

ICEM 12

INFLUENCE OF THE LINEAR TIP RELIEF MODIFICATION IN SPUR GEARS AND EXPERIMENTAL EVIDENCE

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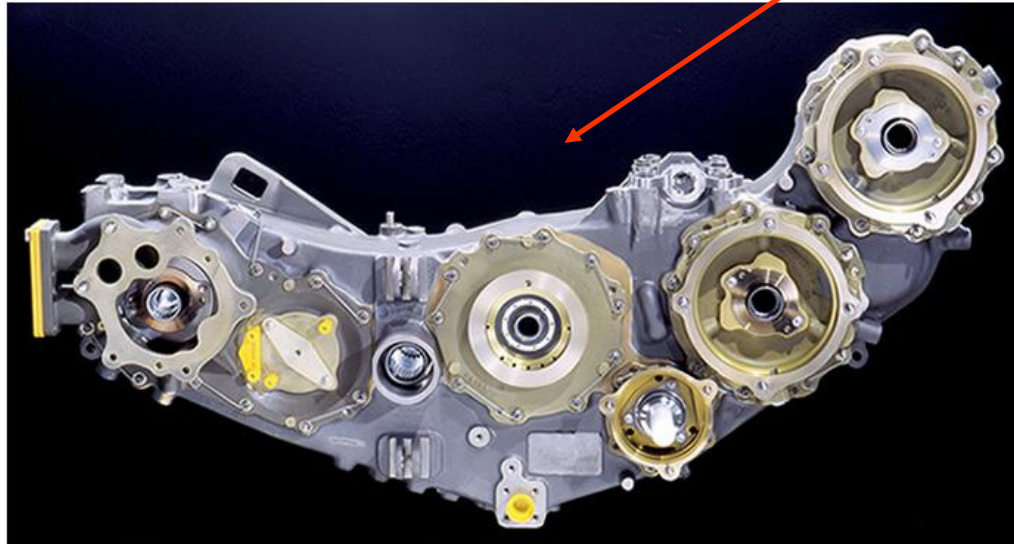
Application of interest

Gear Box for Aerospace vehicles

- high performance
- low weight



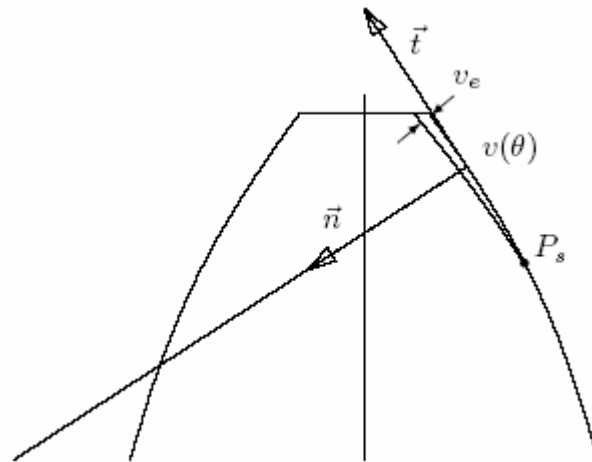
Spur Gears



Tip Relief Modification

What is Tip Relief Modification ?

Material removal along the involute profile at the tip of the tooth



Bidimensional
sketch for a
modified Spur
Gears Tooth

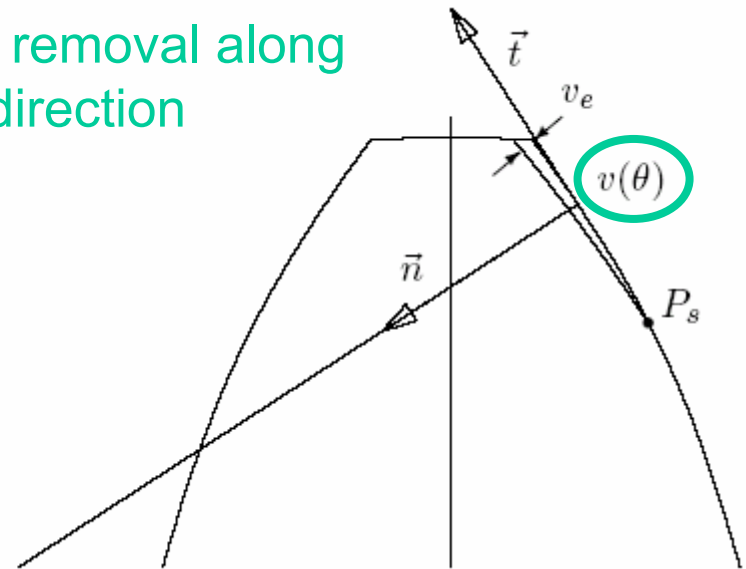
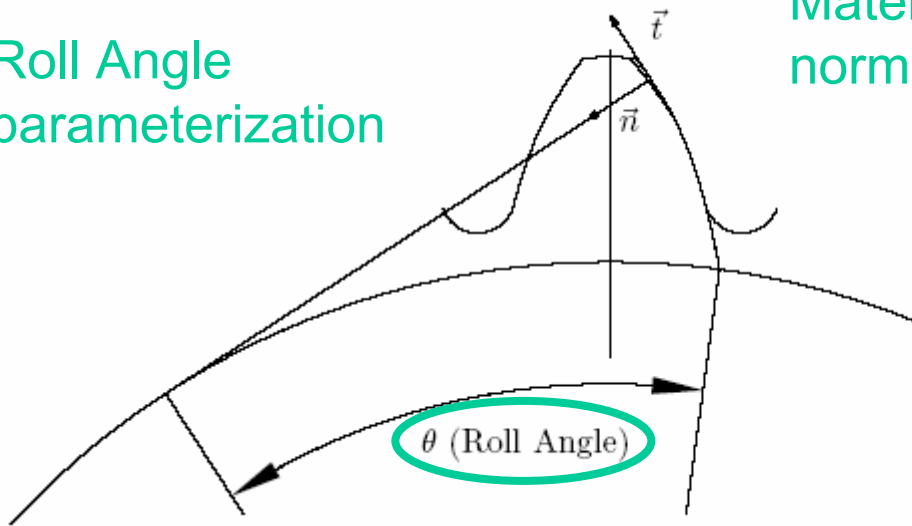
What is the use of Tip Relief Modification ?

- Better meshing engagement of tooth pairs
- Transmission Error trace modified (PPTTE reduced)

Tip Relief Modification

Roll Angle
parameterization

Material removal along
normal direction

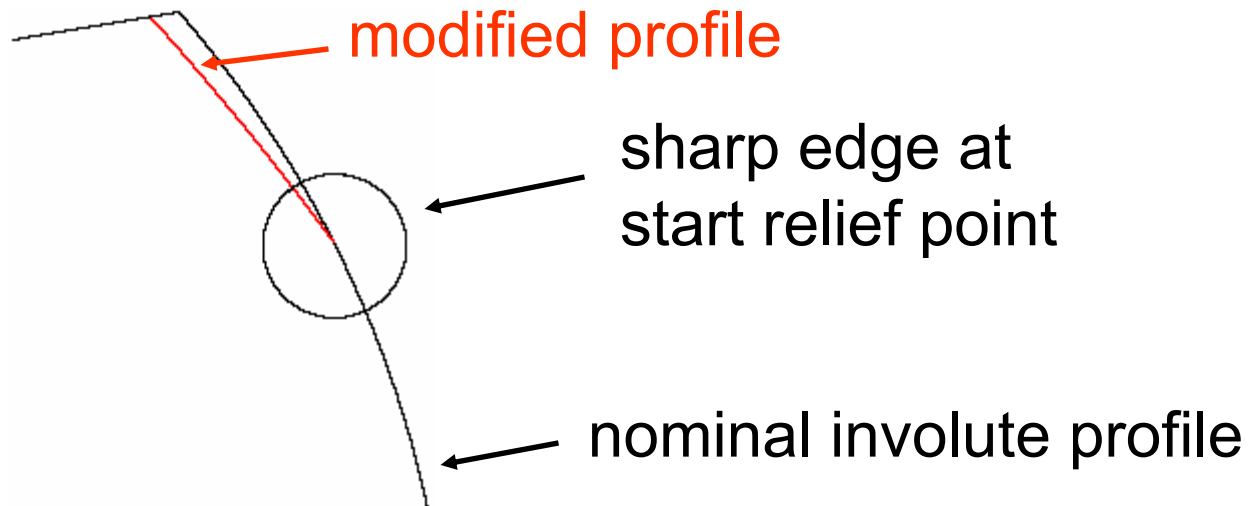


Geometrical definition of Tip Relief Modification

- Tip Relief Topography (either Linear or Parabolic)
- Start Tip Relief P_s (related Roll Angle)
- Max. material removal at the top v_e

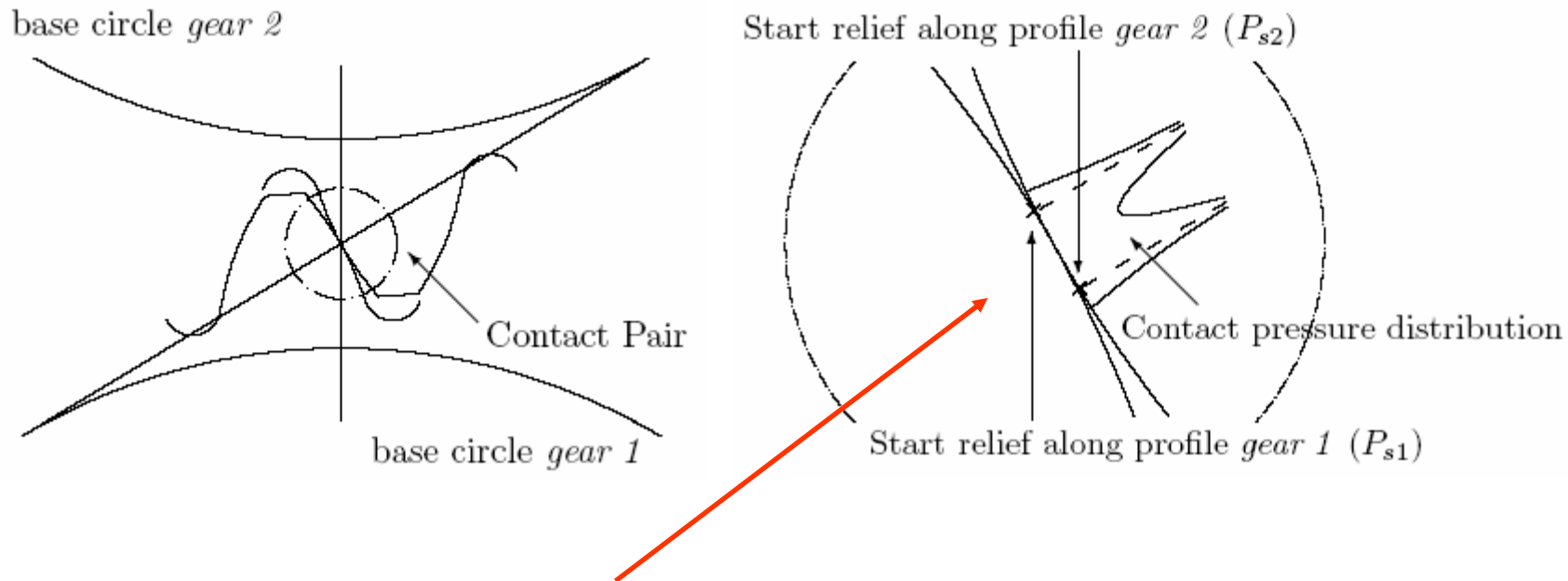
Linear Tip Relief Modification

- It produces a low PPTTE, very useful in terms of whining noise, especially for Spur Gears, so this kind of modification is very appreciated
- It generates a sharp edge at the Tip Relief start Point. Even though the angle is very flat, the solid elastic Contact Pressure solution is singular



Linear Tip Relief Modification

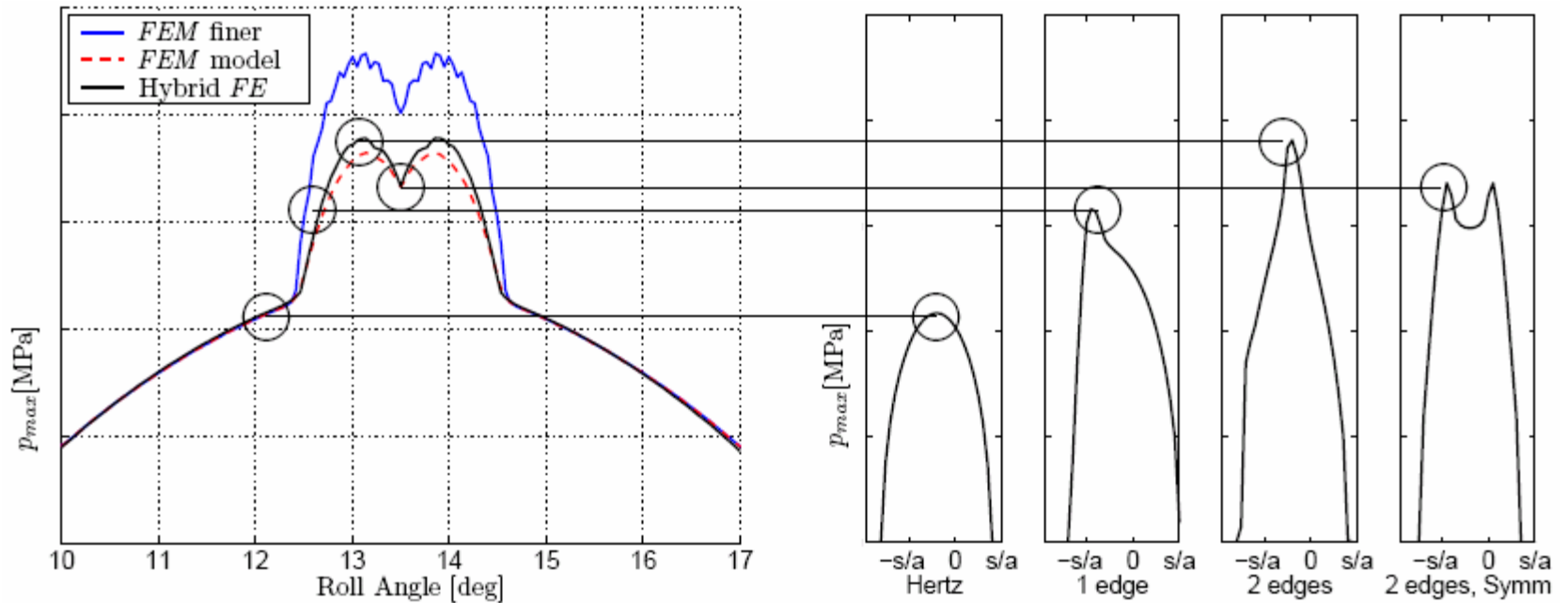
- Nominal Contact Pressure solution



If the contact zone encompasses one or both the start relief points, Contact Pressure rises to infinity

Numerical models

Numerical models produce **not stable results** (mesh depending) when the P_s is inside the Contact Region



stable Result

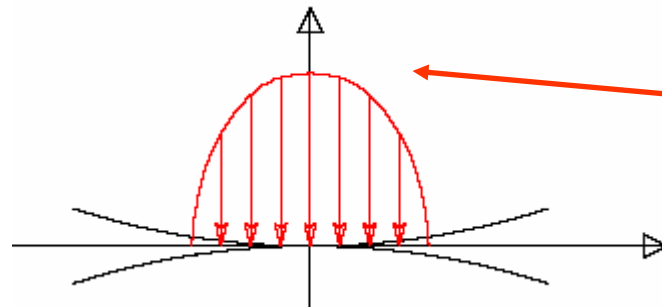
not stable Result

Why not to accept sharp edge and singular contact pressure

- Every **technological process** can not produce a perfectly sharp edge
- The **angle at the tip relief start point is so flat** that the **surface roughness** has to be considered for defining the corner region
- After a **short run in** the **material necessarily yields** or wears, and sharp edges should be blunted

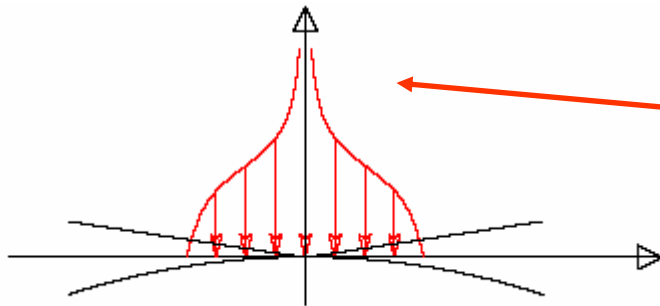
Micro pitting prediction model needed

- If C^2 (even C^1) continuity condition is satisfied the Hertz Contact Pressure is accepted to be the nominal stress for Micro-Pitting material resistance prediction



Nominal Hertz
max. Pressure

- If C^0 continuity condition is satisfied only, a nominal Contact Pressure stress value is not available



Nominal max.
Pressure needed

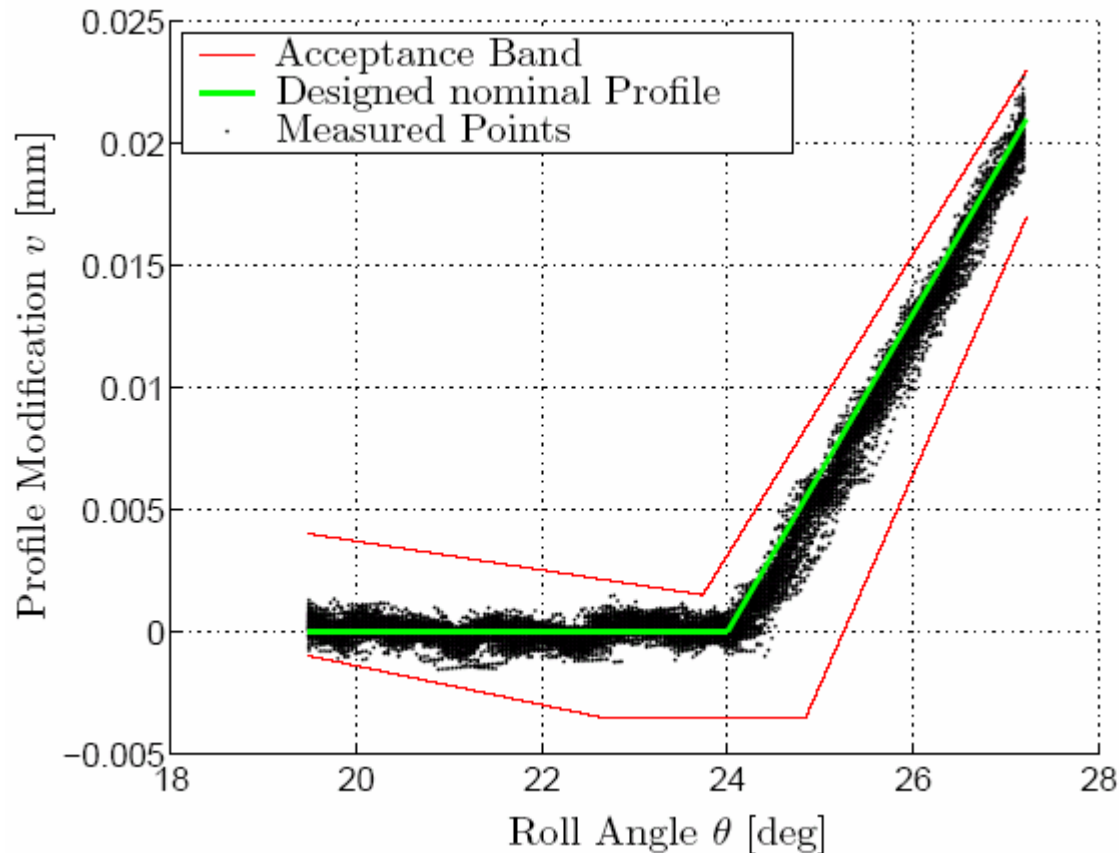
Definition of an effective regular profile

Golden Rules to fulfill for **effective profile** definition

- The profile need to satisfy **C¹ continuity** (enough in terms of well defined Contact Pressure and its regularity)
- The profile in the zone of P_s has a curvature influenced by the **roughness parameters** (such as R_a)
- The profile has to reproduce the **nominal profile as much as possible** (for example not near P_s)
- The method must to be **simple**

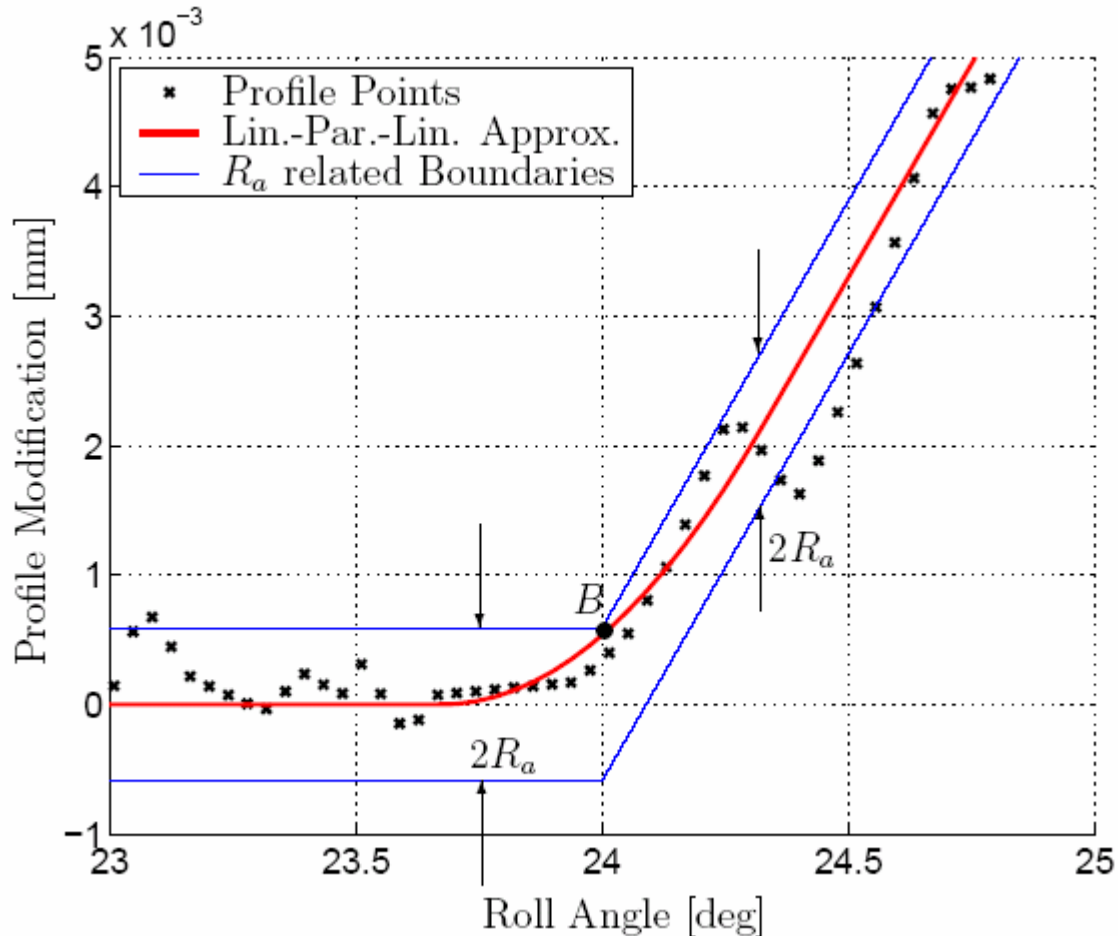
Data for the definition of an effective regular profile

Experimental data available: 800 profiles points inside the **design tolerance band**, on which define the effective profile



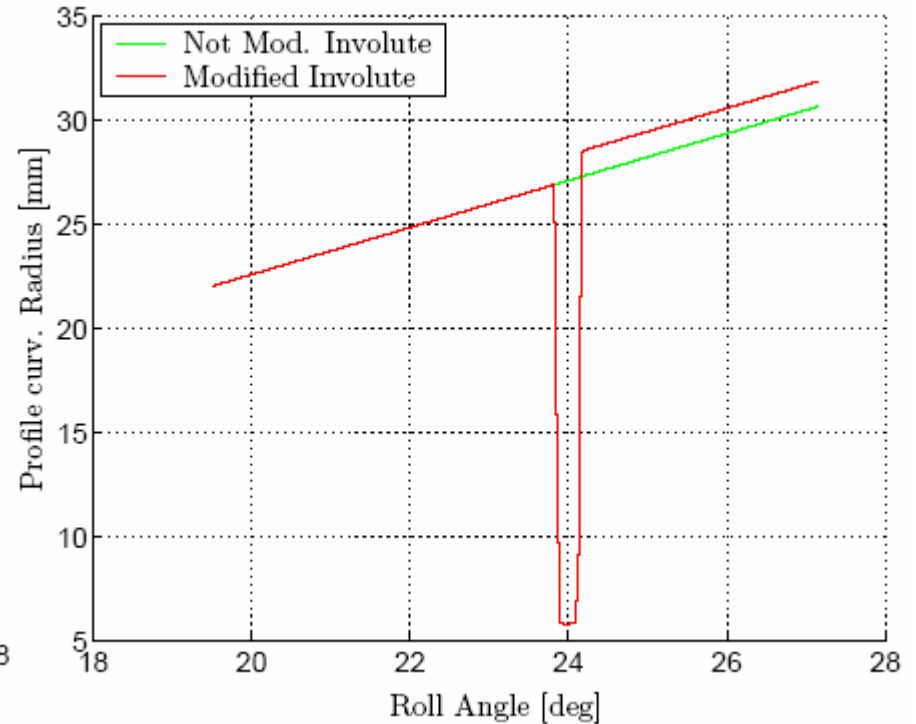
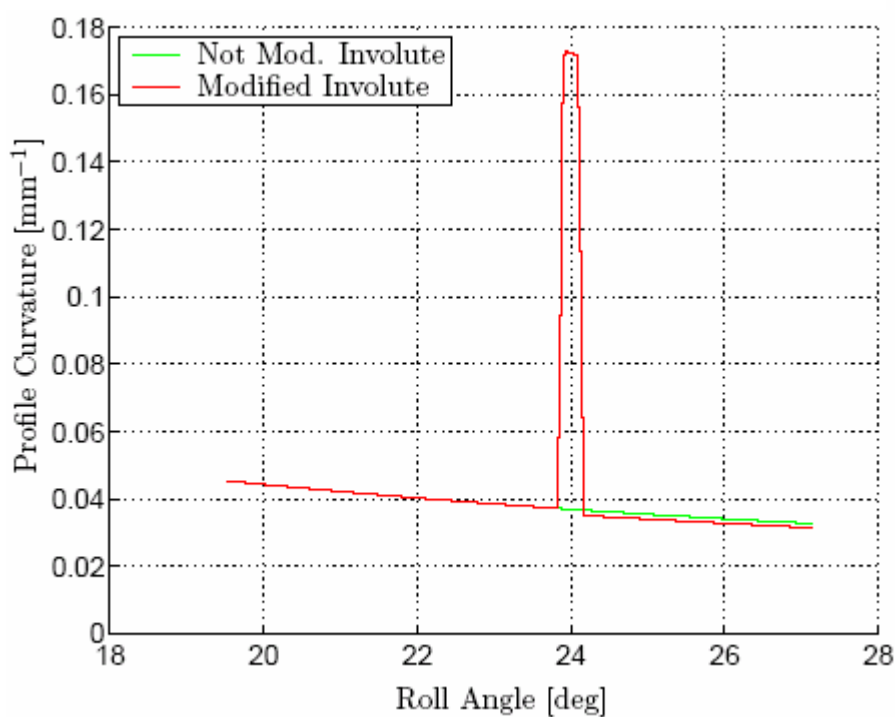
Definition of an effective regular profile

$2R_a$ related boundaries offset with reference to nominal design



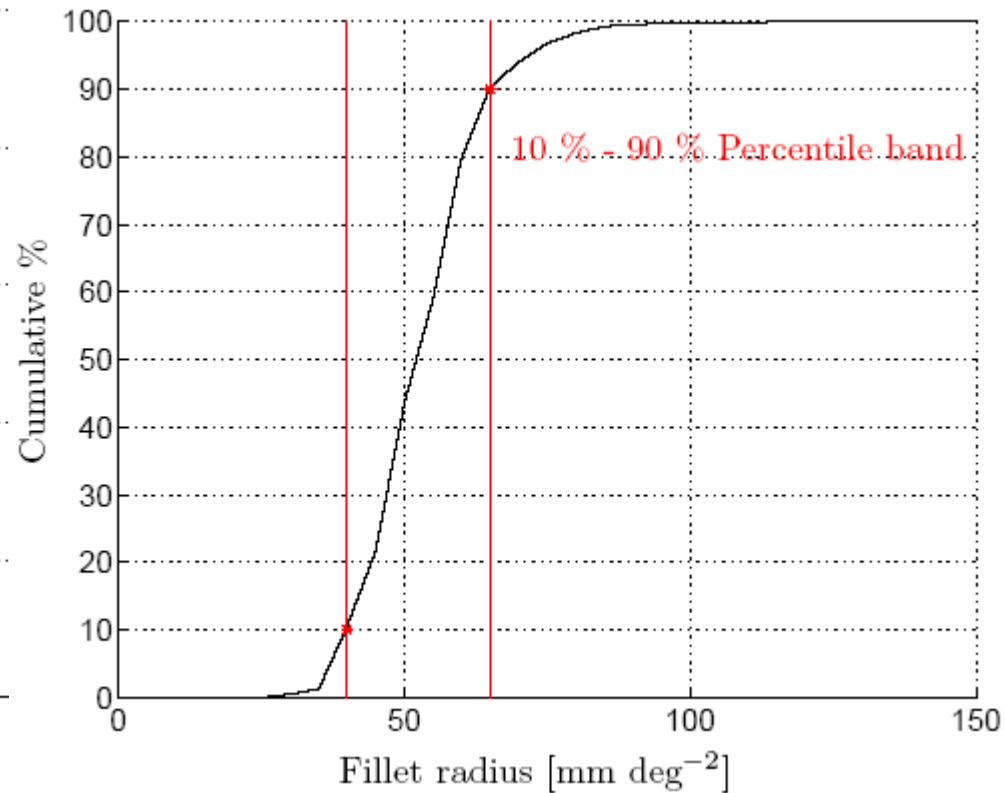
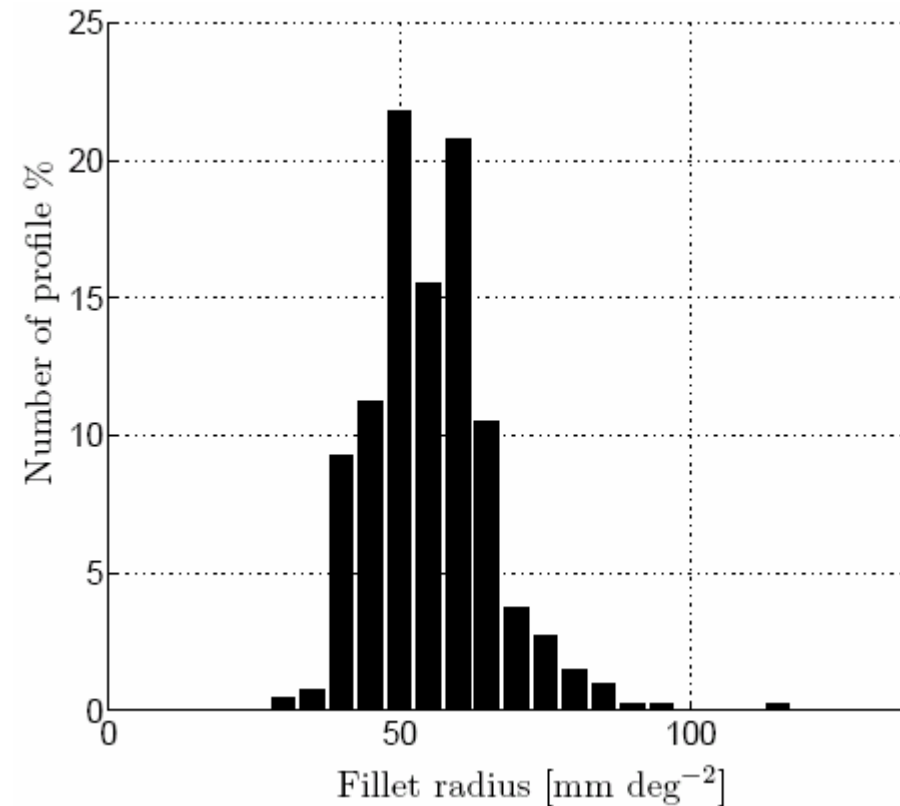
maximum Radius Linear-Fillet-Linear, with parabolic fillet

Definition of an effective regular profile



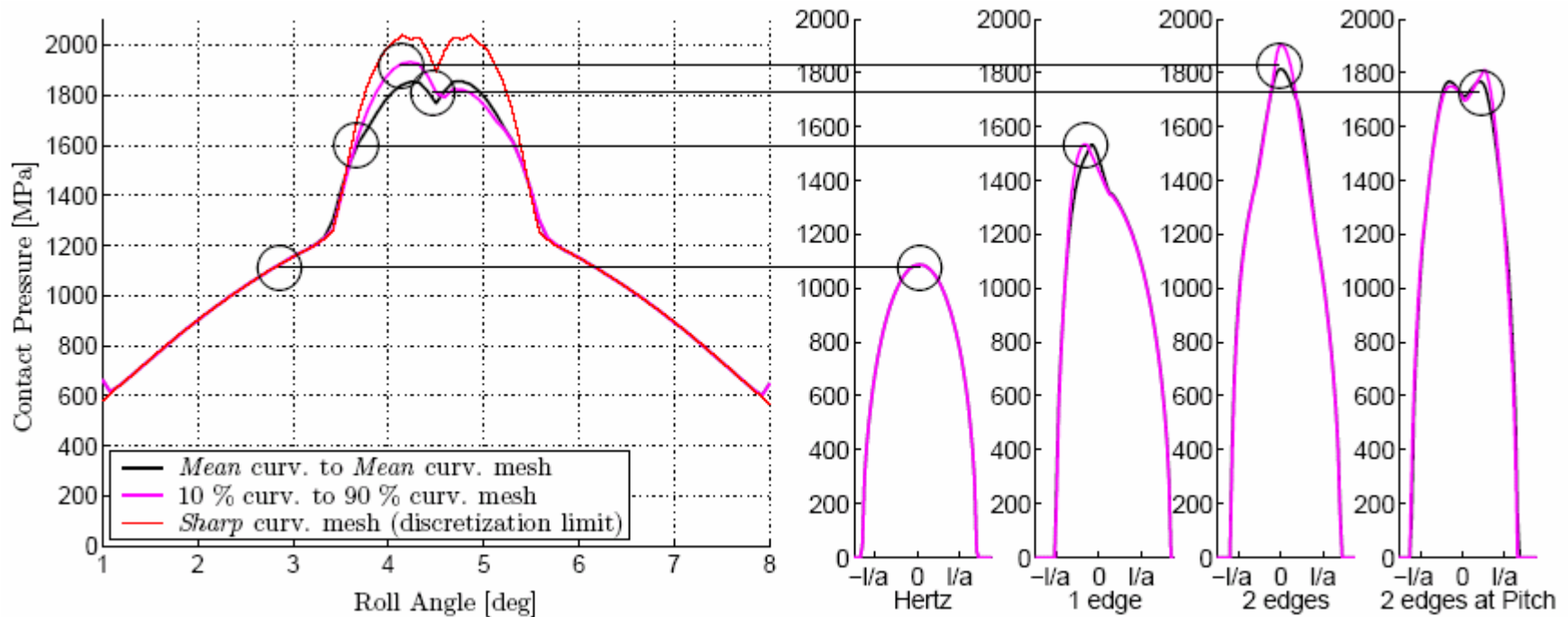
Strong **curvature step**, but **C¹** condition fulfilled

Definition of an effective regular profile



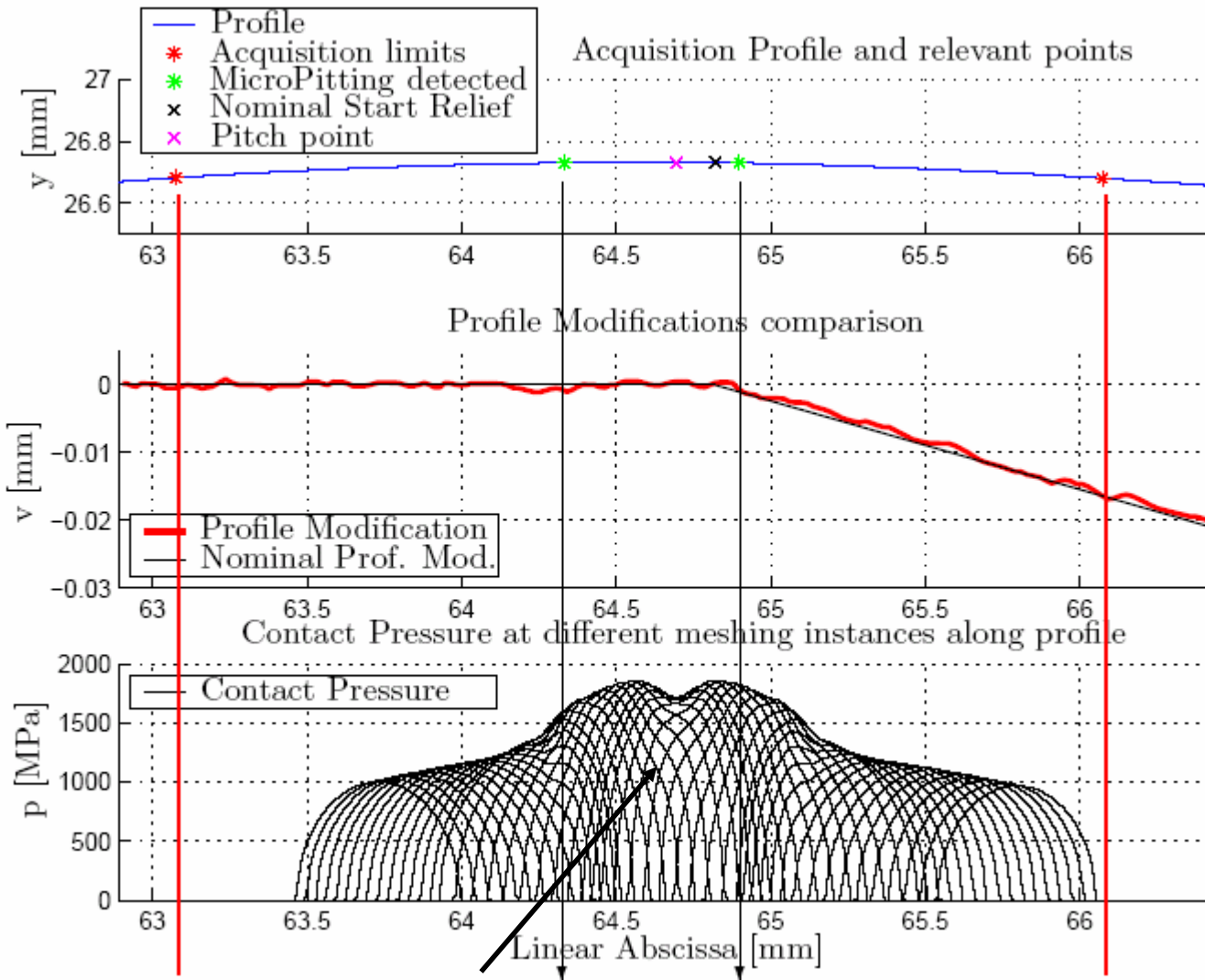
Quite narrow statistical distribution of fillet Radii

Contact Pressure Results



- Numerical **stable results**
- Different combinations for statistical sake, then statistical results variation
- **Very high** Contact Pressure found

Contact Pressure Results



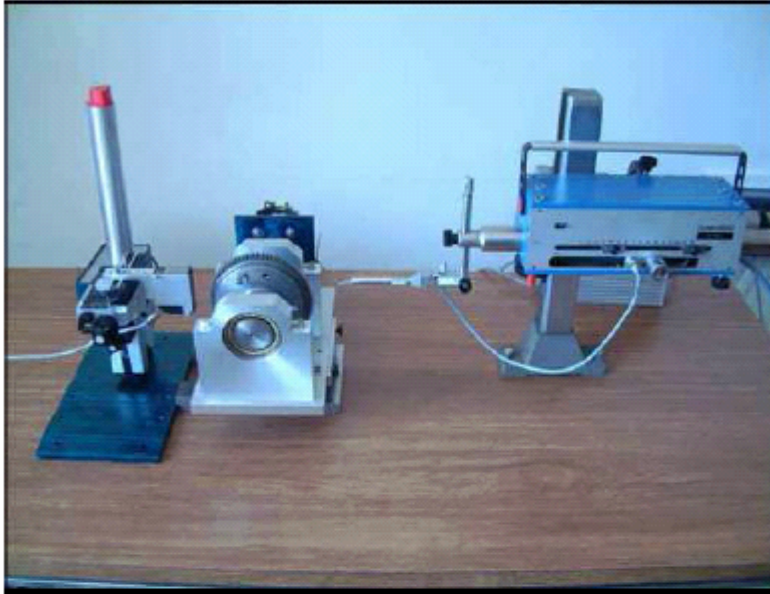
Profile and related points, plus Acquisition limits

Nominal Modification, plus acquisition points

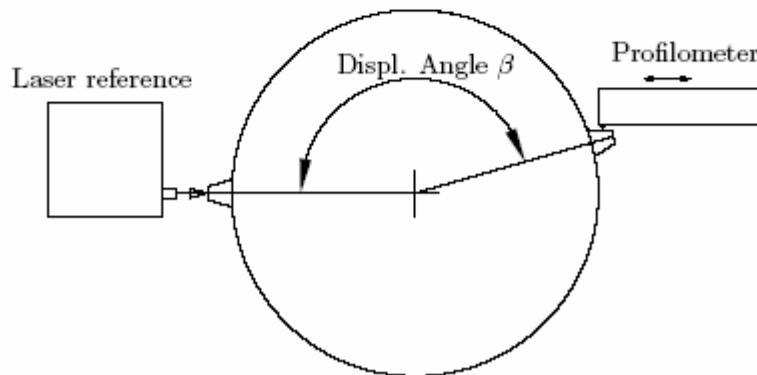
Contact Pressure evolution on the profile

Contact Pressure rise due to “sharp edges” in contact

Experimental Evidence



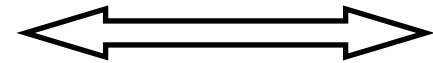
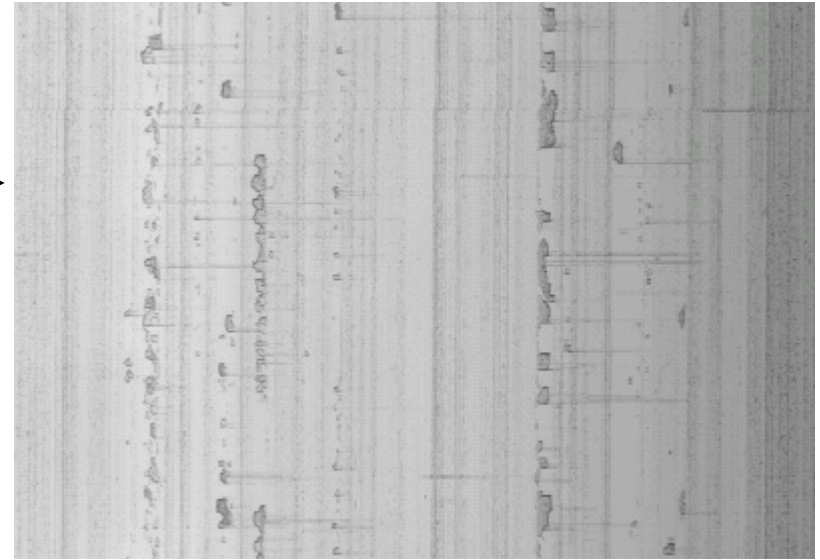
Experimental equipment for Profile and Roughness detection



Equipment scheme for “horizontal tooth flank” displacement

Experimental Evidence

Micro-Pits found

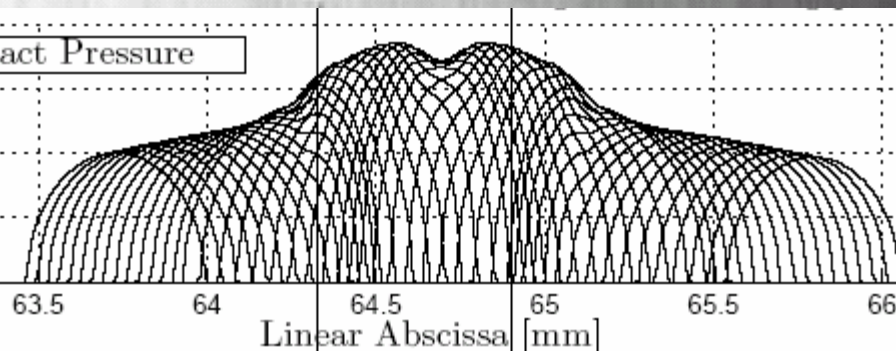


Evidence of opposite
Rolling-Sliding
combinations, from
Pits' borders

micropits

micropits

Contact Pressure



Linear Abscissa [mm]

Micro-Pitting lines

Conclusion

- A **simple** method to perform a regression to a **regular profile**, in the case of **singular nominally profile**, was shown and **experimentally validated**.
- The only **micro-geometry** parameter leading the regression is the roughness R_a , around the Start Relief Point.
- **Numerical simulations** were performed and micro-pitting evidence provided for the **high contact pressure** found.
- The **coincidence** found is good.