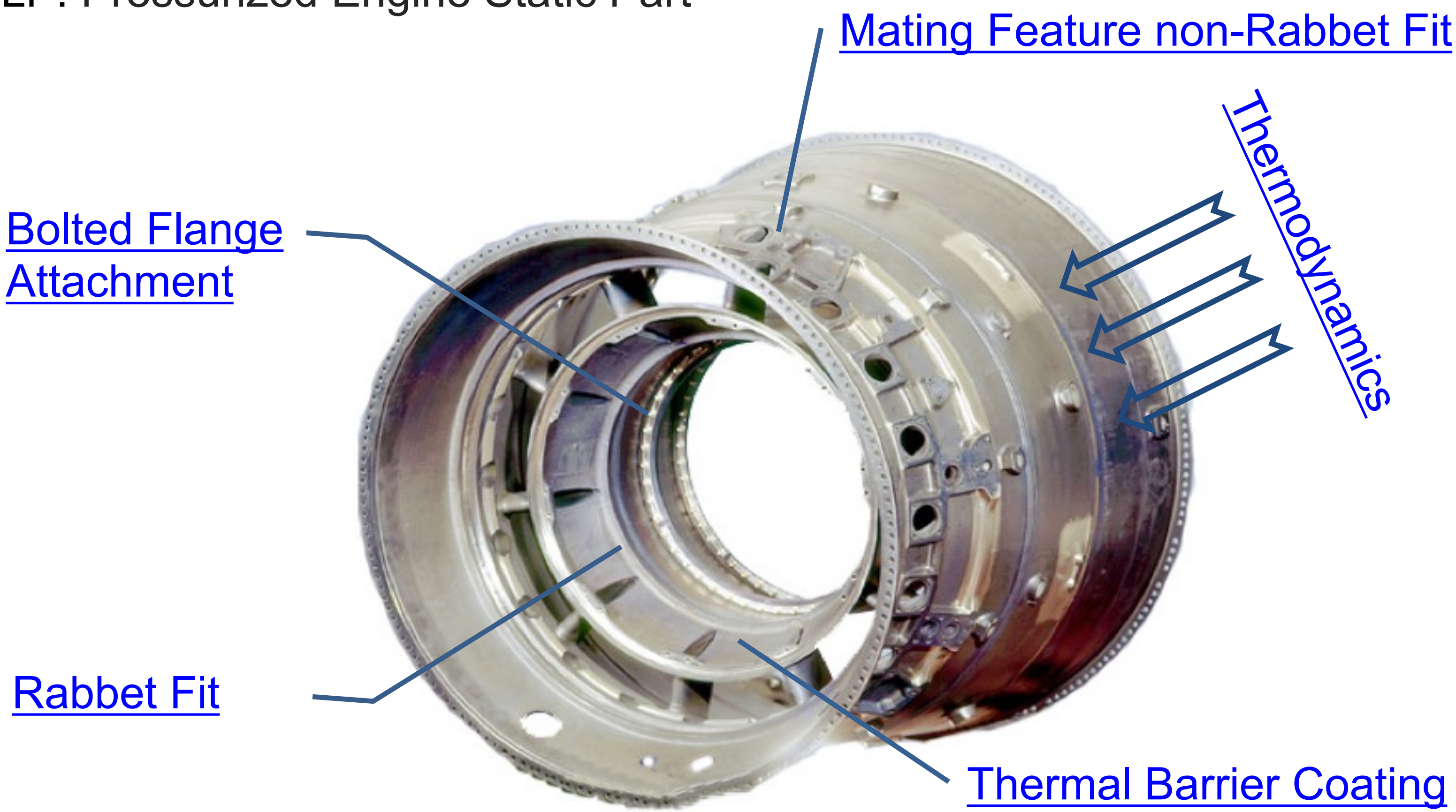
LLP: HPT Disk

Fir Tree Blade Attachment

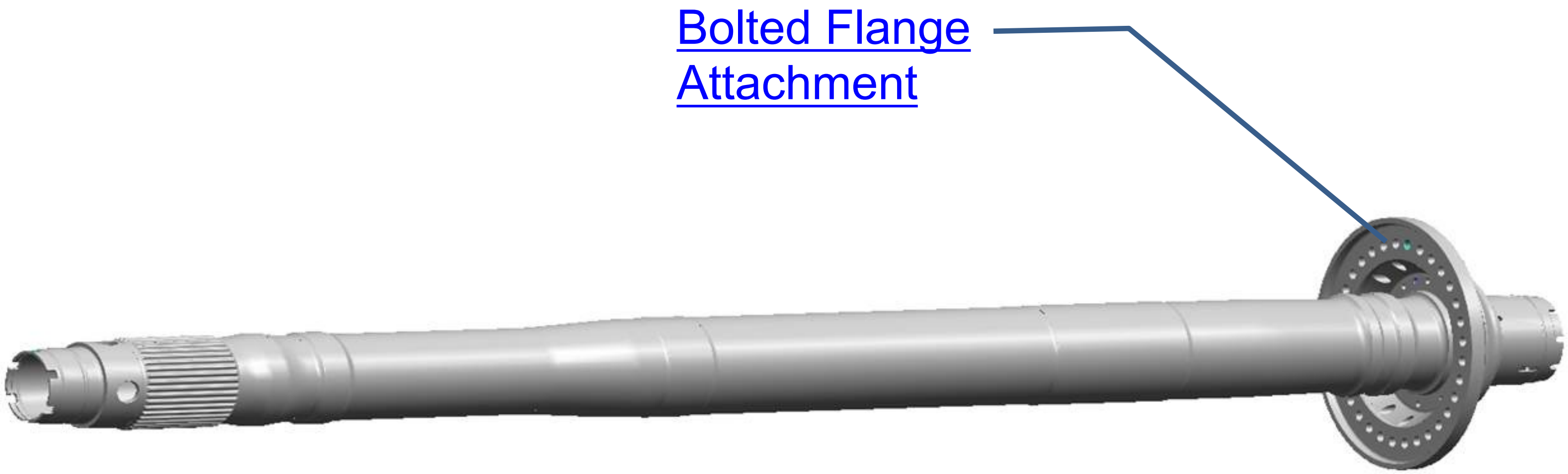


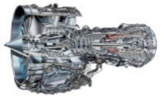
Bolted Flange Attachment

LLP: Pressurized Engine Static Part



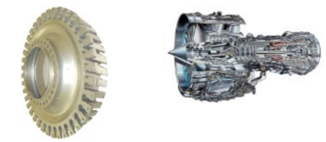
LLP: Turbine Shaft

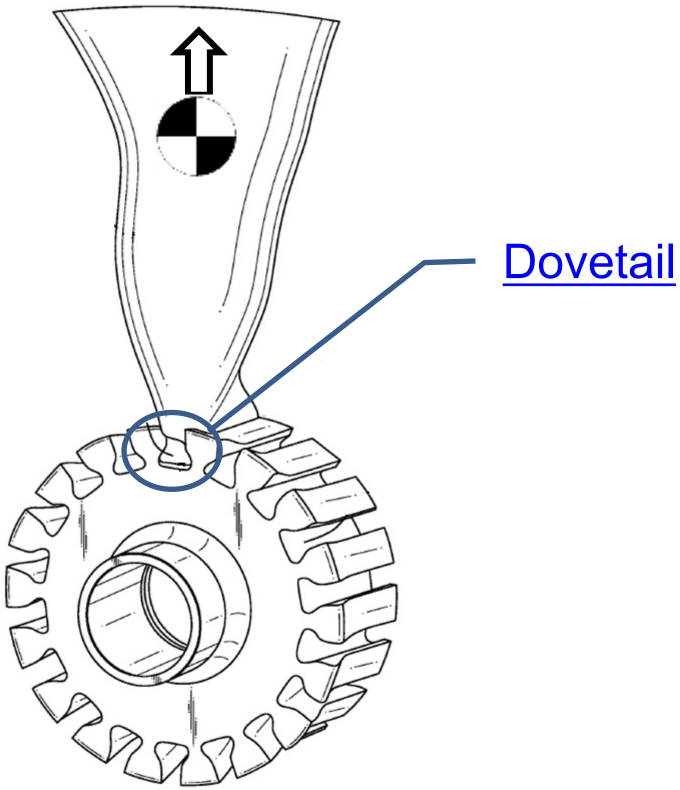




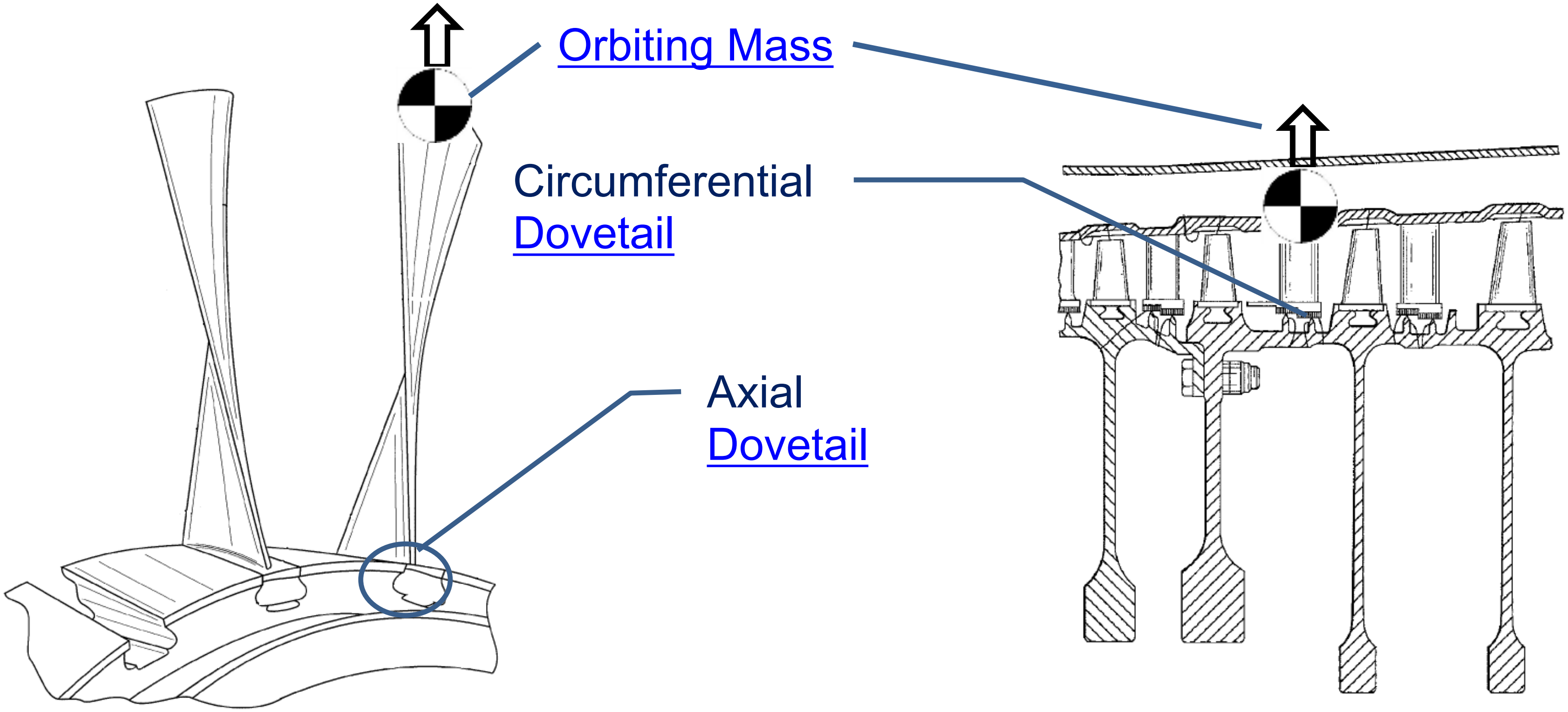
Influencing Part Section

Influencing Part: Dovetail Fan Blade

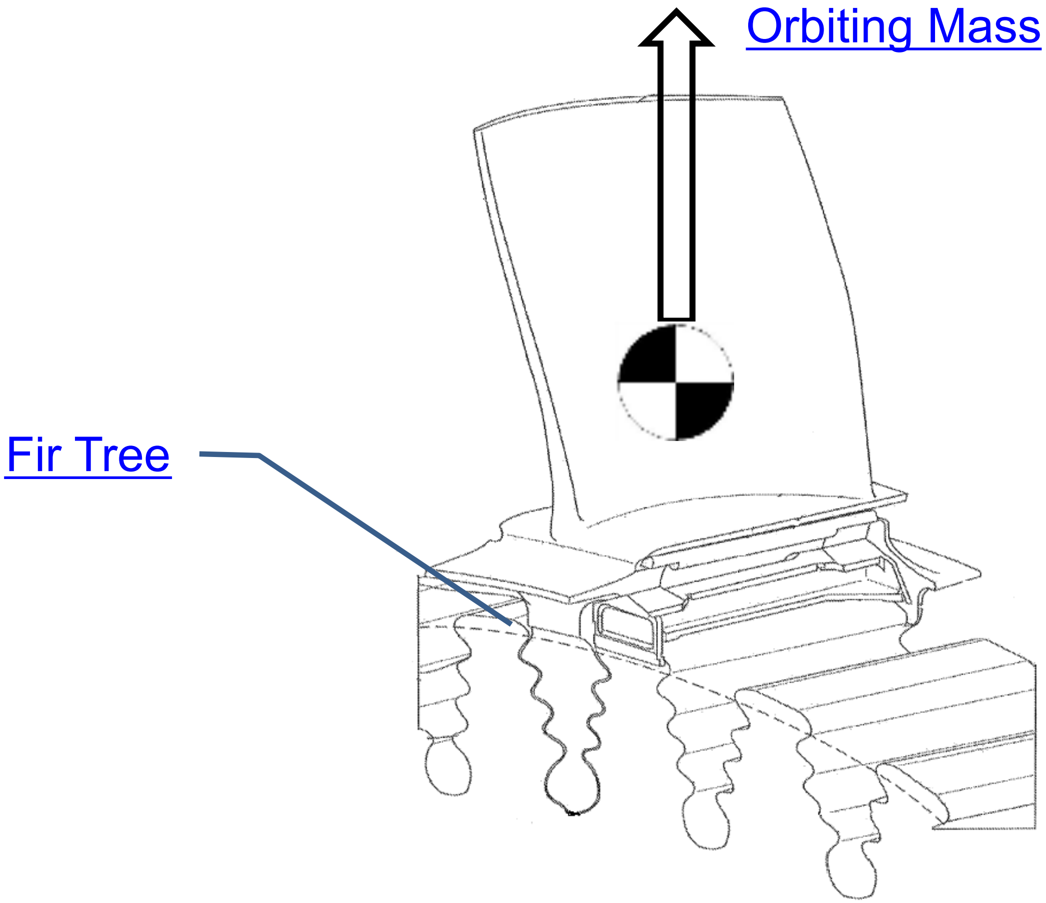




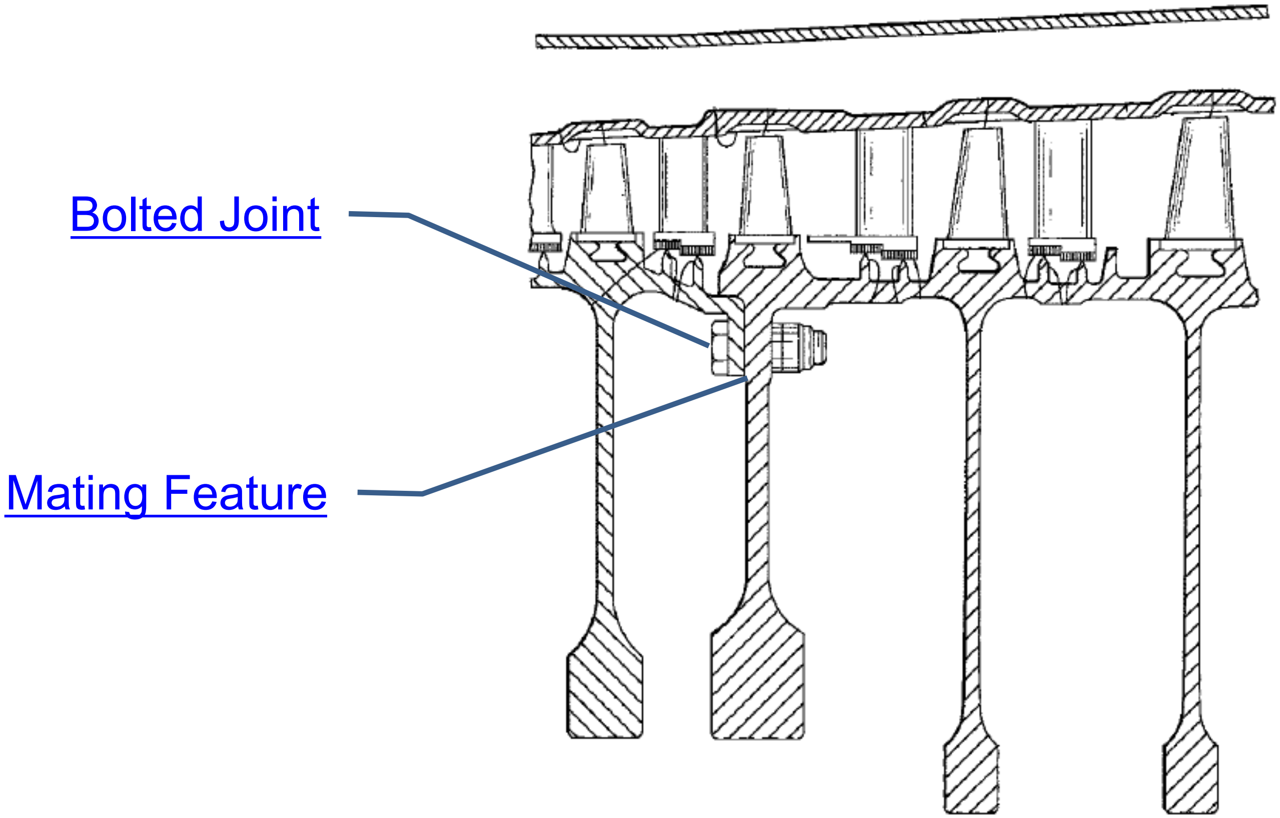
Influencing Part: Dovetail Fit Compressor Blade



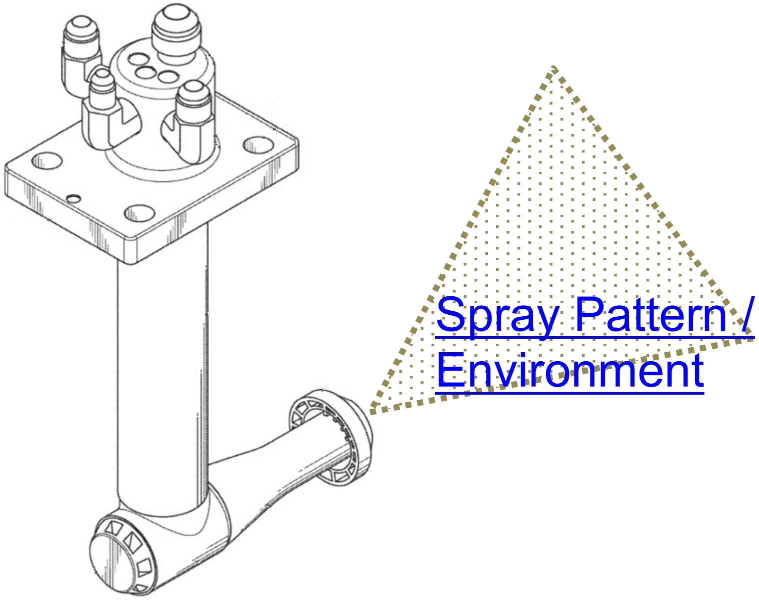
Influencing Part: Fir Tree Turbine Blade



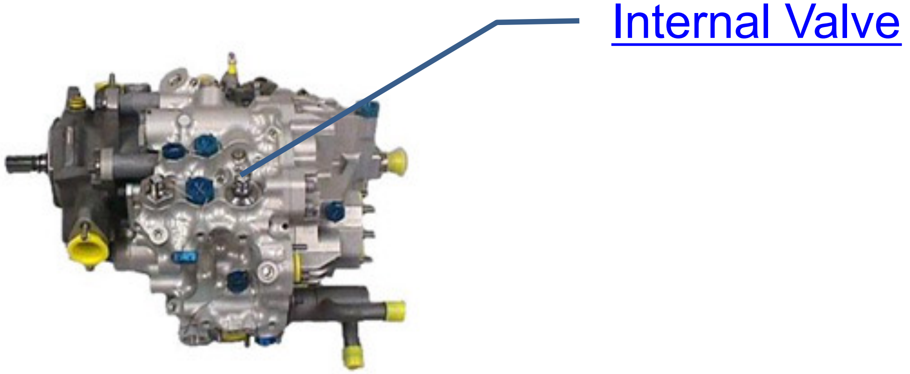
Influencing Part: Bolted Joint / Mating Feature



Influencing Part: Fuel Nozzle

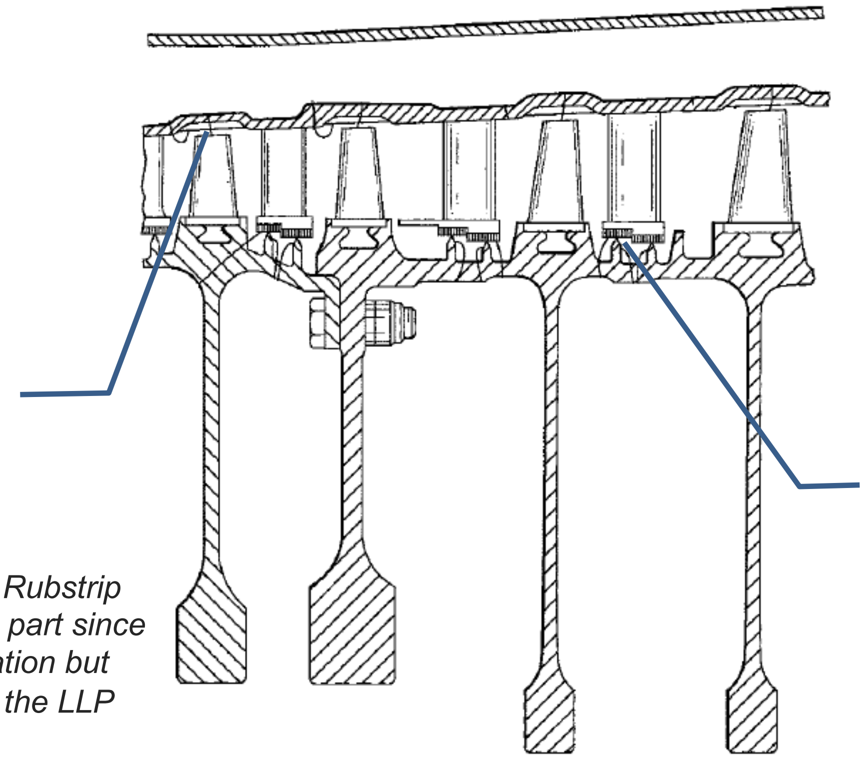


Influencing Part: Controls & Components



Influencing Part: Blade/ Knife Edge Seal Tips



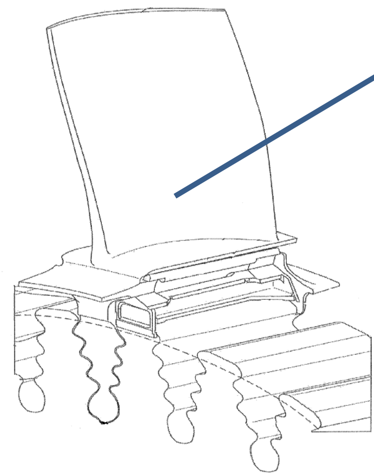



***Note**: Conventional Blade to Rubstrip interaction not an influencing part since it does not affect LCF calculation but could cause a HCF failure of the LLP that should be considered.*

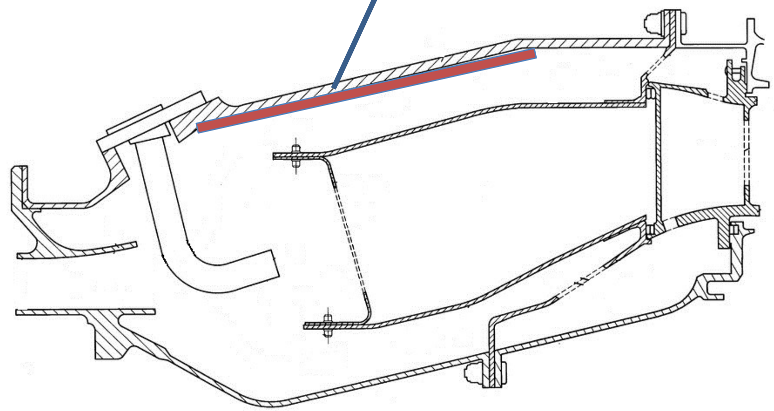
Integral Blade LLP to Rubstrip interaction may be an influencing part and needs to be considered.

Influencing Part: Thermal Barrier Coated Mating Part

Thermal Protection



Thermal Protection



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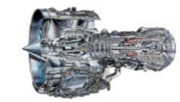
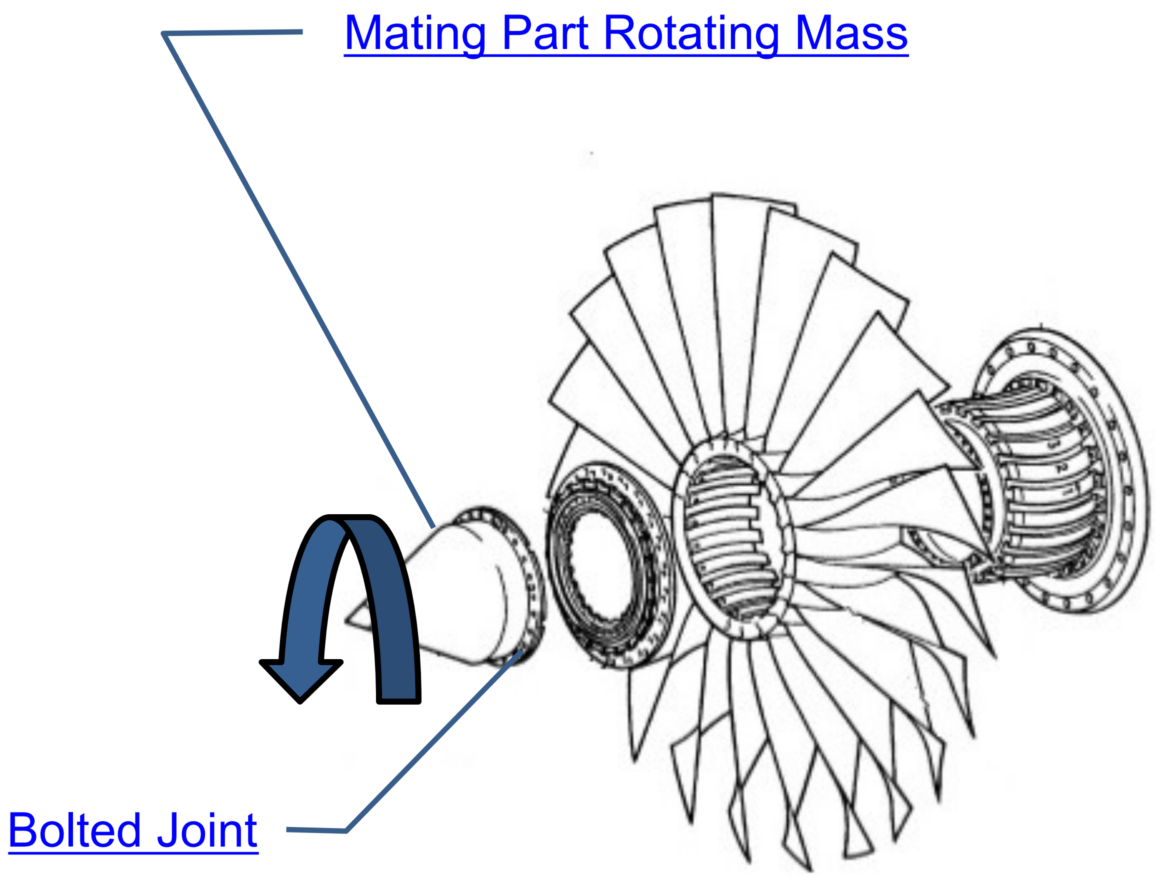
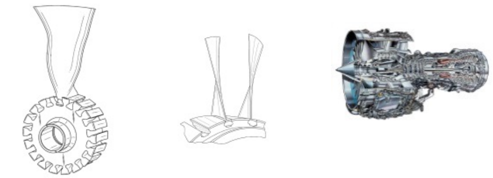
Influencing Part: Rotating Mass of Mating Part

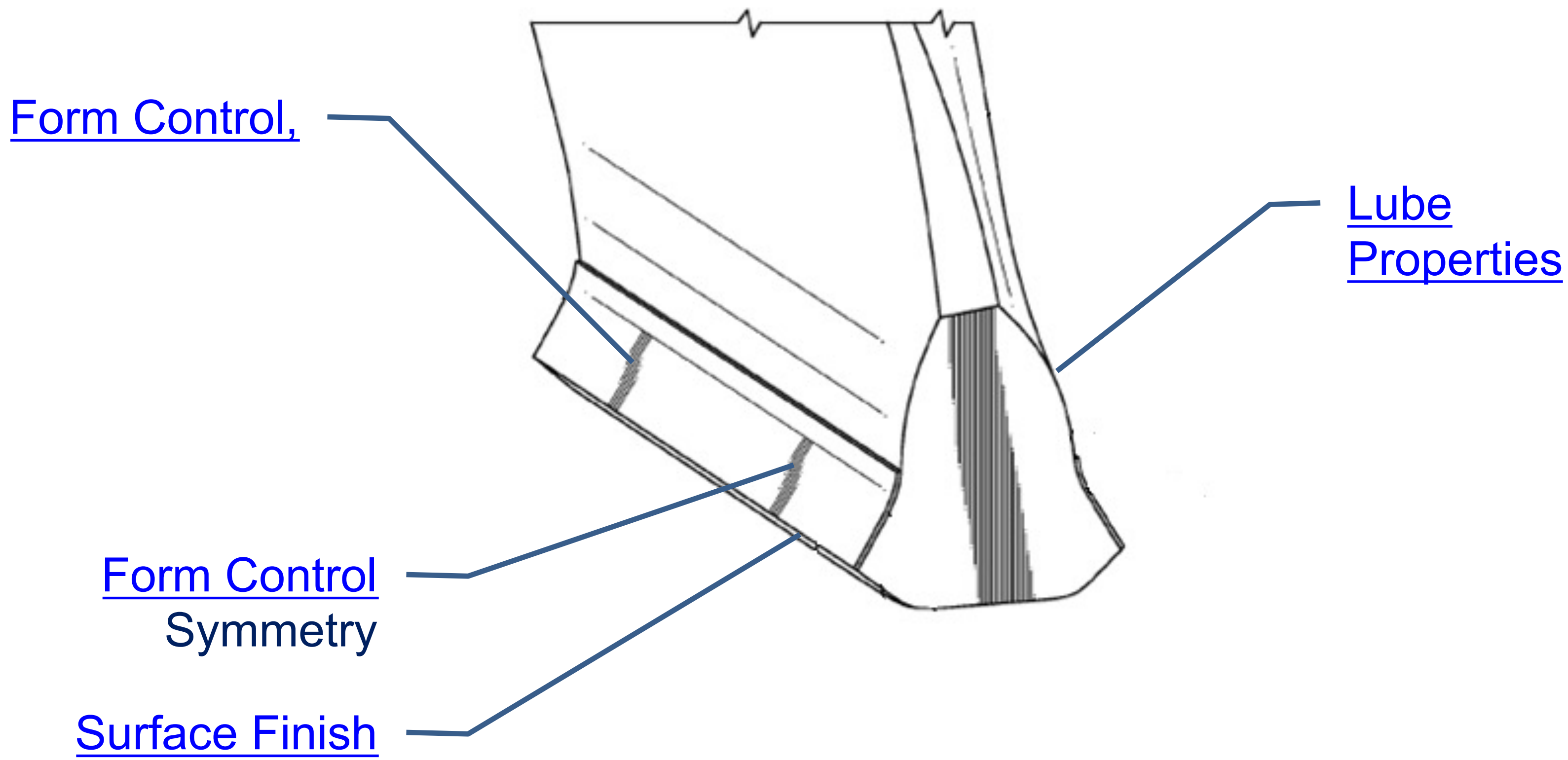




Influencing Feature Section

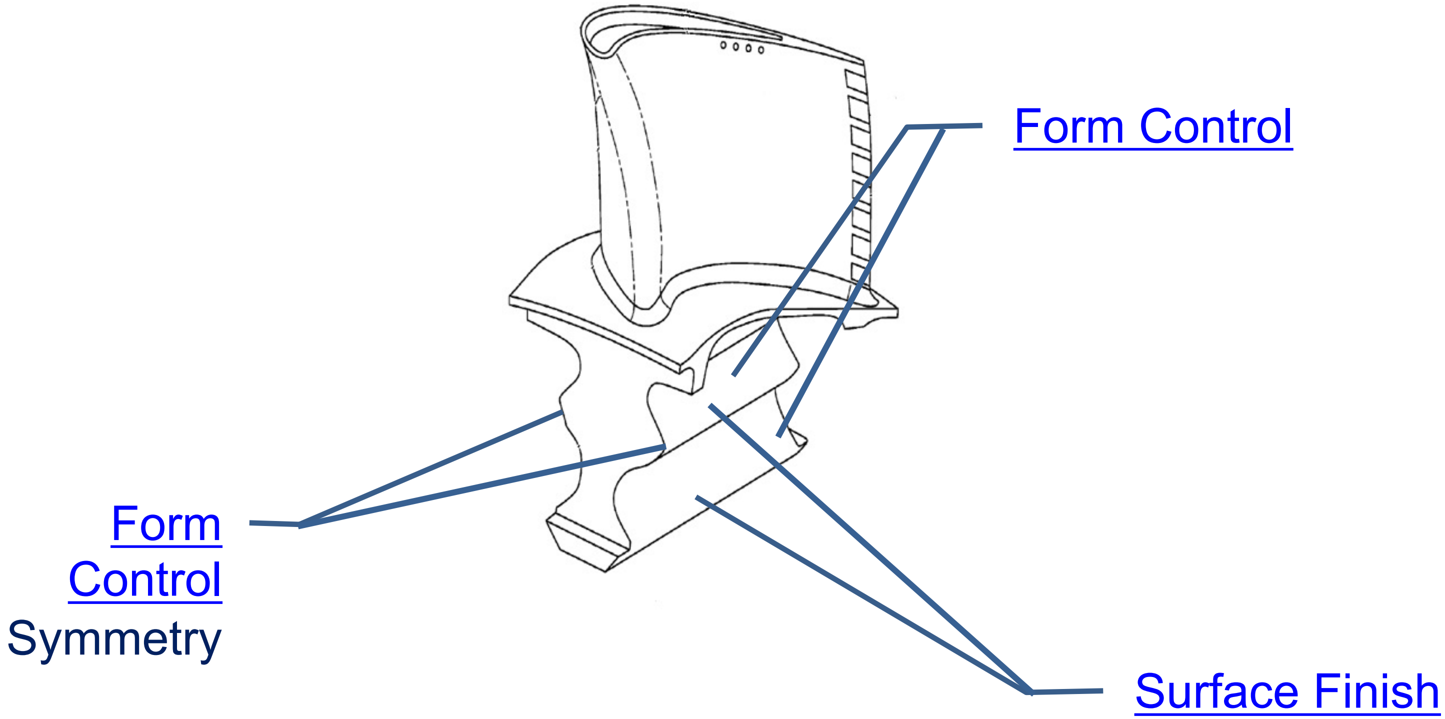
Influencing Feature : Dovetail





Influencing Feature: Fir Tree



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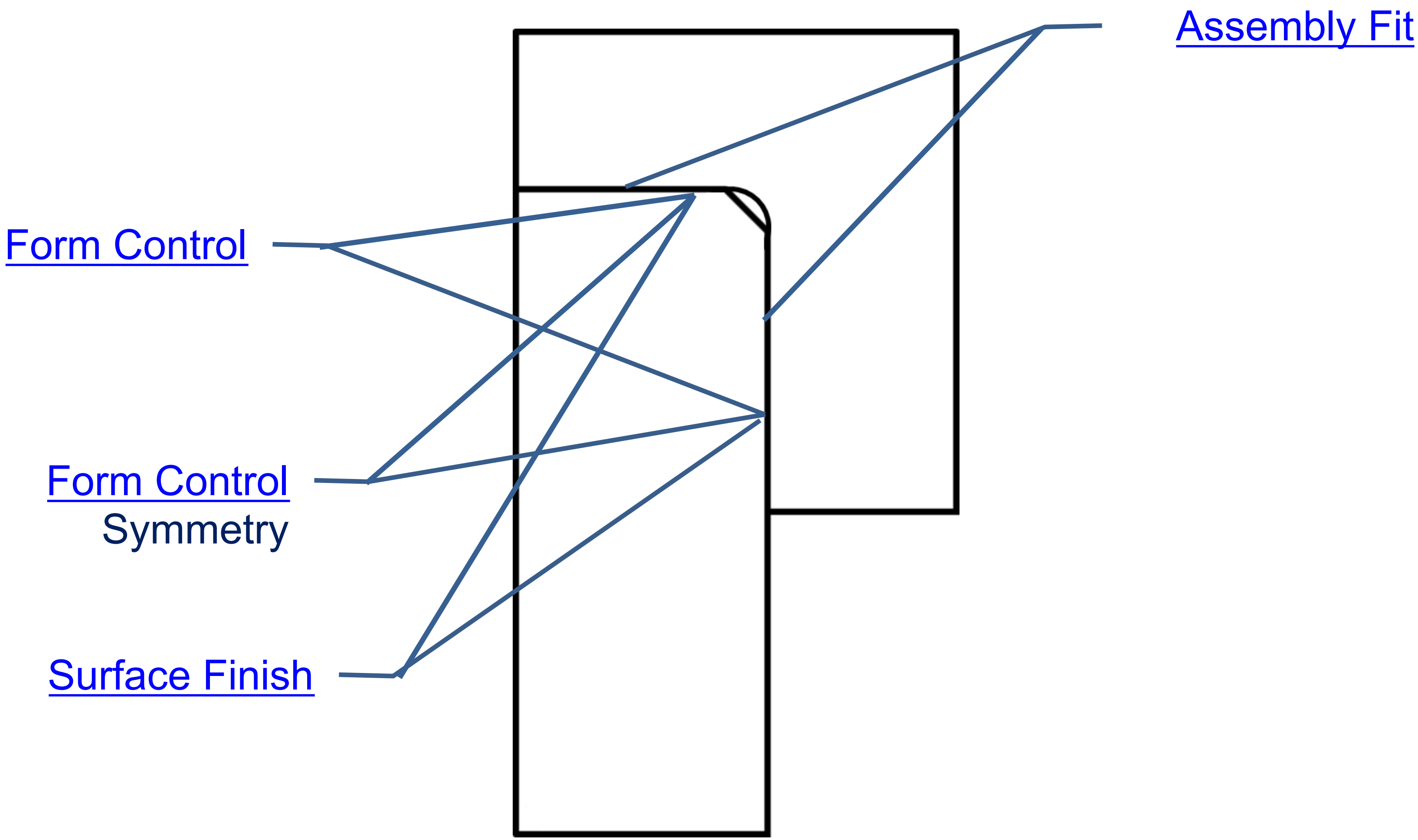
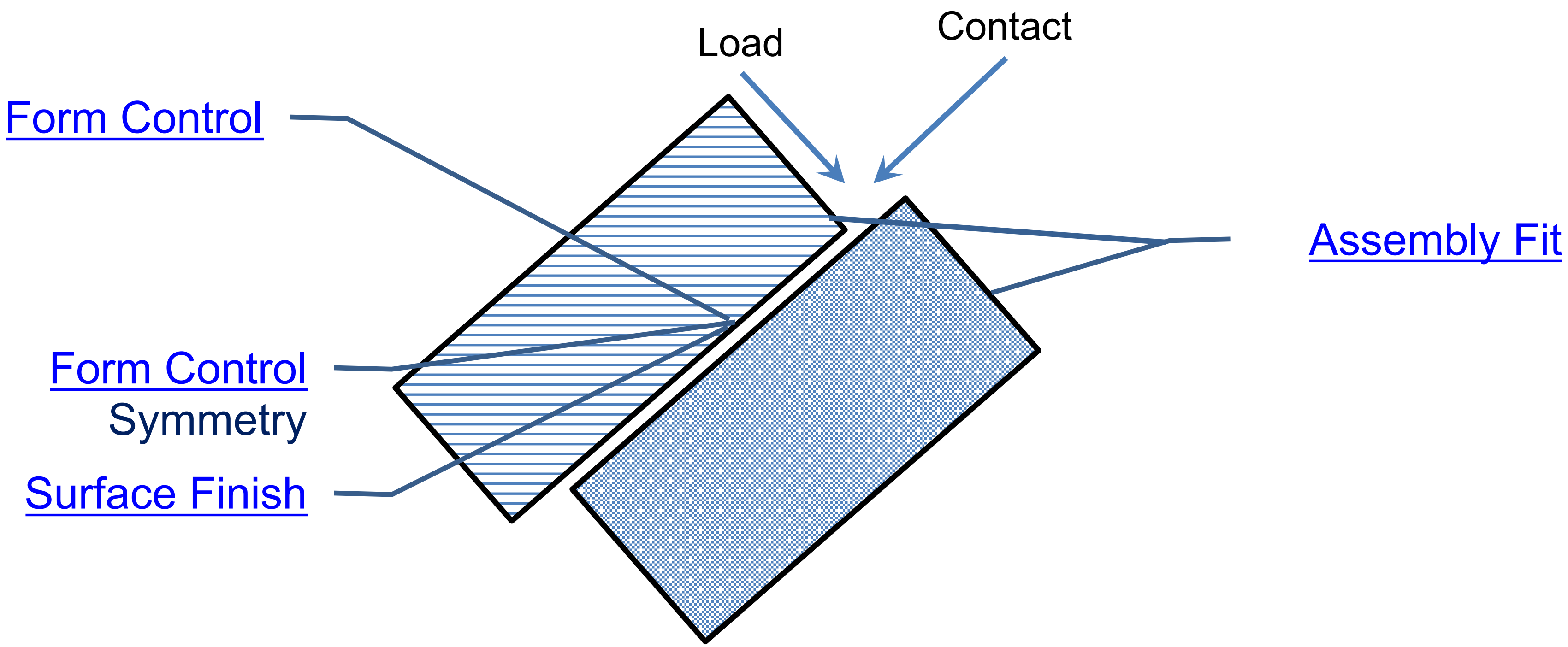
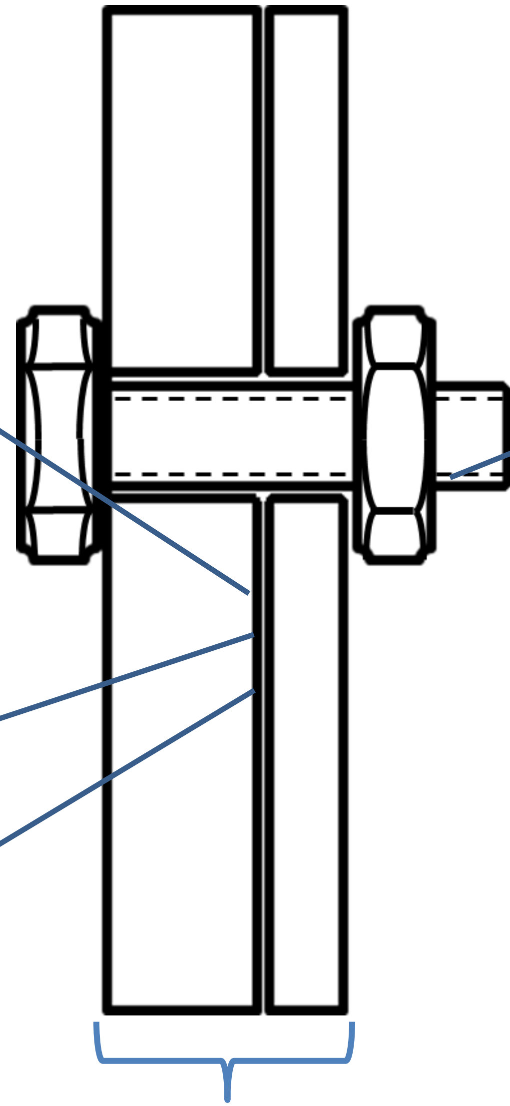
Influencing Feature : Rabbet Fit



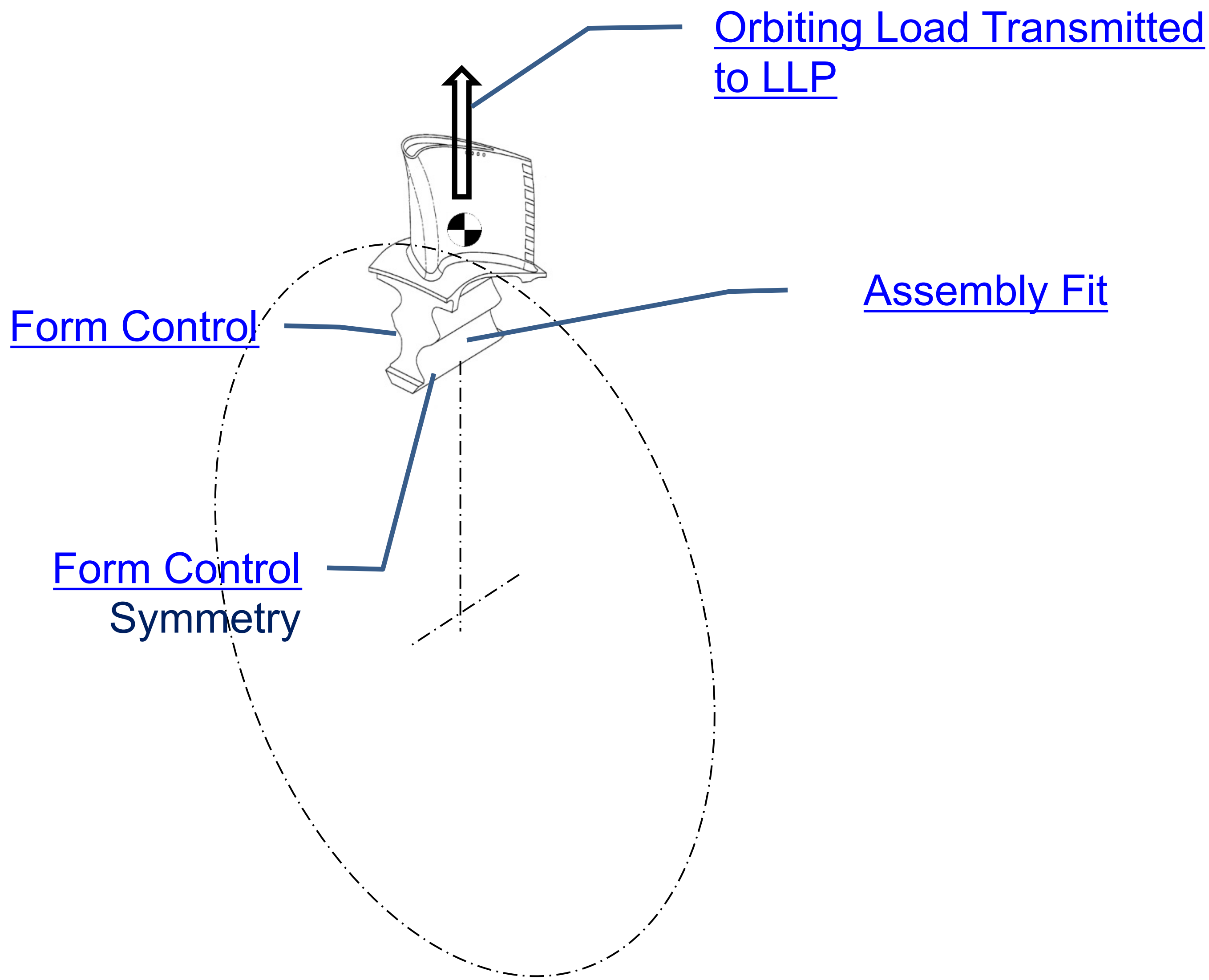
Influencing Feature : Mating Feature non-Rabbet Fit



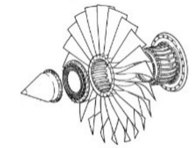
Influencing Feature : Bolted Joint

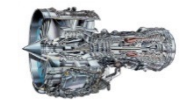


Influencing Feature : Orbiting Mass

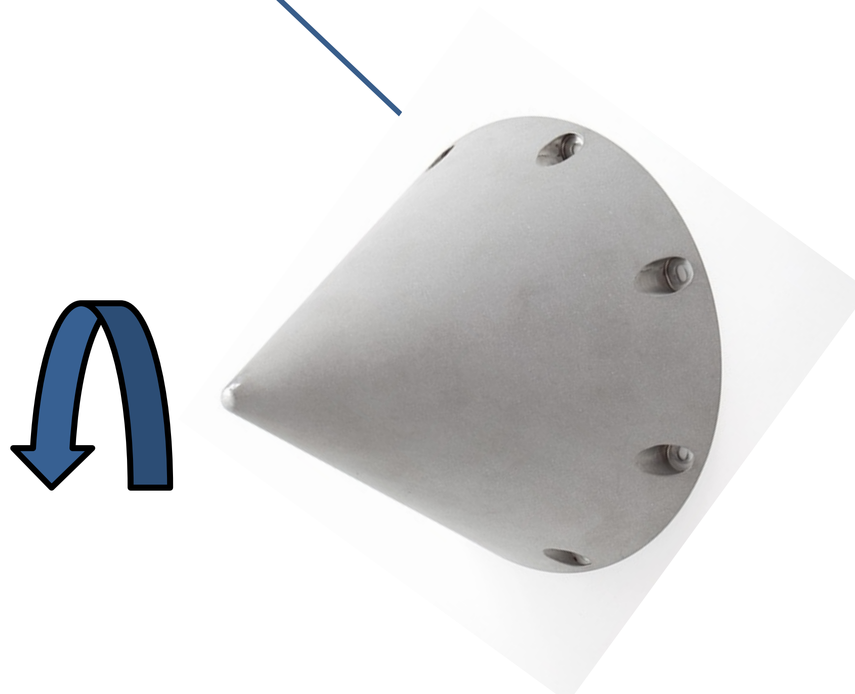


Influencing Feature : Rotating Load Transmission

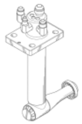


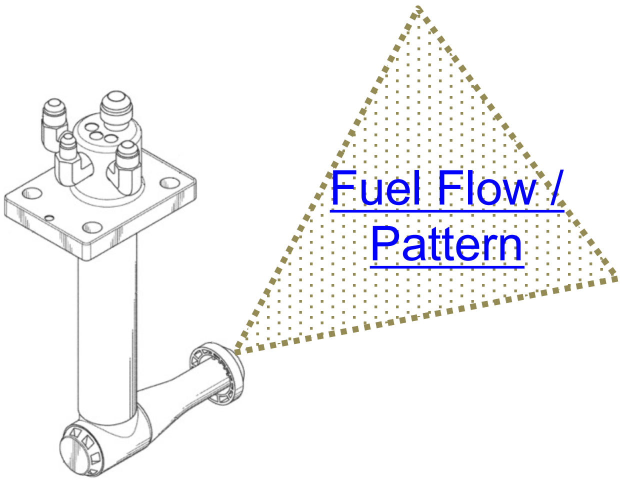


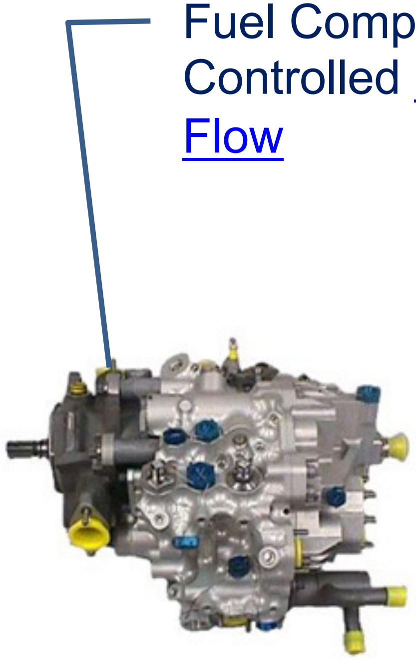
Mating Feature Load transmission



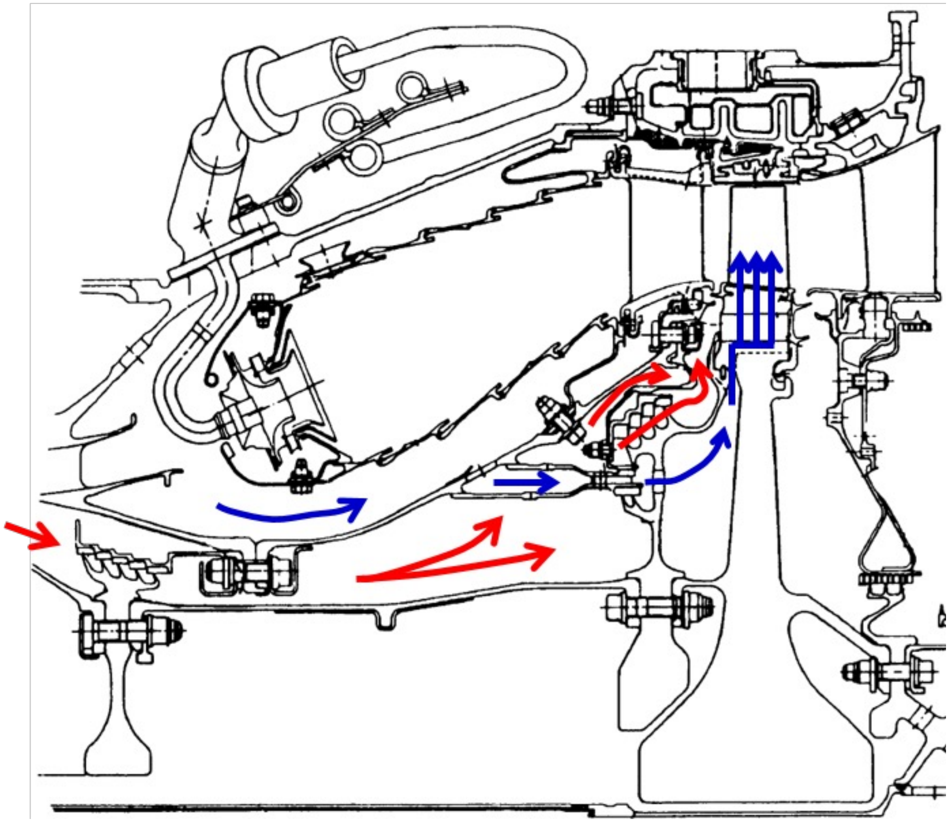
Influencing Feature : Environment







Influencing Feature : Secondary Cooling Flow



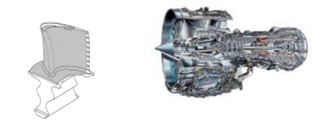
Purge Cooling Flow

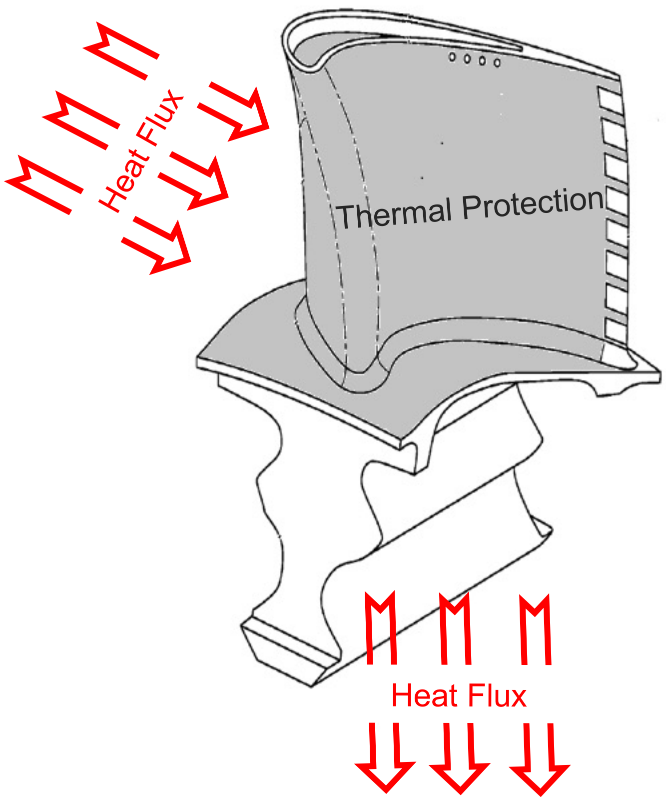
The purge cooling flow maintains pressure balance on rotors and establishes the thermal environment around LLP (i.e. prevents ingestion of hot flowpath gases into rotor cavities)

Cooling Flow to HPT Blade

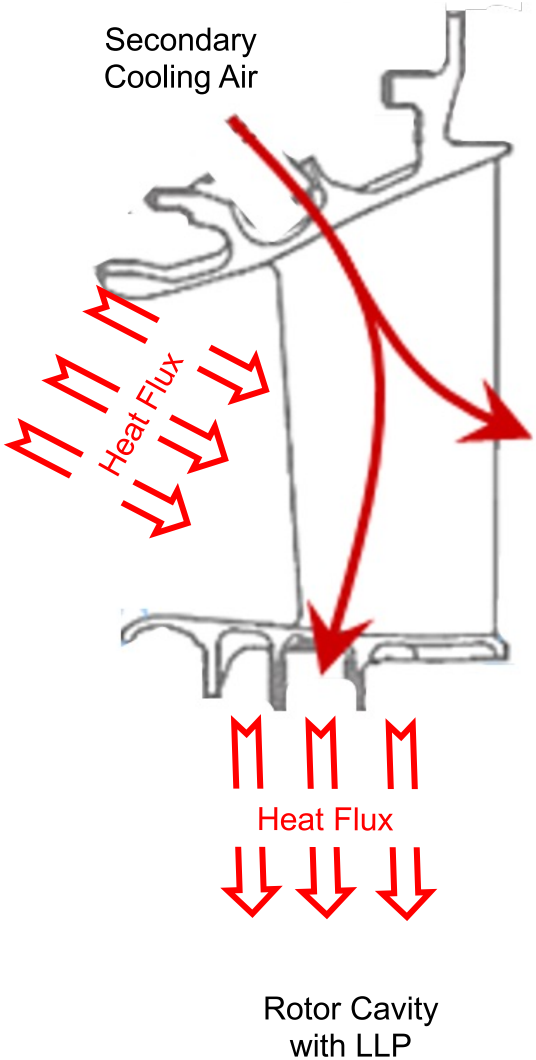
The cooling air sweeps across certain features of the disk prior to entering the blade. Changes in either the temperature of the cooling air or the amount of cooling air delivered to the blades can result in changes to thermal stresses on the disk resulting in significant impact to the life capability.

Influencing Feature : Thermal Properties

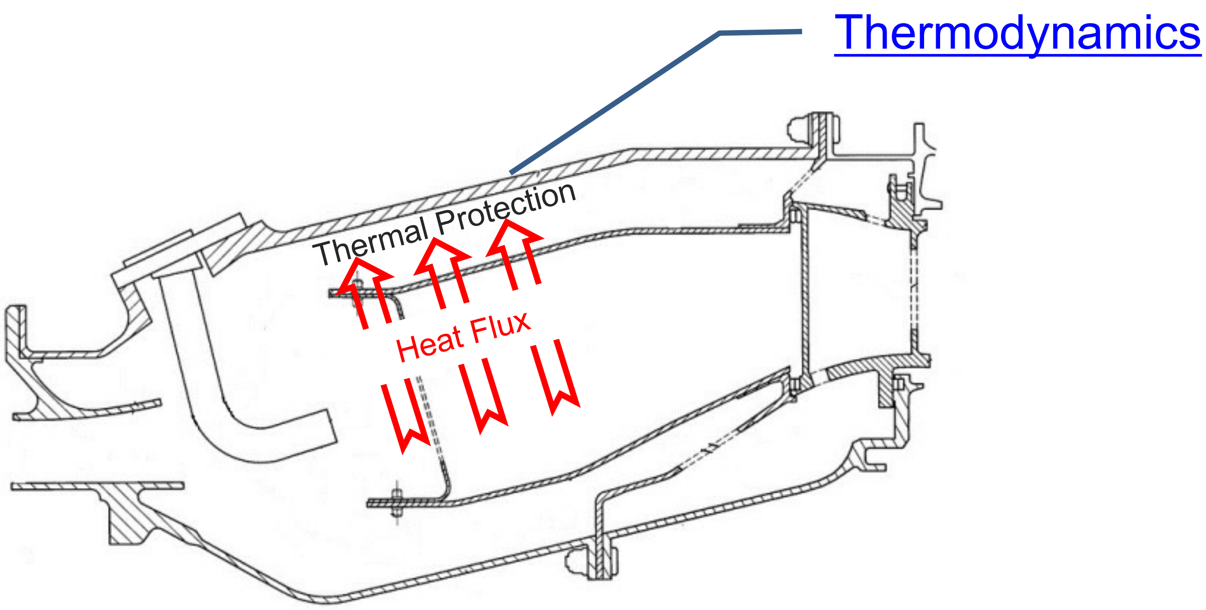




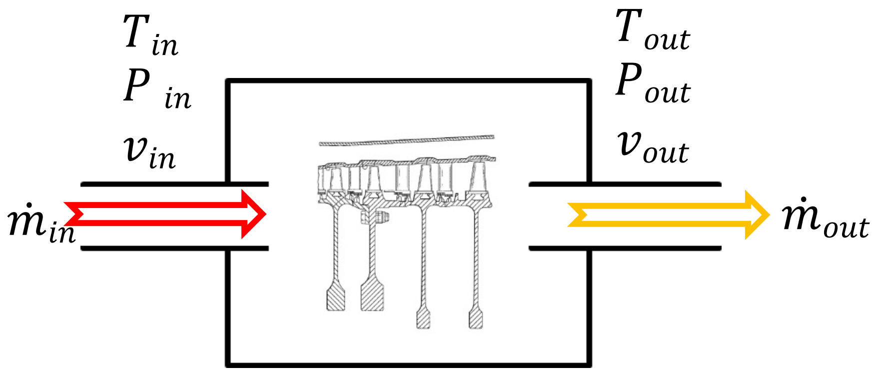
[Thermodynamics]

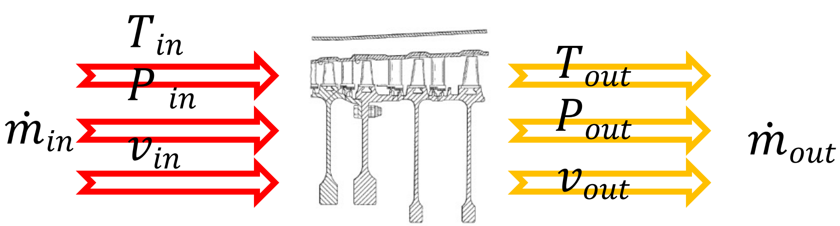


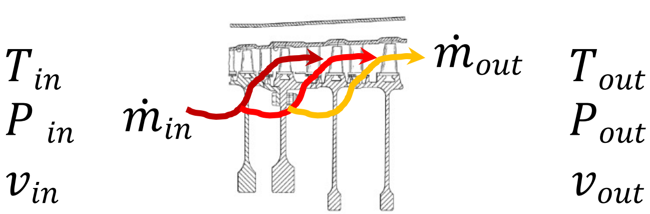
Influencing Feature : Thermal Properties



Influencing Feature : Thermal Environment





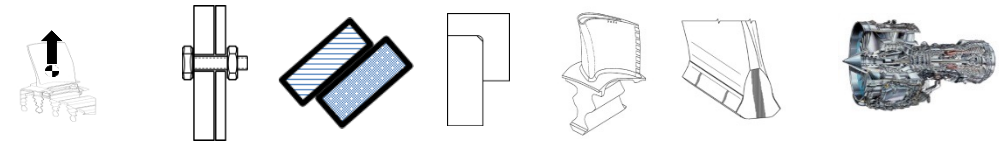


[Thermodynamics]

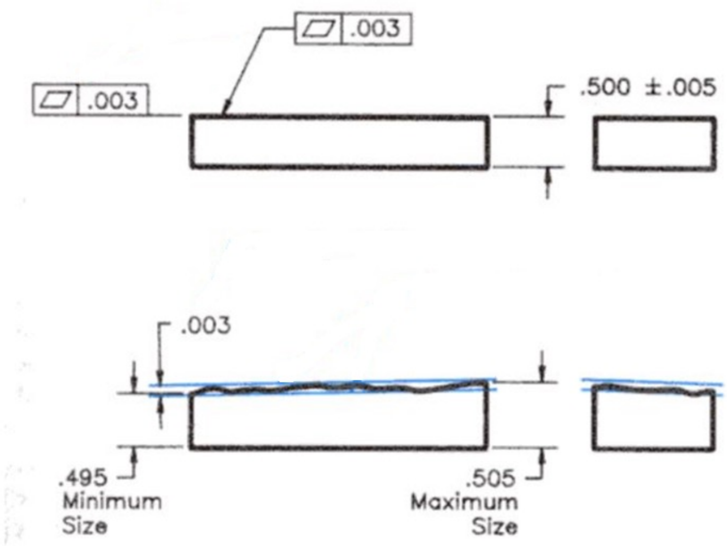
Characteristic Section

Characteristic: Form Control

- multiple types: flatness, angularity, cylinderisity, concentricity, etc. Flatness example given.



Controlling Design Feature:

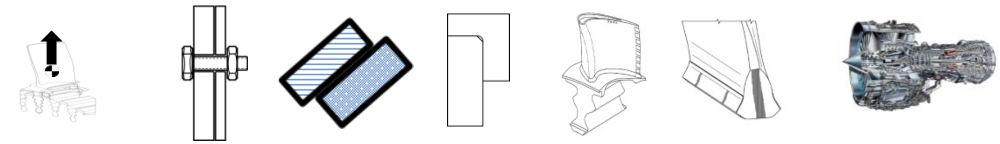


LLP Failure Mechanism:

High Contact Stress (Local, Uneven) leading to Yielding / Burnishing and Wear (Adhesive, Abrasive, etc.)

Design Goals:

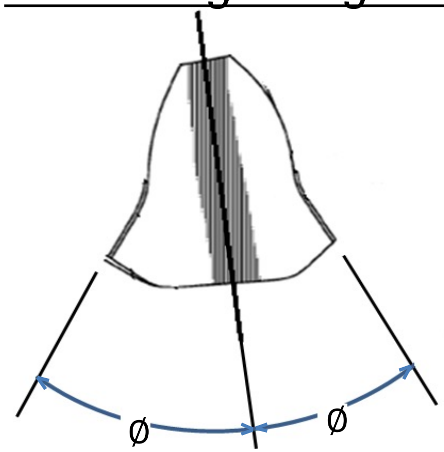
- Proper Contact with LLP
  - No High Spots, Waviness, Off-Angle, etc.
- Proper Transmission of Loads



Characteristic: Form Control

- multiple types: flatness, angularity, cylinderisity, concentricity, etc. Symmetry example given.

Controlling Design Feature:



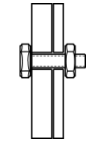
LLP Failure Mechanism:

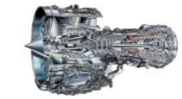
- High Contact Stress (Blade Loads Uneven)
- Yielding
- Wear
- Vibratory Interaction w/Disk
- Assembly Interaction w/Disk

Design Goals:

- Proper Contact with LLP
  - No Asymmetrical (Side-to-Side) Loads
- Proper Transmission of Loads
- Proper Angularity
- Manufacturing Process Controls

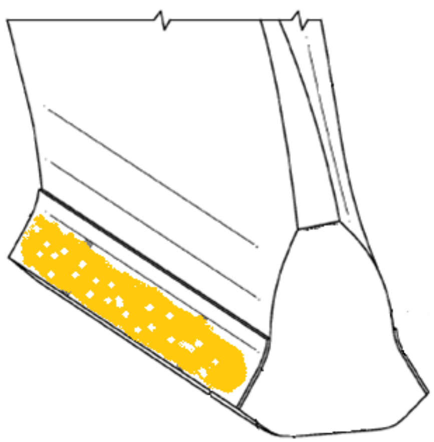
Characteristic: Lube Properties





Controlling Design Feature

- Lube Material Properties
  - Lubricity
  - Material Composition
  - Chemical Compatibility
- Application
  - Thickness
- Instructions for Continued Airworthiness



LLP Failure Mechanism:
- Corrosion
- Stress Distribution Between Parts at Interface
- Wear (Adhesive, Abrasive, etc.)
- Hardness

Design Goals:

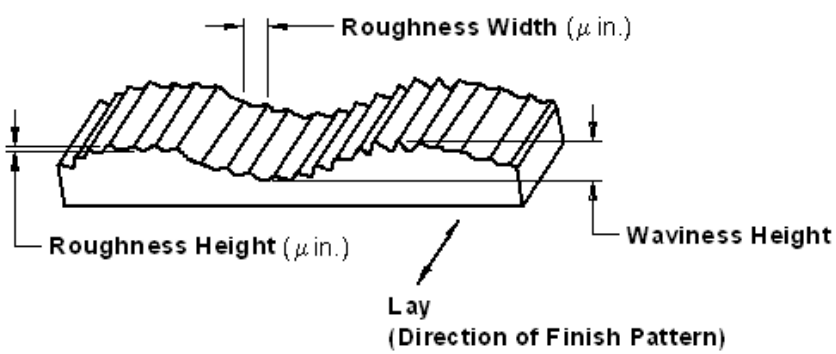
- Material Compatibility
- Equivalent Coefficient of Friction
- Contact / Seating
- Durability until next exposure

Characteristic: Surface Finish

Controlling Design Feature

- Application
- Instructions for Continued Airworthiness
- Surface Finish Callout

LLP Failure Mechanism:
- High Contact Stress from Erosion, Yielding / Burnishing and Wear (Adhesive, Abrasive, etc.)



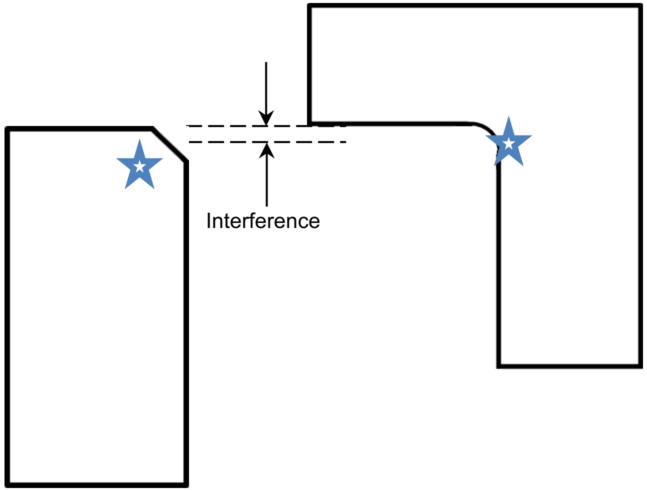
Design Goals:

- Contact / Seating
- Durability until next exposure

Characteristic: Assembly Fit

__Controlling Design Feature__

- Assembly
  - Interface Geometry Boundary Conditions
  - ★ Non-Interference fit between fillets and chamfers
- *Secondary Flow Metering*
- *Load Sharing (redundant load paths)*



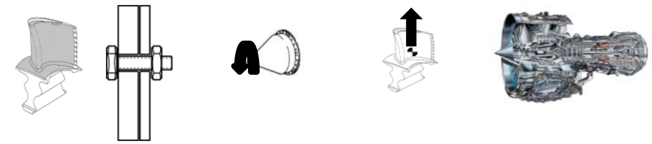
__LLP Failure Mechanism:__

- Incorrect Assembly
- Incorrect stiffness of fit
- Un-intentional interference between Chamfer and Fillet
- At condition looseness
  - All leading to incorrect transmission of loads
- Clocking of mating hardware

__Design Goals:__

- Allow assembly without damage
- Maintain proper fit at condition

Characteristic: Mating Feature Load Transmission



Controlling Design Feature

- Orbiting Mass Weight and CG
- Rotating Mass Weight and CG

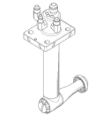
LLP Failure Mechanism:

- Fir Tree lug failure
- Rabbet Fit overload
- Dovetail Overload
- Hoop overload
- Higher stresses due to redistribution of stress
- Opened or closed seals creating improper downstream cooling

Design Goals:

- Control of Load Transmission to LLP
- Proper load distribution at contact points/planes/holes

Characteristic: Fuel Flow / Pattern


Controlling Design Feature

- Fuel Spray Pattern
- Fuel Schedule
- System level thermodynamics
- Part level temperature gradients
- Fuel Flow Distribution

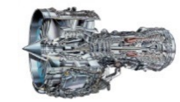
LLP Failure Mechanism:

- Thermal Overload
- Incorrect Burner pattern factor (circumferential temperature variation)
- Incorrect flowpath profile (radial temperature variation)
- Incorrect Secondary Cooling

Design Goals:

- Maintain fuel flow & pressure distributions / patterns
- Correct patter factor
- Correct flowpath profile
- Correct secondary cooling

Characteristic: Rotating / Static Interaction Blade Tip

Controlling Design Feature

- Correct at condition Tip Clearances
- Material Properties at Blade Tip
- Material Properties at Rubstrip

LLP Failure Mechanism:

- HCF Coupling between blade and disk

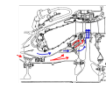
Note*: Conventional Blade to Rubstrip interaction not an influencing part since it does not affect LCF calculation but could cause a HCF failure of the LLP that should be considered.*

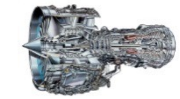
Integral Blade LLP to Rubstrip interaction may be an influencing part and needs to be considered.

Design Goals:

- Correct tip clearances
- Formalized Break in Procedures
- Compatible Blade Tip/Outer Air
- Seal rub system

Characteristic: Rotating / Static Interaction Knife Edge





Controlling Design Feature

- Correct at condition Knife Edge Clearances / Rub Depth
- Material Properties at Knife EdgeTip
- Material Properties at Honeycomb
- Honeycomb Cell Orientation / Size
- Acoustic resonance avoidance

LLP Failure Mechanism:

- Crack initiation of Knife Edge resulting from rotor/stator rub
- Propagation of Knife Edge Crack
- HCF from rotor/stator rub
- Acoustic resonance induced HCF

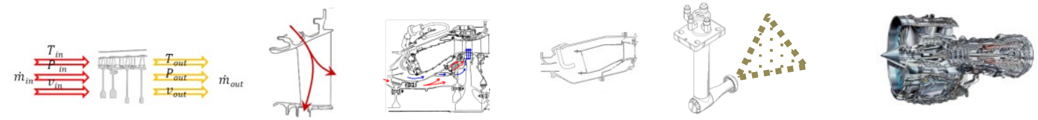
Note: *Conventional Blade to Rubstrip interaction not an influencing part since it does not affect LCF calculation but could cause a HCF failure of the LLP that should be considered.*

Integral Blade LLP to Rubstrip interaction may be an influencing part and needs to be considered.

Design Goals:

- Correct knife edge clearances (Radial and Axial)
- Formalized Break in Procedures
- Compatible knife edge / honeycomb seal rub system

Characteristic: Thermodynamics



Controlling Design Feature

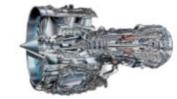
- System level thermodynamics
- Part Thermal Properties
- Cooling Flow Distribution
- Cavity Temperatures
- Thermal Mechanical Fatigue
- Radiant Heat Emissivity

LLP Failure Mechanism:

- Fir Tree lug failure
- Disk Burst
- Dovetail Overload
- Hoop overload
- Ruptured Pressure Vessel
- Thermal Overload

Design Goals:

- Maintain Thermal Conductivity Characteristics
- Maintain temperature distributions / gradients
- Maintain pressure distributions / gradients
- Maintain secondary cooling mass flow distributions / gradients



Definitions Section

Angularity:

Angularity describes the specific orientation of one feature to another at a referenced angle. Typically, angularity relates the orientation of one surface plane relative to a datum plane in a 3-Dimensional tolerance zone.

Application (sub of MFG Process Controls):

The defined series of important steps and methods for applying a coating to the surface of a part. Application steps and methods can include routines for cleaning, preparing the surface for treatment, application of a bond coat, application of the final coating, and any methods of curing.

@ Assembly:

Refers to the as assembled state in the absence of operating temperatures, pressures or other force effects.

Boundary Conditions (Loads):

The complete set of externally applied constraints, forces and conditions which are applied to a part (at some point in time) that allows an accurate determination of the state of stress/temperature in or behavior of that part.

Chamfer: A chamfer is a sloped or angled corner or edge.

Chemical Compatibility:

The ability of parts to function in contact with other components without creating deleterious effects due to chemical instability between materials or coatings within the assembly. Some examples of deleterious effects are stress corrosion cracking, liquid metal embrittlement or spalling .

@ Condition:
Refers to the as operated state including operating temperatures, pressures or other force effects that occur throughout the operating cycle or envelope.

Fillet: A fillet is a rounded corner or edge.

Fuel Flow Rate:
Fuel volume/unit time (e.g. liters/sec) or Fuel mass / unit time (e.g. pounds/hr).

Material Properties:

The quantitative attributes of a material that can be optimized within the design of a part to ensure required strength, reliability or other performance requirement. Material properties can be influenced not only by chemical composition of the material, but also manufacturing process steps such as forging, forming, working and heat treating.

MFG Process Controls:

The mechanisms (both active and passive) implemented within the manufacturing steps to ensure that parts are produced in a consistent and repeatable way.

Orbiting Mass:

Orbiting Mass is a term used to describe the load imparted to a rotating component by an object attached to the rotating component. Increasing the mass of the attached object or increasing the radius of the center of gravity of the orbiting part increases the load on the rotating component. (e.g. during rotation of a turbine disk the orbiting mass of the turbine blades imparts a load to the disk).

Radiant Heat Emissivity:
The emissivity of the surface of a material is a measurement of its effectiveness in emitting energy in the form of thermal radiation.

Rotating Mass:
Rotating mass is a term used to describe the relationship of the mass of a component to the stress imparted to that component during rotation. The greater the mass of the part or the greater the rotational velocity of the part, the greater the rotating mass.

Secondary Cooling Flow:
Secondary Cooling Flow refers to flow systems that are NOT part of the primary flow path but whose function is required for overall engine operation. Secondary cooling flow systems form some of the most complex engine system interactions. Examples include purge air to prevent hot gas path ingestion in cavities where LLP operate, disk bore heating, and maintaining pressure balance on rotors.

Stiffness:
A measure of resistance of a part or material to deflection or deformation as a result of an applied force. The stiffness of a part will also contribute significantly to its vibratory behavior in terms of forced response or aerodynamic flutter.

Spray Pattern:
The term spray pattern is used to describe the dispersion of liquid over an area to increase the surface area of the liquid. (Spray pattern has a critical influence on combustion efficiency.)

Thermal Conductivity:
The rate at which heat passes through a given material. Thermal Conductivity is expressed as the amount of heat that flows per unit time through a unit area with a temperature gradient of one degree per unit distance.

Thermal Properties:
The specific quantitative attributes of a material or part that determine how it responds and interacts within an environment governed by thermal growth and heat transfer via conduction, convection and radiation.

Contributions to this tool made by:

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