



JANUARY 07, 2023

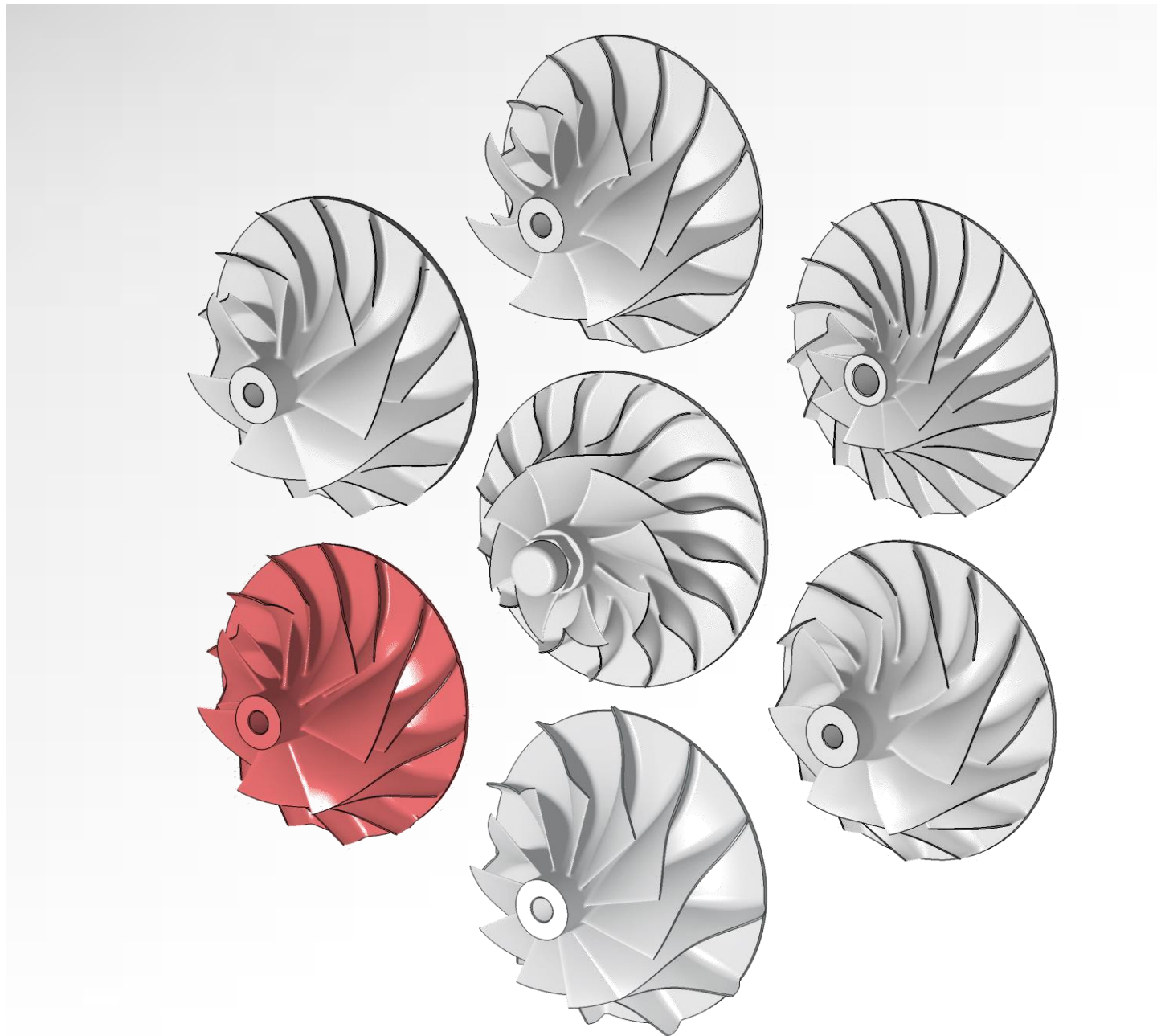
# 高性能柴油机增压器可靠性研究

何宁

**Garrett**  
ADVANCING MOTION

# 1

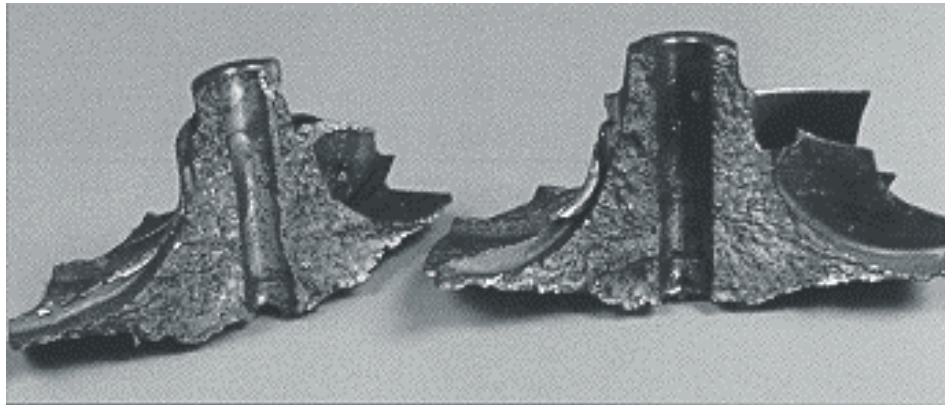
## 增压器压气机叶轮失效模式



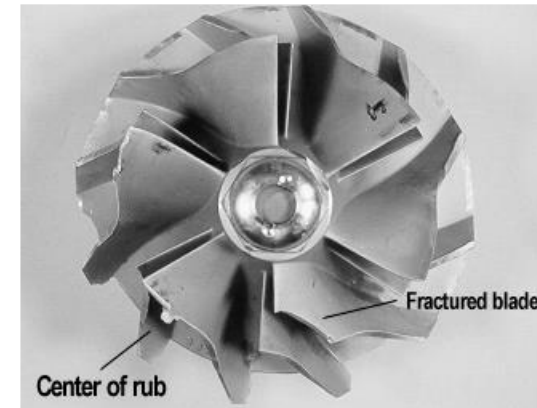
# Fatigue Definitions

Two major modes of fatigue occur in turbocharger wheels:

- Low (Slow) Cycle Fatigue (LCF) caused by turbo speed change
- High (Fast) Cycle Fatigue (HCF) caused by excitation of blade natural frequencies



Low cycle fatigue

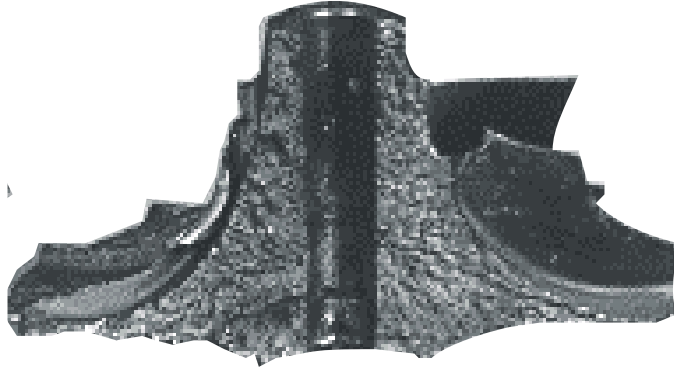


High cycle fatigue

**HCF should avoid during compressor development**



# Typical LCF Failure Modes



**Hub Mode**



**Chordal/Backdisc Mode**

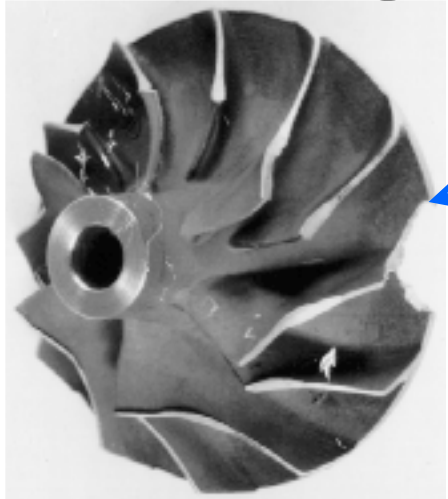


**Blade/Backdisc Bending Mode**

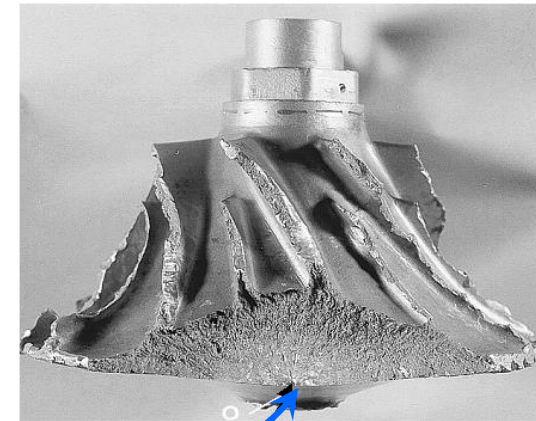
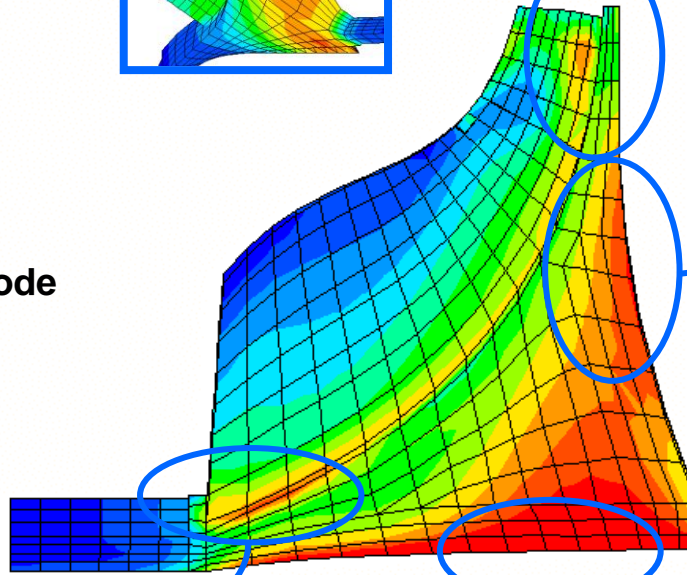
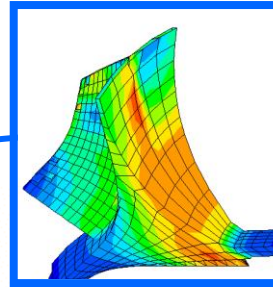


**Blade Mode**

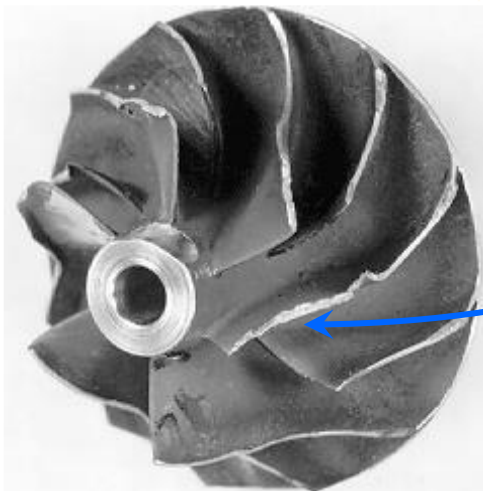
# Compressor Wheel High Stress Areas



**Blade/Backdisc Bending Mode**



**Backdisc Failure**



**Blade Mode**

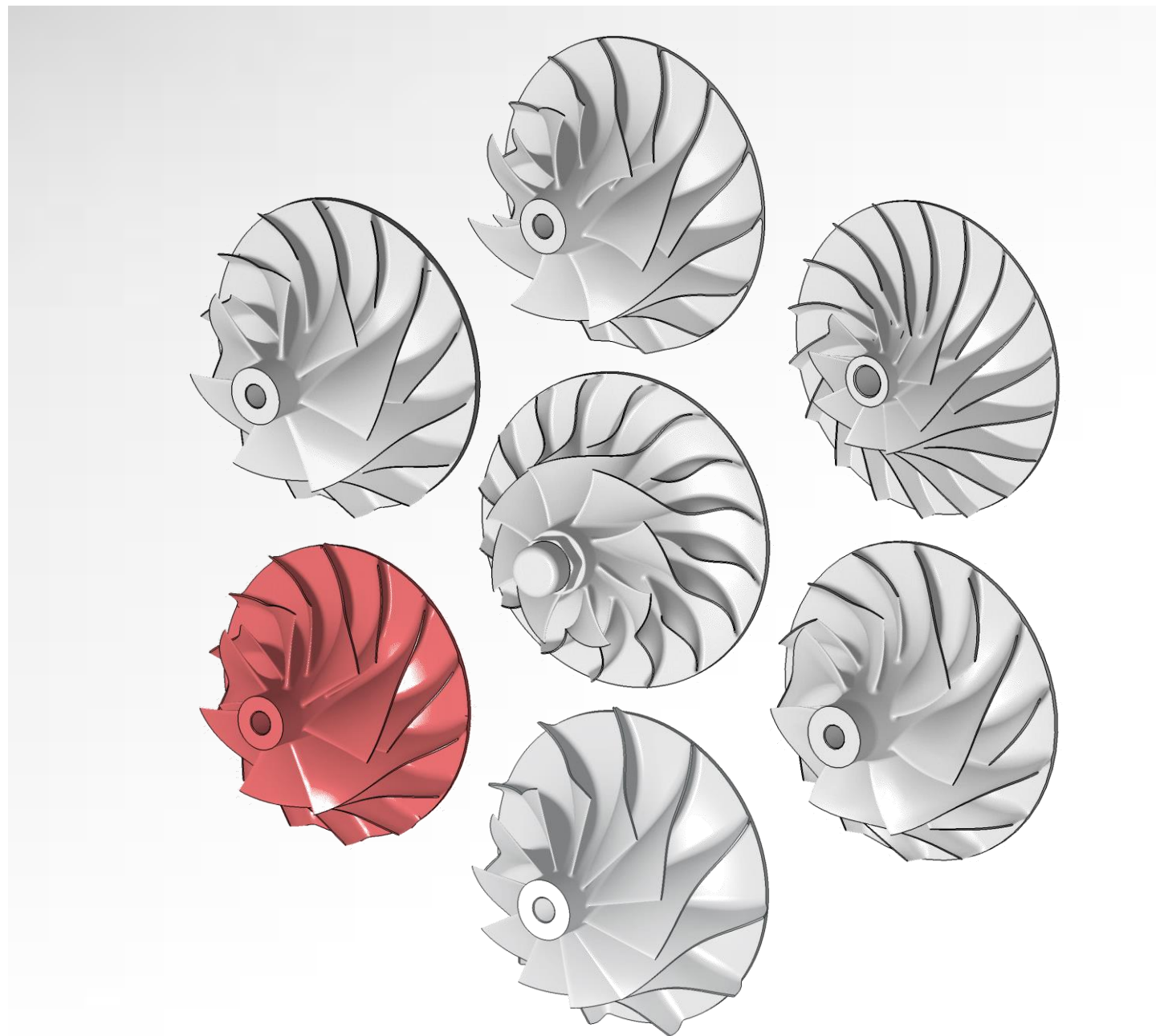
**Failures initiate from high stress areas**



**Hub Failure**

# 2

## 增压器压气机叶轮表面处理





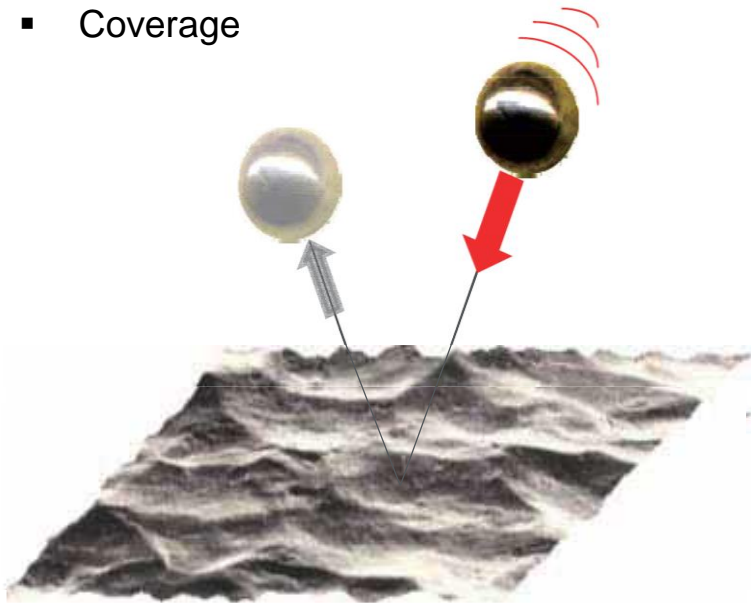
# Shot Peening | Process – What Is It?

## WHAT ?

Impact a surface with shot with force sufficient to create plastic deformation.

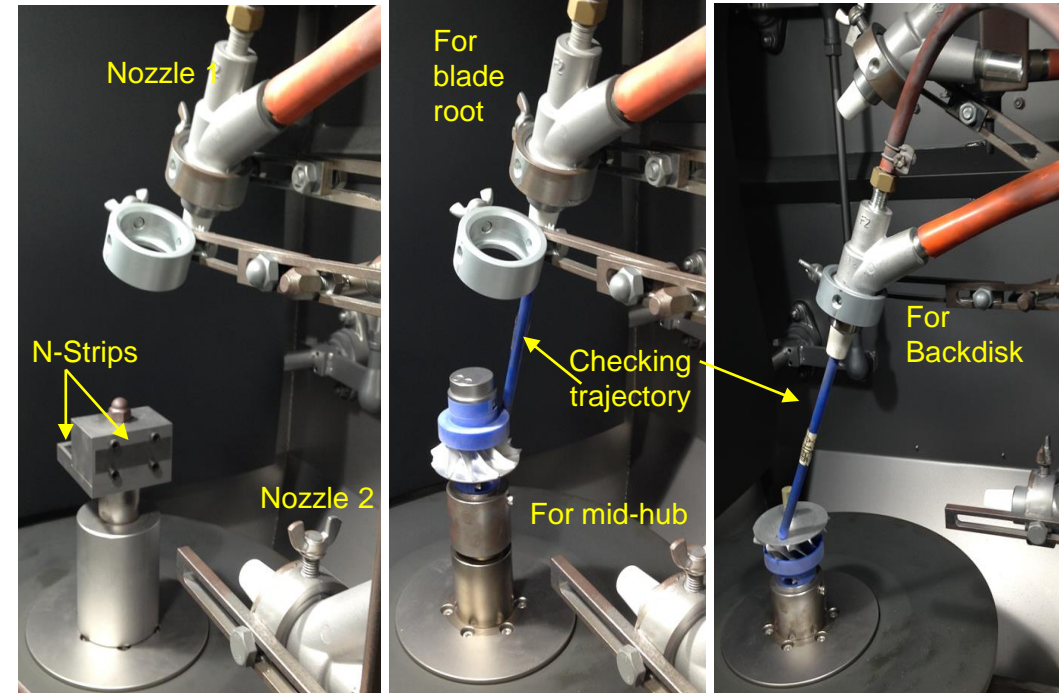
Parameters:

- Media (glass, steel...)
- Shot Velocity
- Impact angle
- Shot diameter
- Coverage



## HOW ?

Masking inducer blade tips

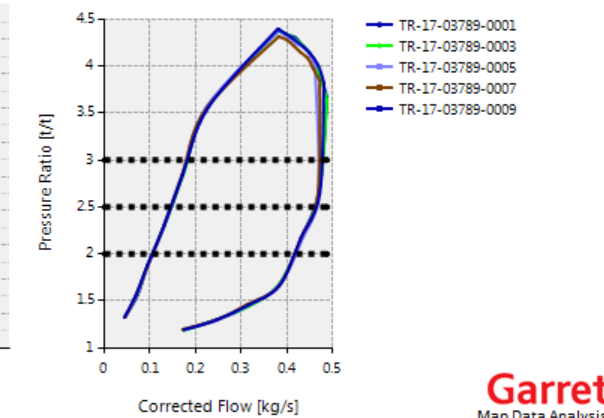
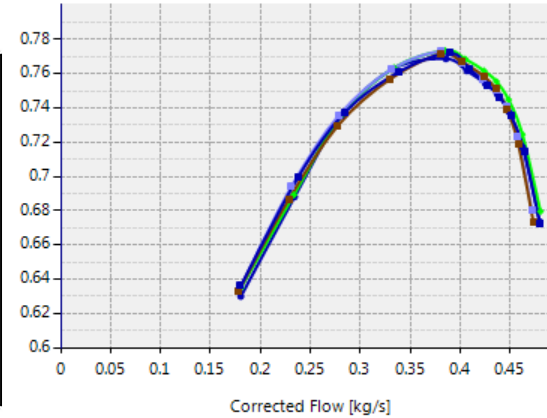
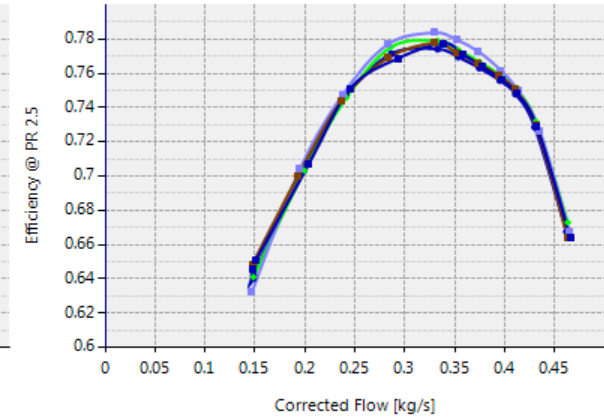
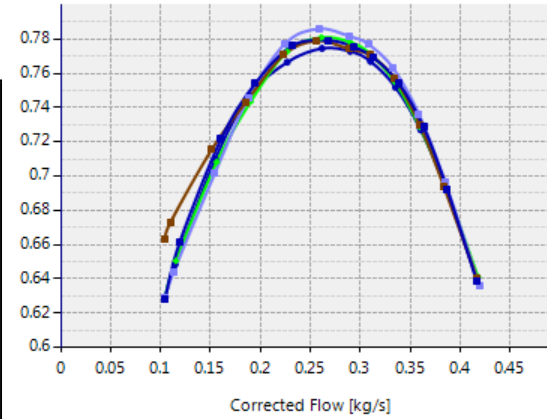
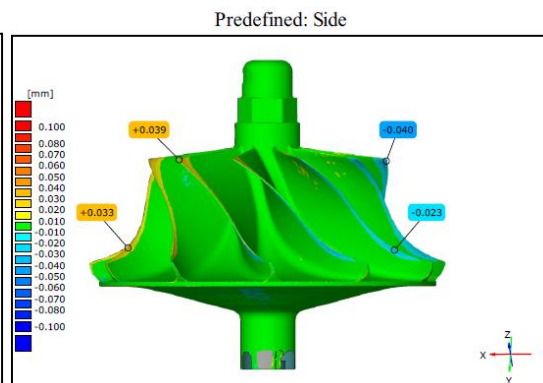
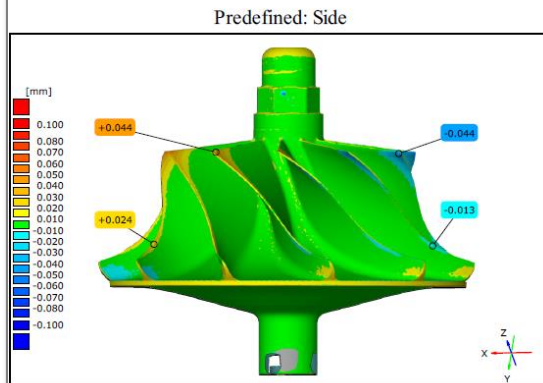
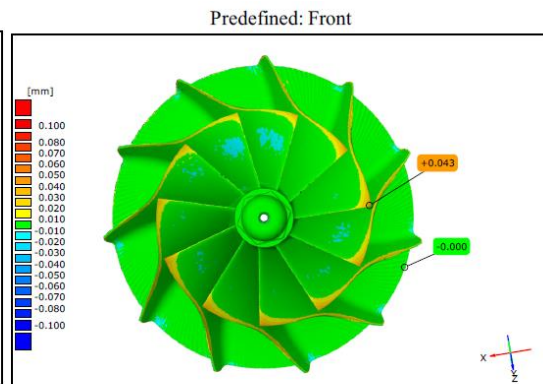
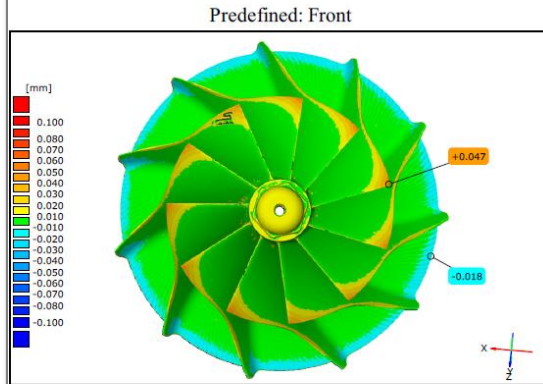


# Shot Peening | Qualification – Process Variation

GOM before/After SP with masking

0.2mm.N With masking

0.3mm.N With masking

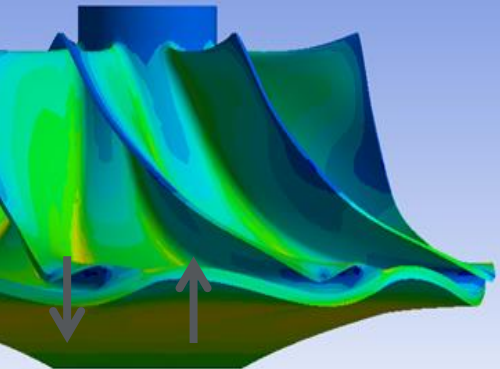


No significant impact on performance

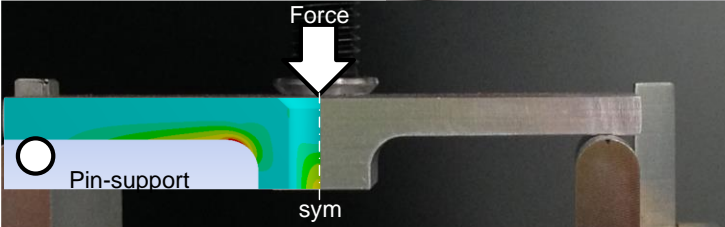
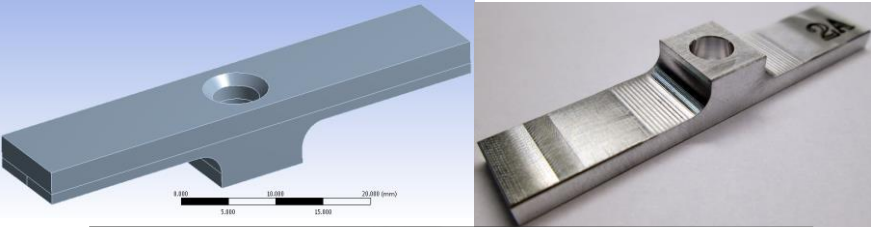


## Coupon Geometry and Setup

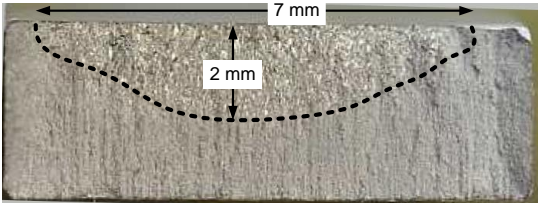
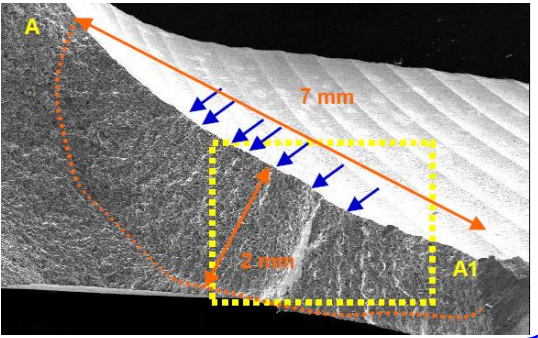
Wheel Failure Mode (Bending)



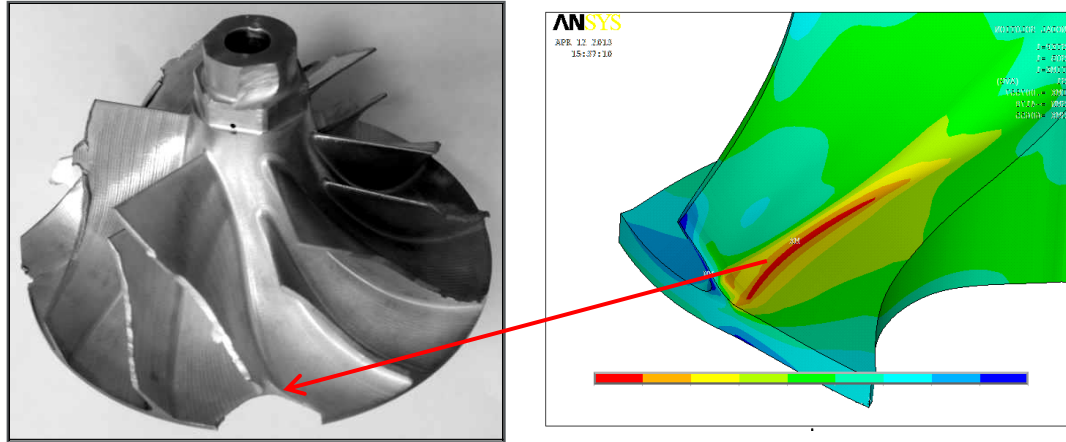
Bending Coupon



## Coupon Details

- 1) Coupon details
  - 1) Bend specimen
  - 2) Prepared with same 5-axis machine for C288A (cusps, tools, machining parameters)
  - 3) Same material source as C288A wheel family
  - 4) Similar failure scenario
    - Initiation site: 0.010~0.020 mm dia.
    - Final crack size: ~7 mm width and ~2mm depth
- 2) Fractography Coupon:  
C288A(82):

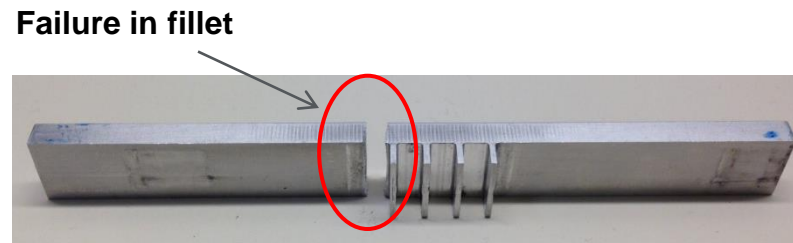
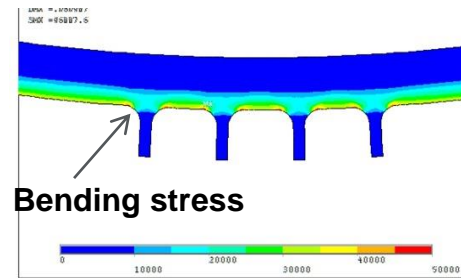
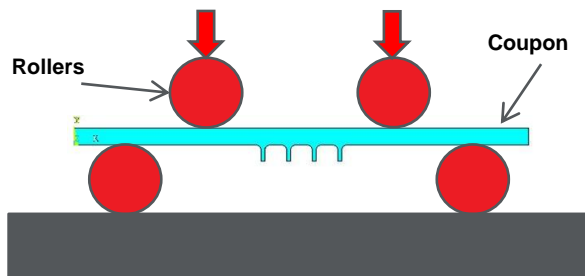
# Coupon Testing: 4 Point Bending



**Coupon based test to reproduce blade fillet failure mode.**

- Coupon designed to inherit key geometry features and relevant stress state.

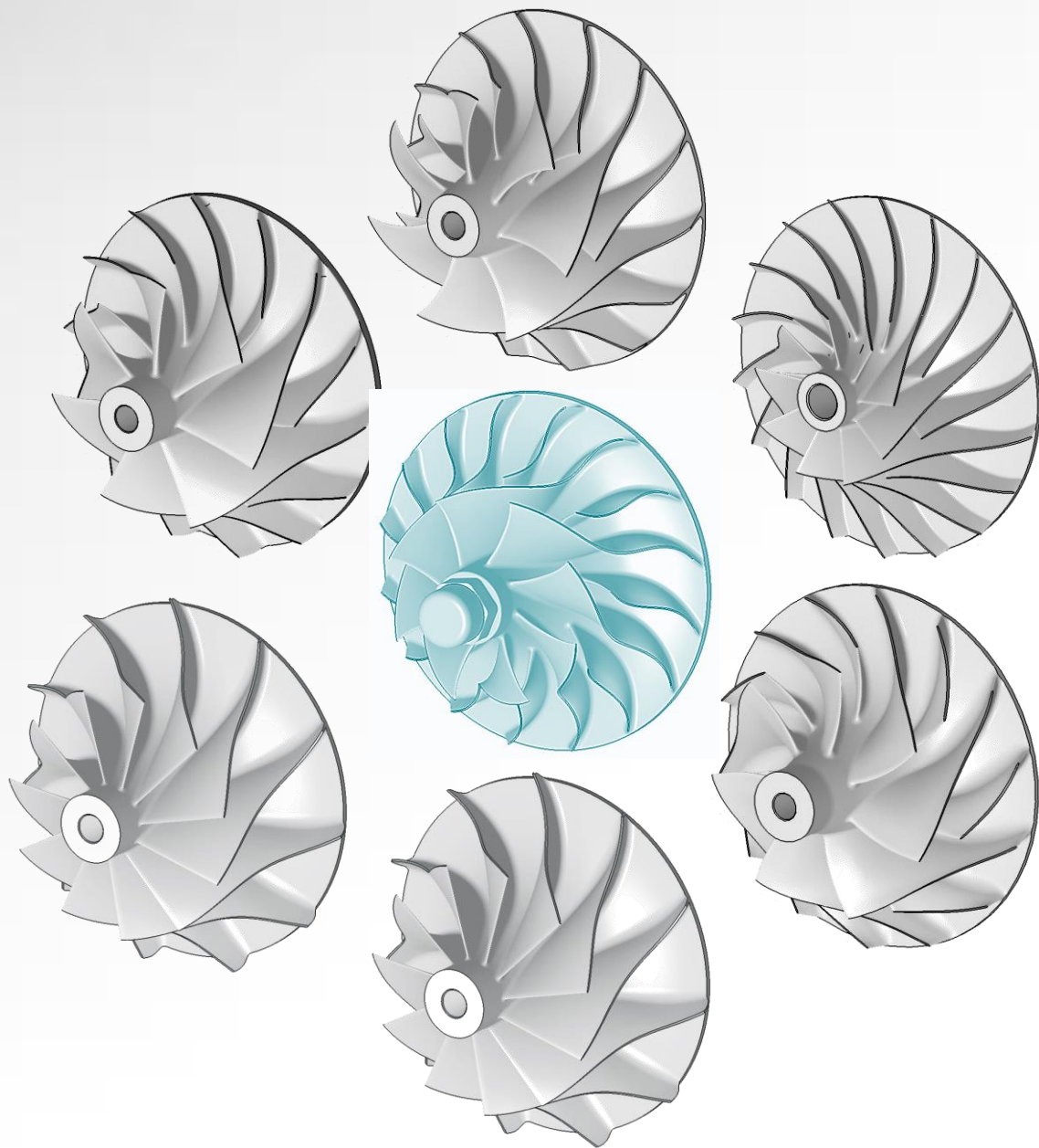
**Tests conducted on UTM machine at representative stress state and stress ratio.**



**Feasibility Proven | Tests underway**

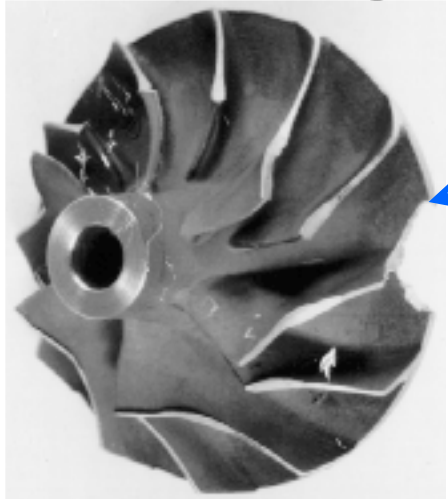
# 3

## 增压器压气机叶轮盲孔设计

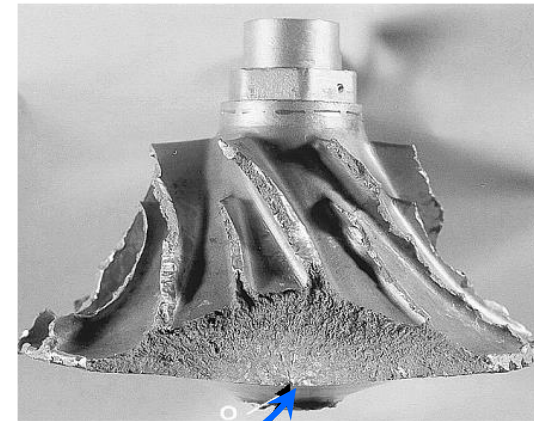
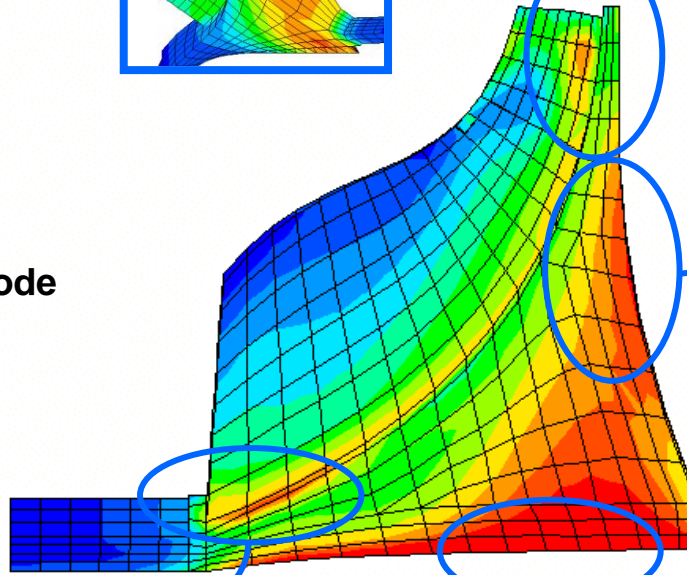
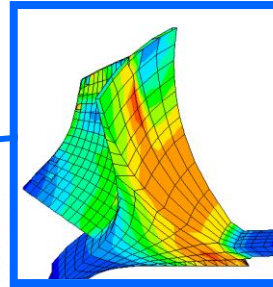




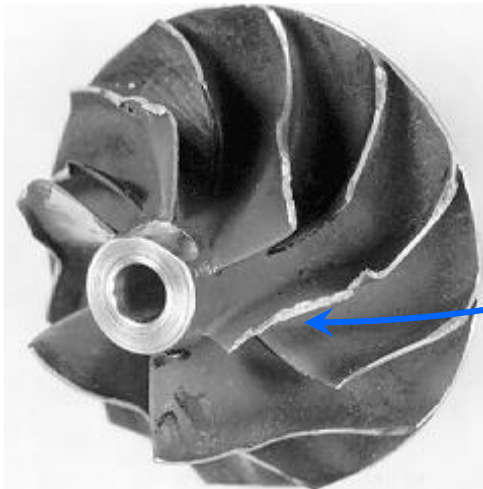
# Compressor Wheel High Stress Areas



**Blade/Backdisc Bending Mode**



**Backdisc Failure**



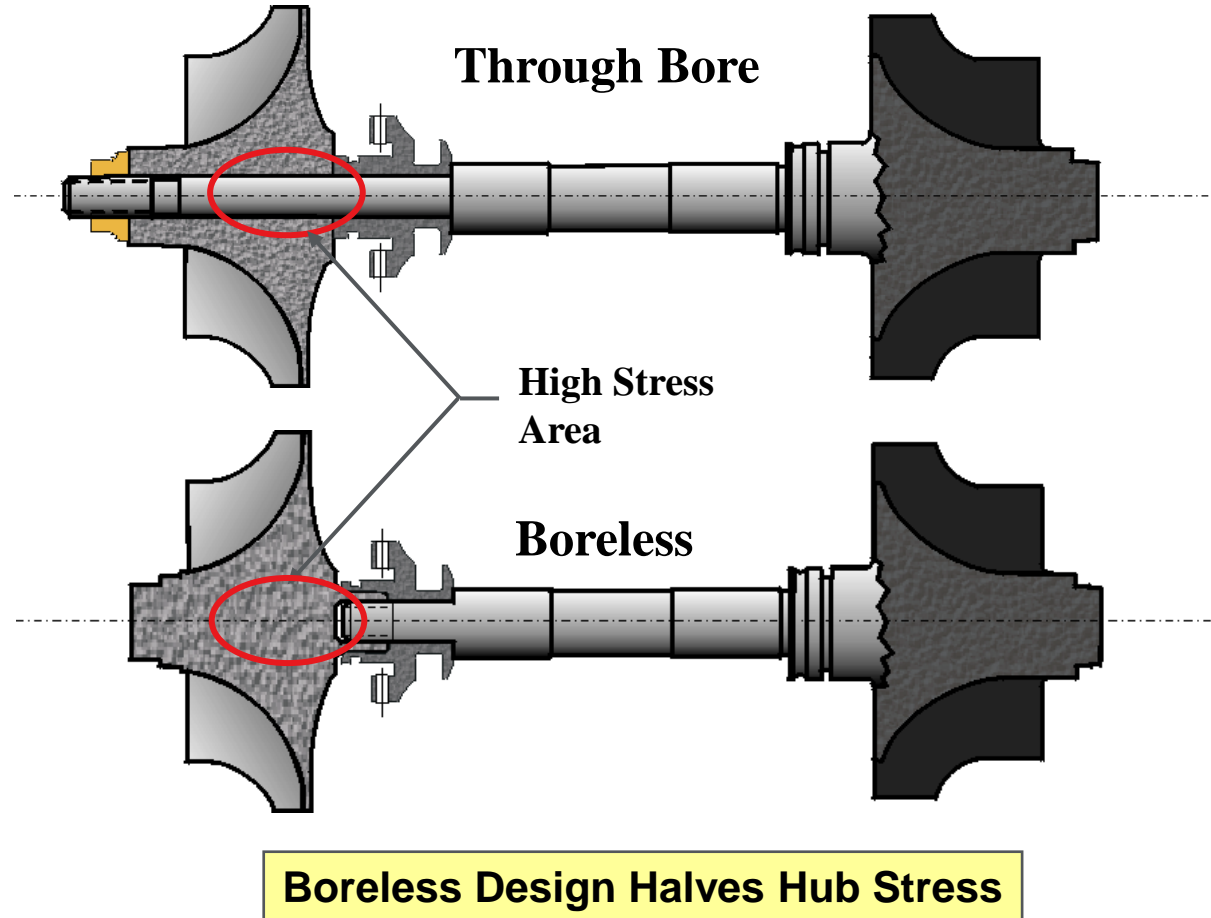
**Blade Mode**

**Failures initiate from high stress areas**



**Hub Failure**

# Fatigue Life - Design Reduction of Hub Stress



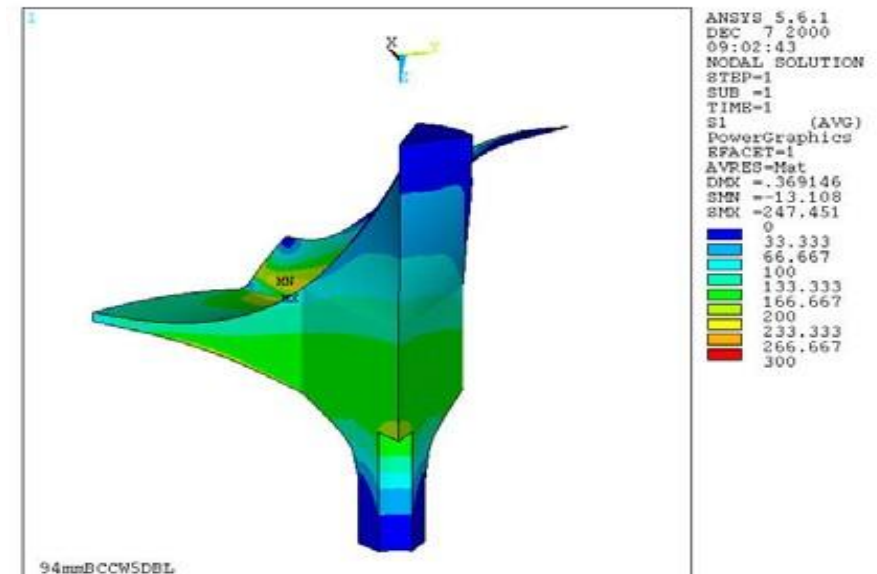
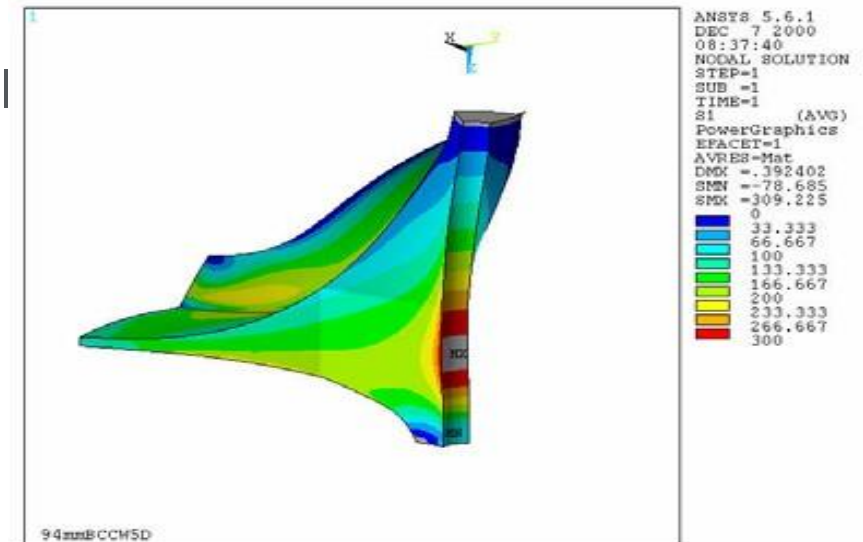
# Forged Fully-Machined Boreless





# Boreless Compressor Wheel

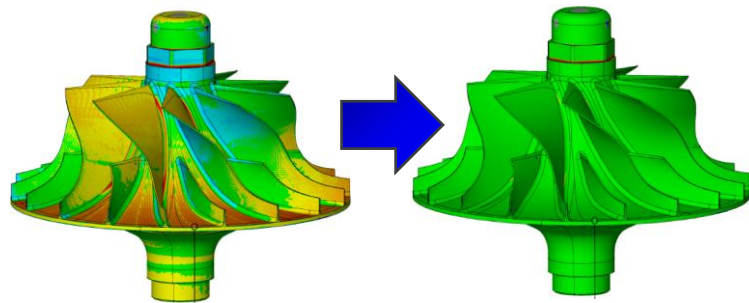
- 2.5 times greater life vs. conventional compressor wheel
- Garrett patented
- Cost effective solution to improve turbo LCF life
- Over 1 million shipped in production



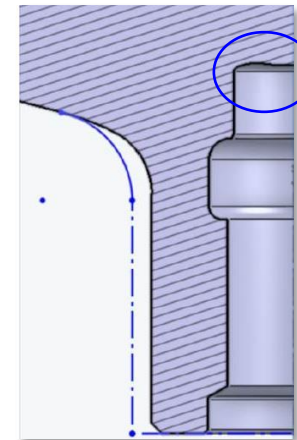
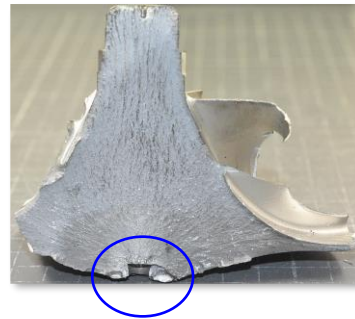
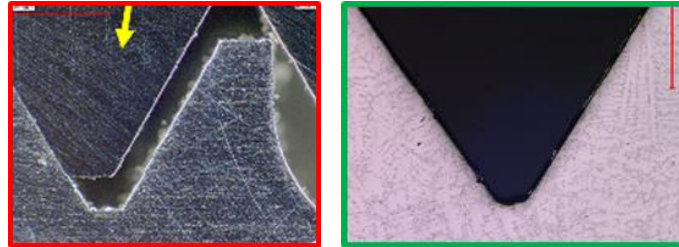
# OFF-HWY: Durability Enablers

## CAST TI TO FM TI

- **Move from Cast to FM:** when cost allows it  
→ Better life and process control
- 22 P/Ns – all models recreated from **reversed engineering**, mechanical assessment



## BORELESS JOINT



- Improve stress / life **prediction method** thru historical data collection and design comparison
- Define **geometric limitations: Increase joint wall thickness and cavity end ellipse**
- **Standardize** bore joint at supplier: Improve thread (implemented)

## SHOT PEENING

- **FM Shot Peened** wheel: first PPAP of C288 in 2019 with validated x4 life improvement



- Assess **temperature impact** and **deploy** where applicable
- **Cast BL SP** LCF ongoing to assess life improvement over (expected 2-3X life improvement)

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