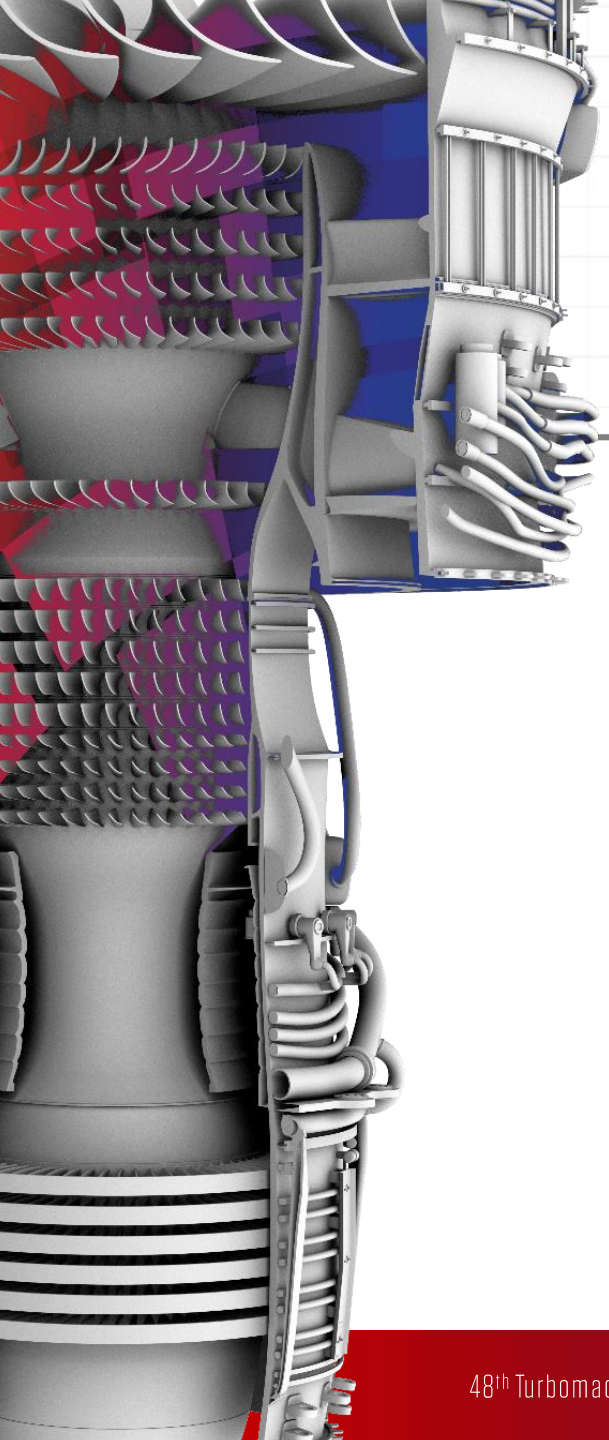


TURBOMACHINERY & PUMP SYMPOSIA

Keyless Taper Fits with Non-Uniform Section Hubs

Collin McConnell, B.Eng. (Hons), AMIMechE.

Bibby Turboflex, Altra Industrial Couplings.

Presenter Biography

Collin McConnell is the Principal Engineer for Bibby Turboflex, a premier brand of Altra Industrial Motion.

2013 saw Collin joining the API 671 Task Force, contributing towards the 5th edition. He has served on the Industrial Advisory Panel for the University of Huddersfield and is also an active member of the Leeds Association of Engineers.

He holds a B.Eng. (Hons) in Mechanical Engineering from the University of Leeds and is currently working towards Chartered Engineer status with the Institute of Mechanical Engineers.

Problem

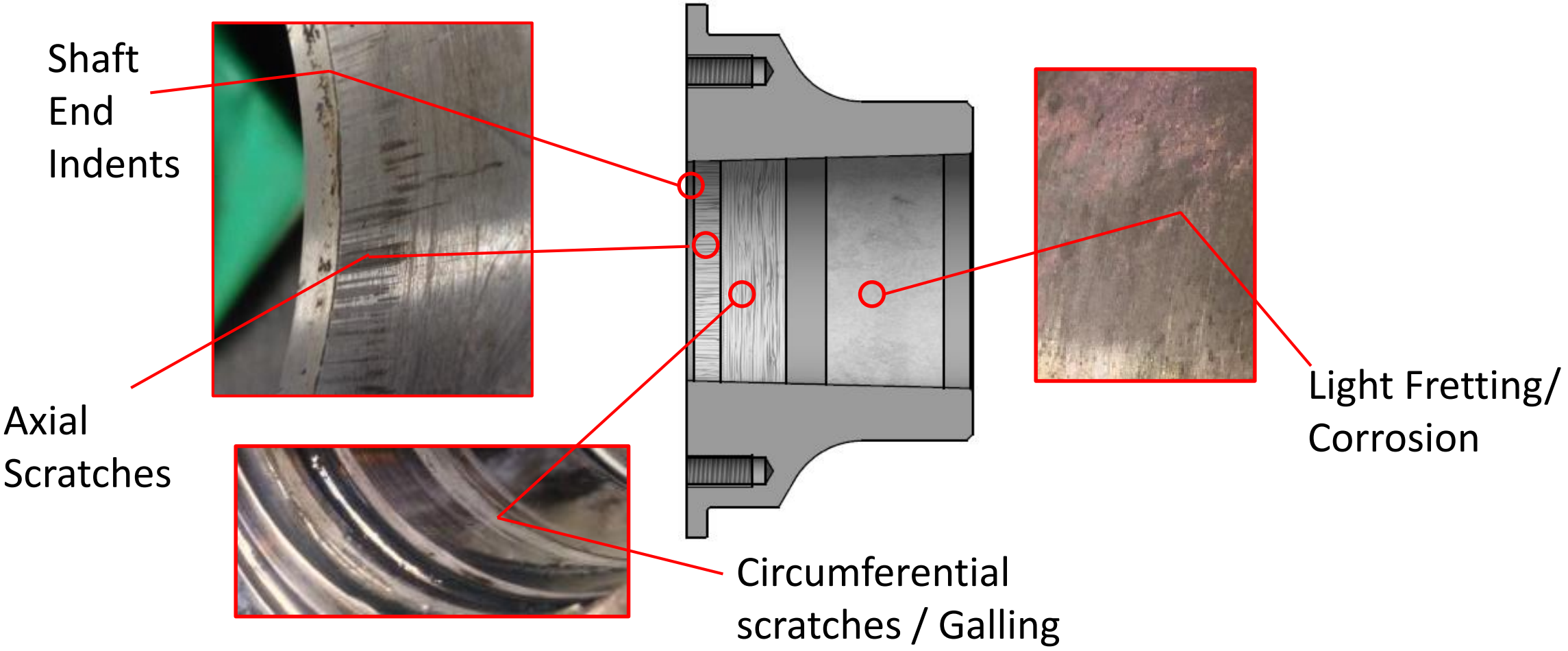
During an investigation of bore damage on a flexible coupling between a motor and pump, the hub's non uniform design came into question as a potential factor.

The American National Standard

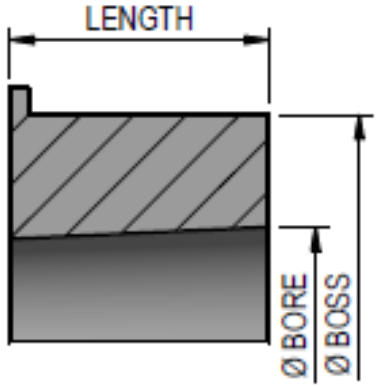
"Flexible couplings – Keyless Fits (ANSI/AGMA 9003-C17 or 9103-C17)", provides a good guideline for the design, inspection and instalment of hubs having a uniform cross sections.

What if the hub is not of a uniform cross section?

Background – Hub bore damage

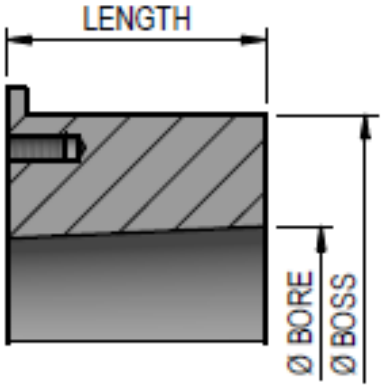


Background – Hub Evolution



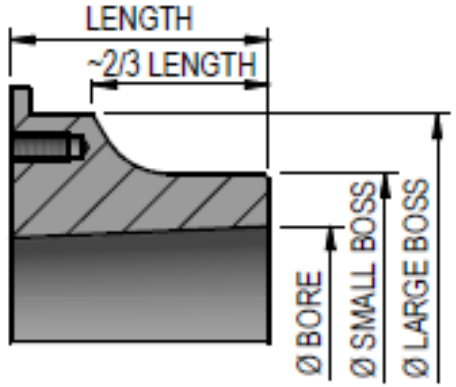
Standard hub
(Uniform Section)

Problem!
High Pressure
Needed to
remove hub



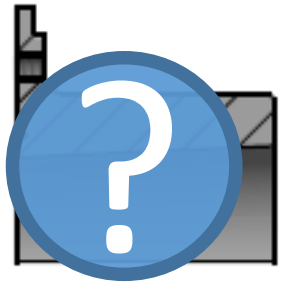
Puller holes added
to "drag" hub off at
lower pressures.

Problem!
High axial loads applied
to puller holes caused
thread/bolt damage.



Profiled boss
(Non Uniform Section)

Problem!
Hub bore surface with
4 areas of damage.
Also issues with
mounting/dismounting.



Final
solution

ANSI/AGMA 9103-C17, Flexible Couplings – Keyless Fits (Lamé's Equations)

ANSI/AGMA 9103-C17, Flexible Couplings – Keyless Fits, generally uses Lamé's equations for a thick wall cylinder to estimate the contact pressure and stresses in a uniform hub section.

The standard requires the hub to be split down into multiple sections of varying outside diameters, taking average bore diameter over the length of that section.

The standard has limitations, in particular to stress and mounting pressures when the hub has multiple sections.

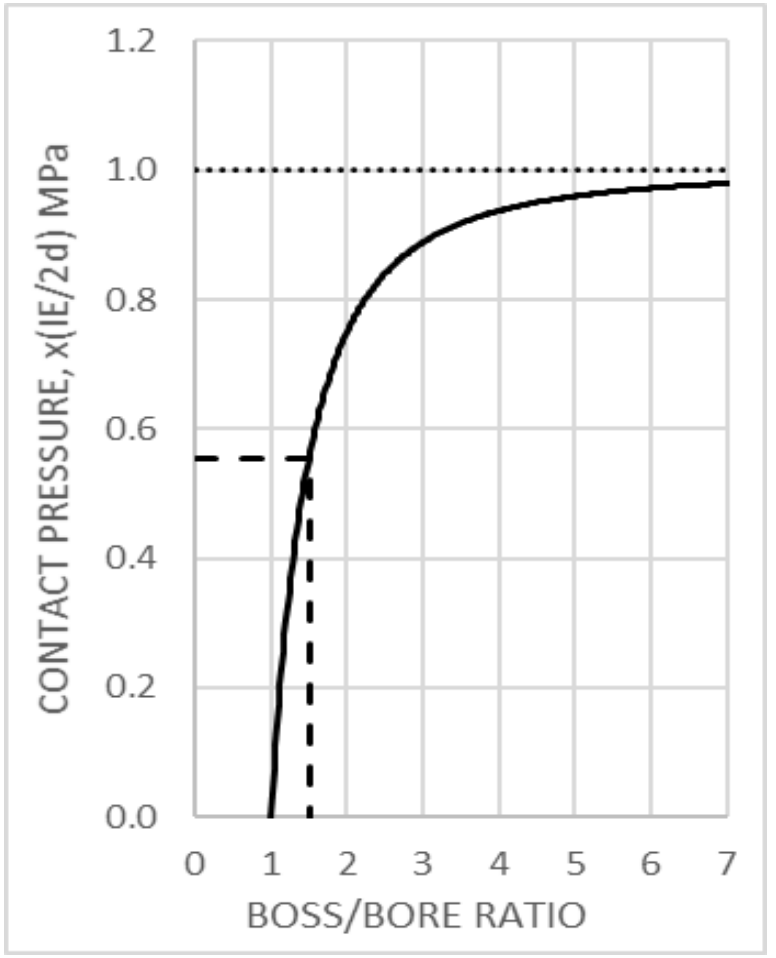
Lamé's Equations

- Lamé's equations estimate the hoop and radial stresses in a pressurized thick walled cylinder.
- Internal pressure is generated by the Interference fit created by having a shaft slightly larger than the bore into which it is fitted. Atmospheric pressure is negligible by comparison and is therefore ignored.
- The internal pressure is assumed to be evenly distributed.
- Plane Cross-sections remain plane when under pressure, that is to say no axial stresses.
- The equations assume a homogeneous and isotropic materials, ANIS/AGMA further assumes the shaft is solid, and both shaft and hub are steel.

Lamé's Equations

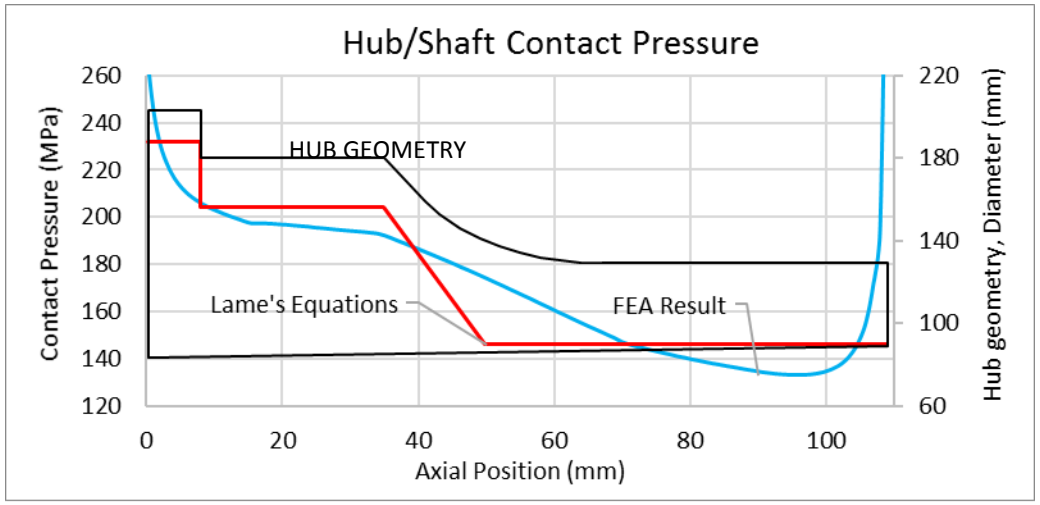
From Lamé's equations it we can see that,

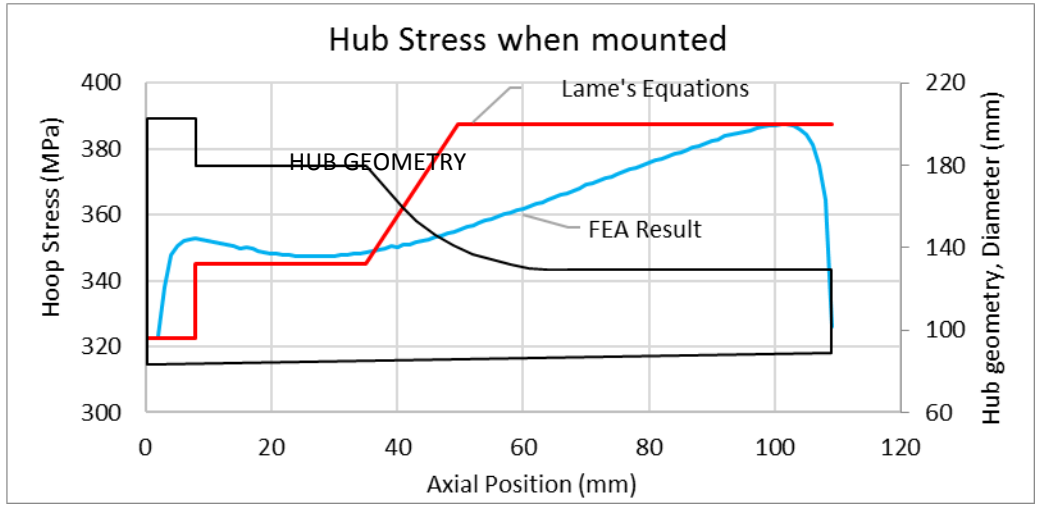
- Increasing the boss diameter has a nonlinear increase on the contact pressure
- As the boss diameter approaches infinity, the contact pressure converges to a maximum pressure.
- Due to the gradient of change at the optimal 1.5 boss/bore ratio, a large change in contact pressure may result from a relatively small change in boss diameter.



Contact Pressure due to Boss/Bore Ratios (k value)

Non-Uniform Hub Contact Pressure / Stress



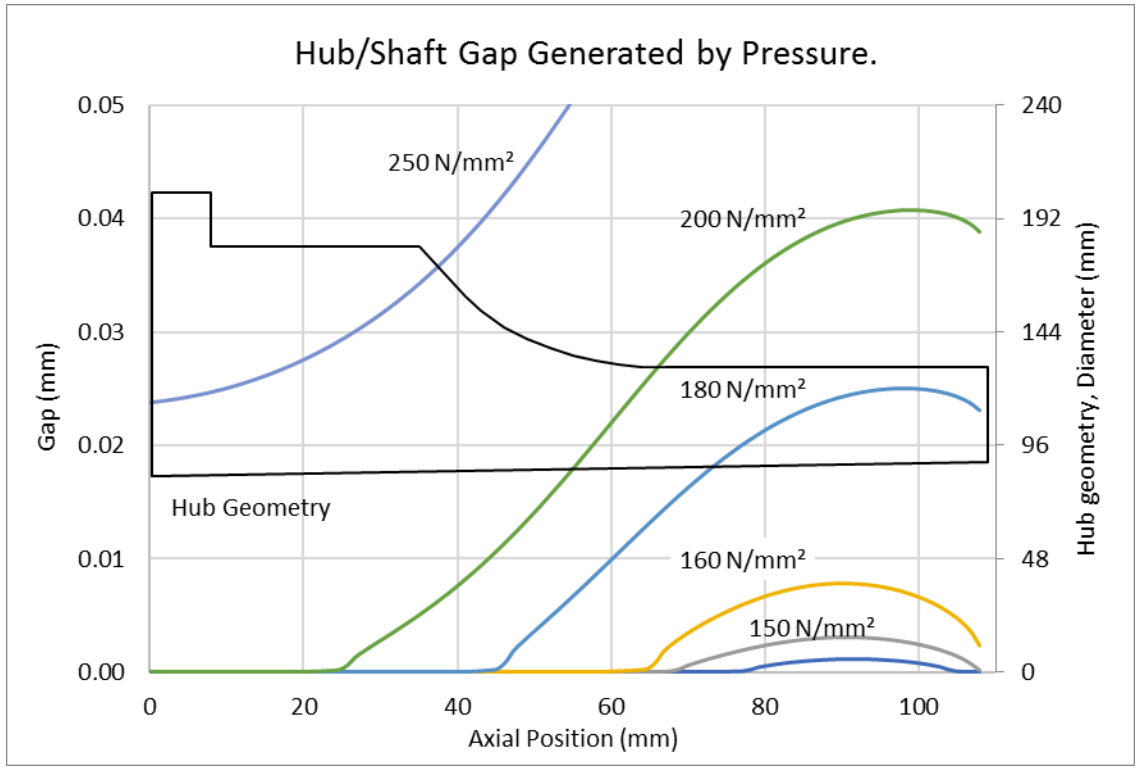


A Finite element comparison shows stress raising and transition effect between section and validates Lame's Equations.

Affect of neighbouring sections highlighted by the FEA.

- Large boss lifts up the pressure in the small boss
- Large boss pulls down the pressure in the flange region.
- Highest stresses are in the smallest boss areas. This may cause yielding in this area when dismounting.

Non-Uniform Hub, Deflection



Deflection is greater at the smaller boss diameters.

With increasing dismount pressure, the seal at the rear of the hub (smaller boss diameter) is potentially lost.

The front portion of the hub (larger boss diameter) is still gripping the shaft.

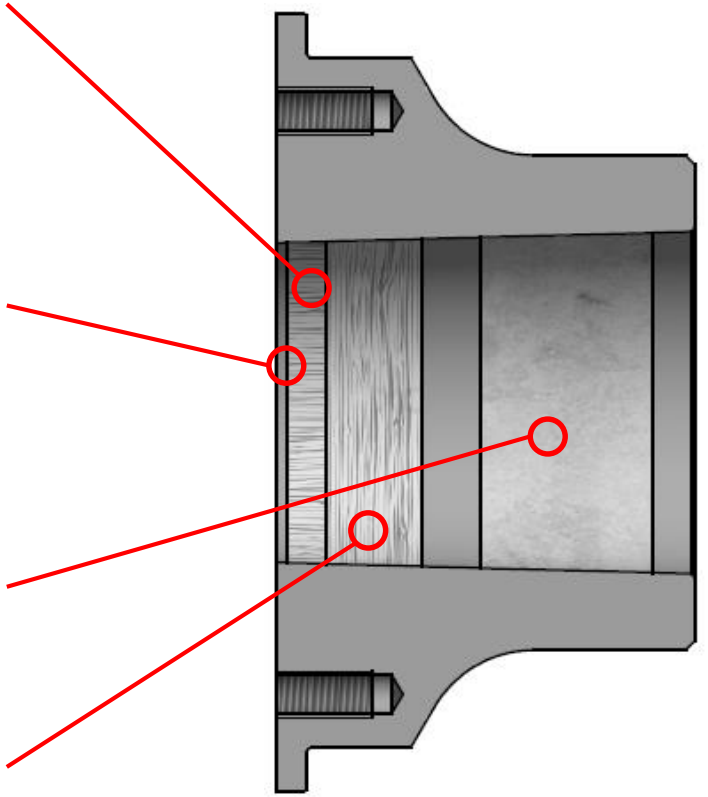
Relating to the damage

- High contact pressures may result in the shaft end scraping against the bore during mount/dismount.
(Axial Scratches, Circumferential indentation).

- Also possible embedding of the shaft into the bore surface.
(Circumferential indentation)

- During mounting/dismounting a risk of plastic deformation could lead to lower contact pressures, allowing hub/shaft movement with torque fluctuations. (Fretting)

- Loss of grip elsewhere could result in slipping in the remaining areas as hub capacity is compromised (Circumferential scratches)



Conclusion

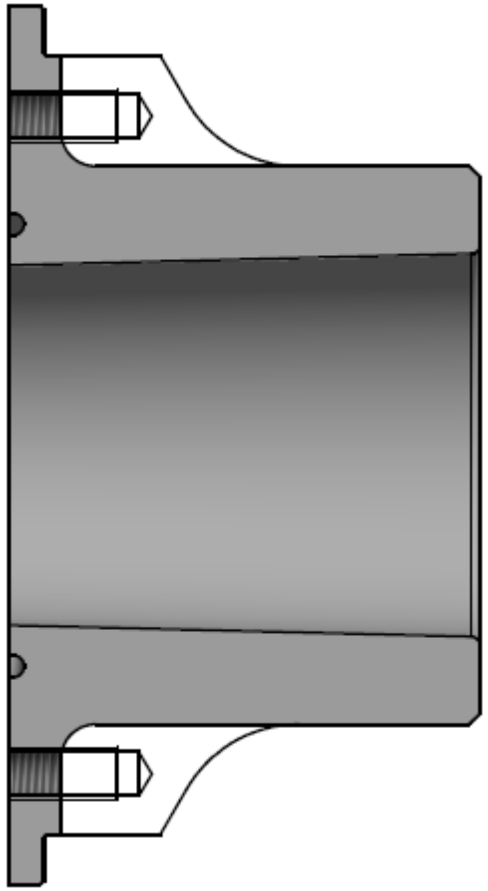
- It is possible to analyse Hubs of Non-Uniform Sections using ANSI/AGMA 9103-C17 provided the effect of one section has on the others is well understood.
- The use of graphics to represent the results will help to highlight significant differences between neighbouring sections.
- If in doubt use more advanced methods such as Finite Element Analysis.

Recommendations

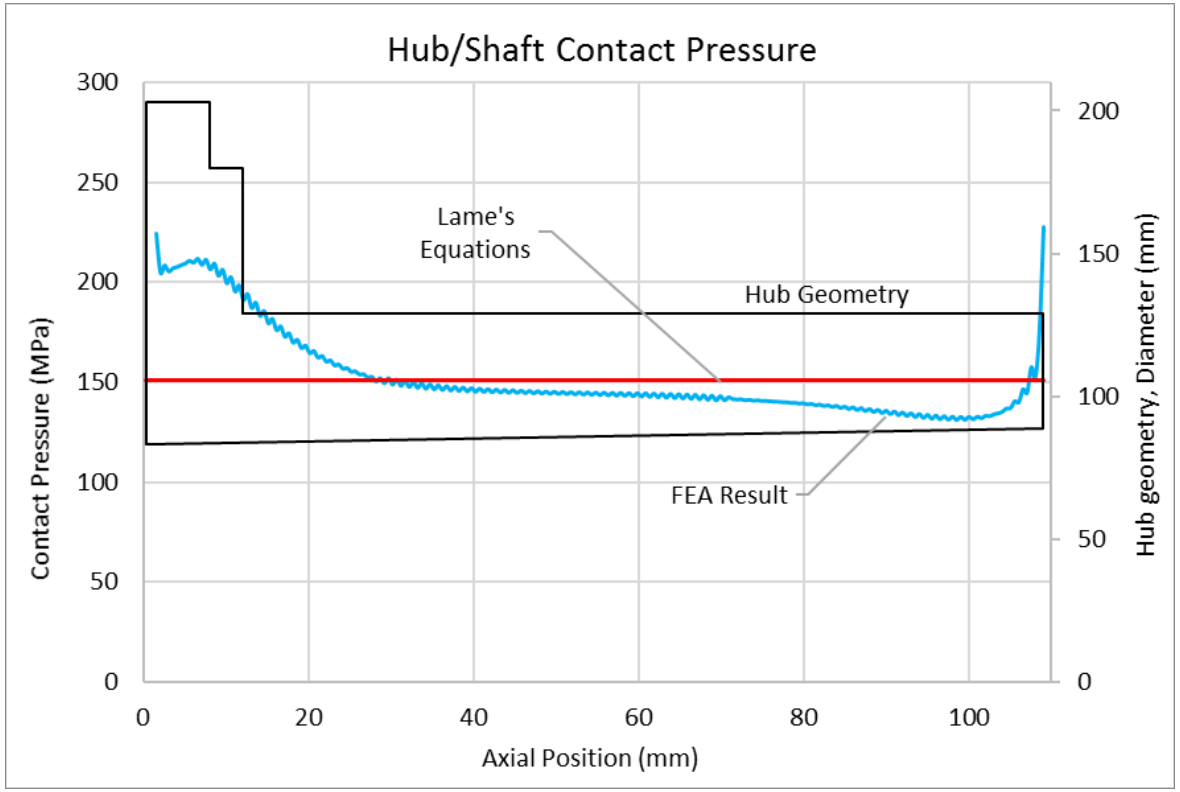
Possible solutions

- Add a seal to the hub to prevent leakage.
- Move the oil injection point to the area of maximum contact pressure.
- Redesign the hub to be more uniform.

The New Hub – Successful?



- A new hub has been fitted successfully with no reported issues.
- No requirement as yet to dismounted the hub.



Lessons learned

- Ask “WHY ?” Review both the final design and specification with a critical eye.

- Keep It Simple. Look for ways to simplify designs.

References

- ANSI/AGMA 9103-C17, Flexible Couplings – Keyless Fits (metric Edition), published by the American Gear Manufacturers Association, 1001N. Fairfax Street, Suite 500, Alexandria, Virginia 22314, http://www.amga.org.)