

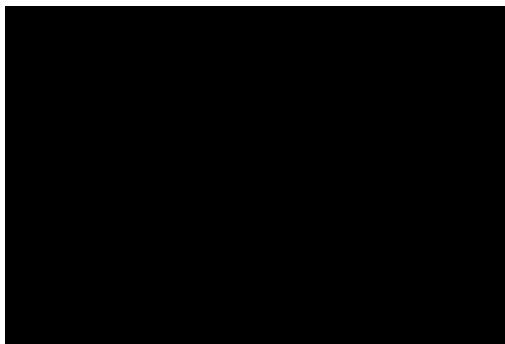
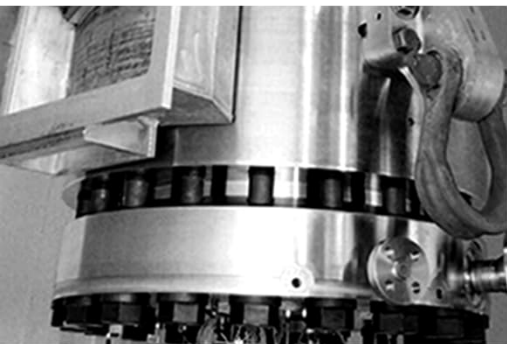
**CURTISS -  
WRIGHT**



CW Surface Technologies  
Metal Improvement Company



## Shot Peening & Super Finishing Optimization of Gearing



# **CURTISS - WRIGHT**

## **Surface Technologies**

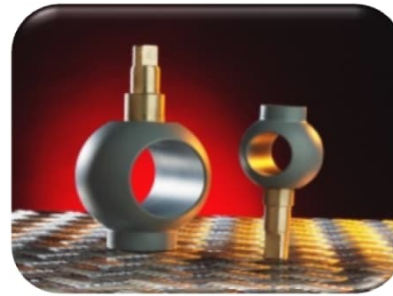
## Metal Improvement Company, LLC



Shot Peening



Shot Peen Forming



Solid Film Lubricants



Parylene Coating



Thermal Spray



Laser Peening



Isotropic Finishing

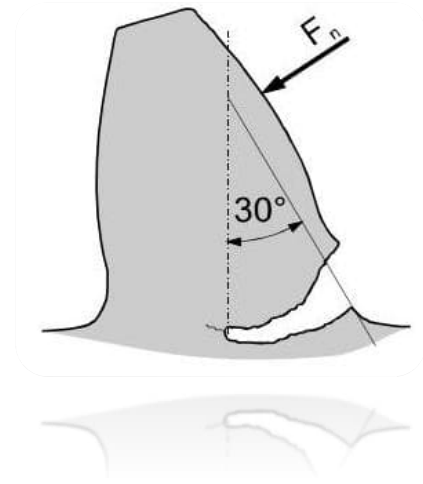


Analytical Services

# PRIMARY PURPOSE OF SHOT PEENING GEARING

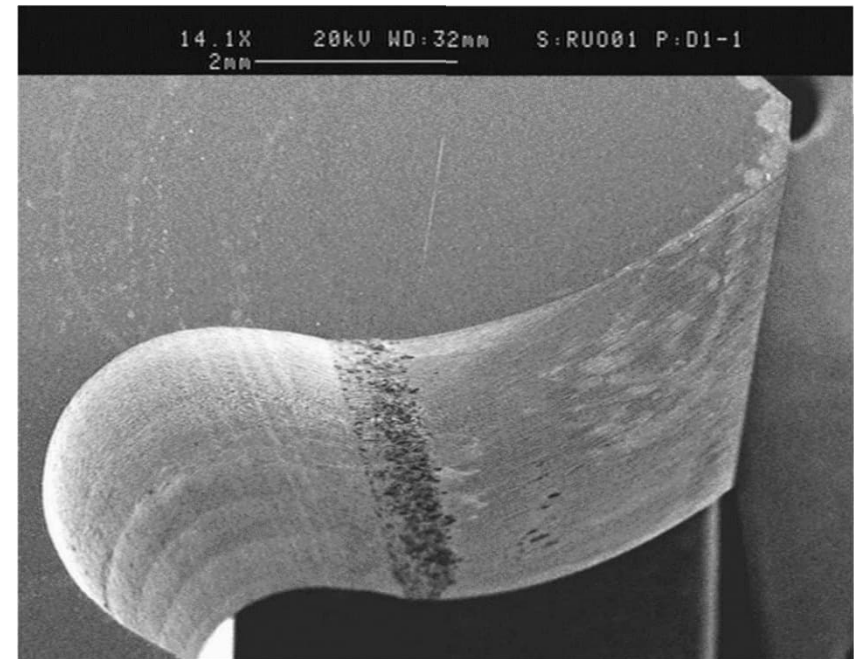
## Induce Residual Compressive stress

- Residual compressive stress is beneficial for high cycle fatigue. It offsets applied tensile stress that causes fatigue failure.
  - ✓ Very beneficial for tooth root bending strength
- Is proportional to surface hardness/strength. Harder gear surfaces produce higher residual compressive stress when shot peened.
  - ✓ Carburized (most)
  - ✓ Induction hardened (significant)
  - ✓ Through hardened (large)



## Fatigue Strength Improvements for Gearing

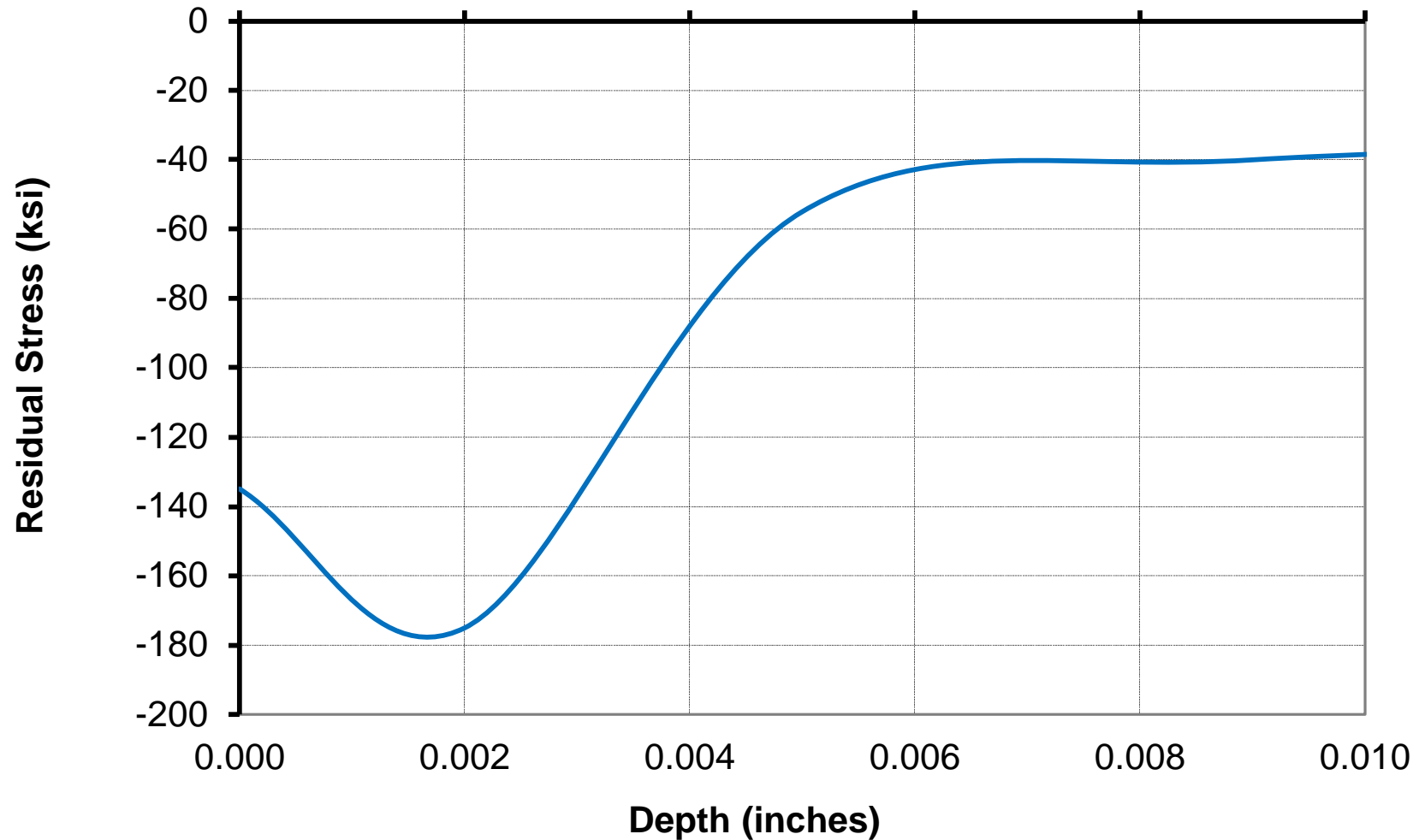
- ✓ Tooth root bending: 15-30% can be expected.
- ✓ Tooth flank fatigue: 15-20% (surface durability)



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

- The world of gearing is very broad in size, tooth geometry, heat treatment, and tooth flank finishing
- There is no gear geometry that isn't a candidate for shot peening.
- Tooth root fillet radius, flank surface finish & failure mode are the primary variables in customizing a peening callout
- We believe that many older gear designs have outdated shot peening callouts that can be improved.
  - ✓ "Regular" hardness shot media (Boeing callout) may offer limited 'up-rating'.
  - ✓ High shot peening callouts on precision gears may erode surface finish to an undesirable level.

## CARBURIZED GEAR: RESIDUAL STRESS CURVE

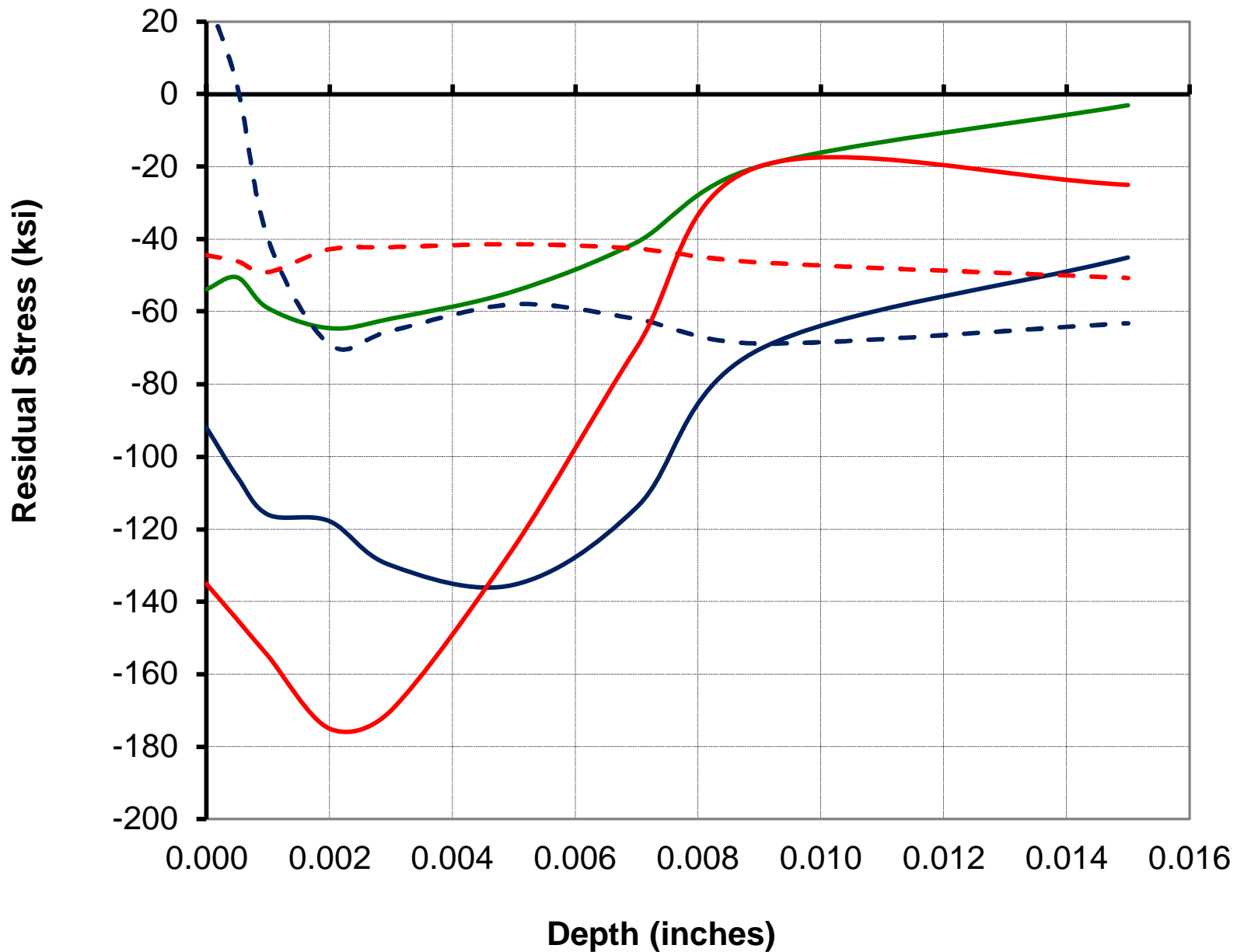


### Residual stress when shot peening carburized gears:

- ✓ Max compressive stress is slightly subsurface
- ✓ Surface is less compressed (than subsurface)
- ✓ Surface can be subsequently processed (Dual peen, Vibe SF) for additional improvement

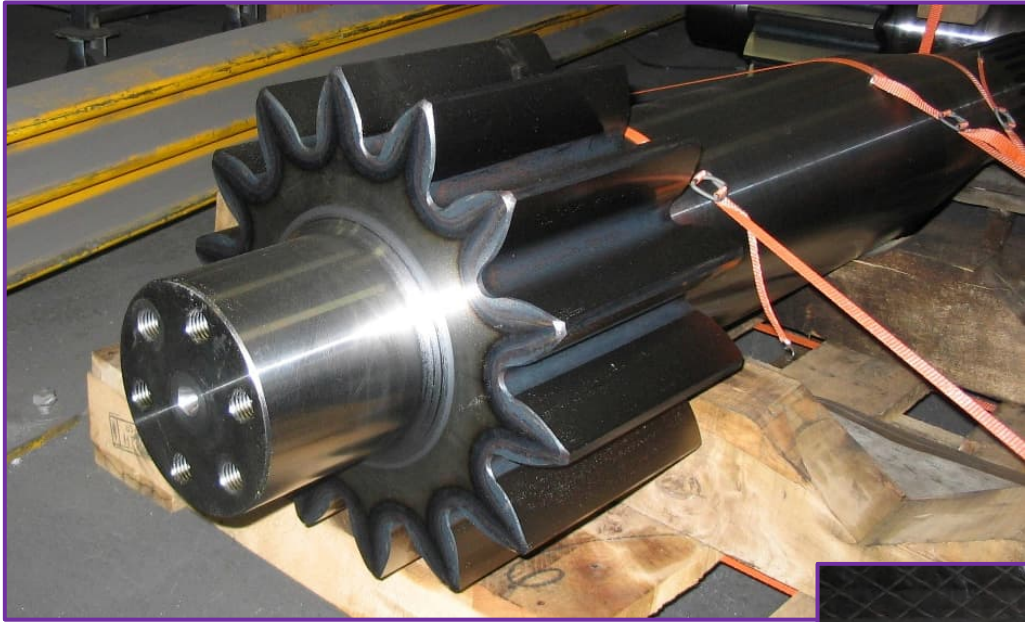


# RESIDUAL STRESS FROM PEENING DIFFERENT GEAR STEELS



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?



## Very large mining pinion gears:

- ✓ Induct hardened & ground
- ✓ Large steel shot, minimize overspray on tooth flanks
  - *No masking of flanks*

## Agricultural gears:

- ✓ Carburized
- ✓ Steel peened



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?



## Recreational marine pinion gears:

- ✓ Carburized
- ✓ Dual peened
  - *Steel then smaller steel media*



## Recreational marine gears:

- ✓ Carburized & ground
- ✓ Dual peened
  - *Steel then glass beads*



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?



## Very large mining pinion gears:

- ✓ Through hardened
- ✓ Large steel shot, minimize overspray on tooth flanks

## Very large mining bull gear:

- ✓ Through hardened
- ✓ Large steel shot, minimize overspray on tooth flanks



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

## What types of gears does MIC process?



High Volume:  
Powdered Metal Gears



High Volume: Automotive gears

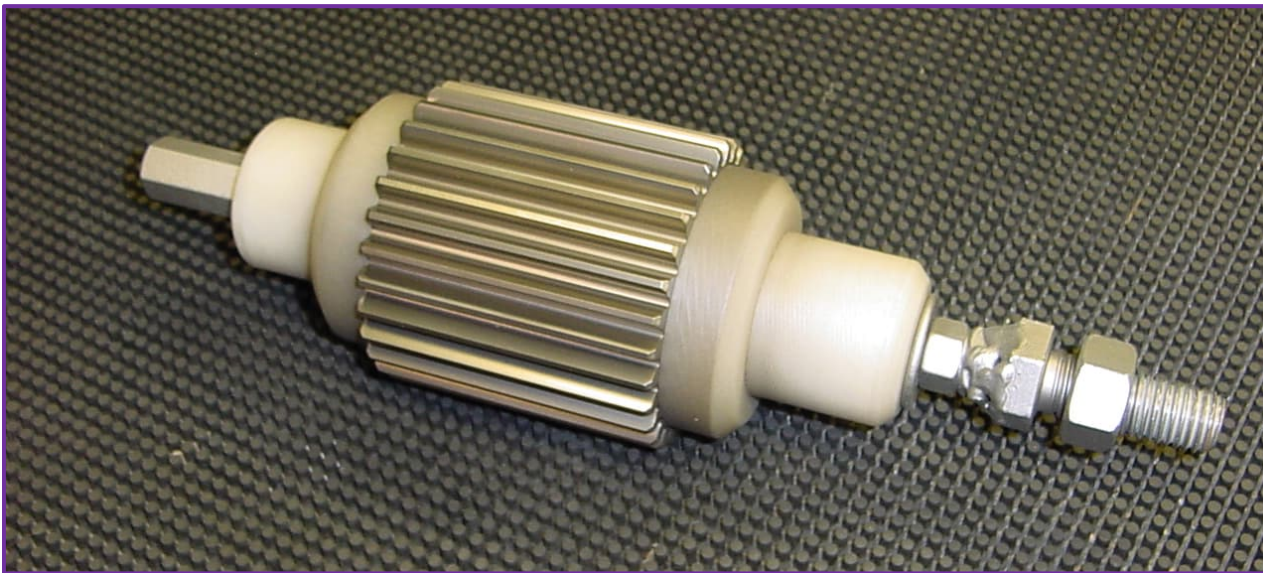


# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?

## Aerospace gears (with tooling):

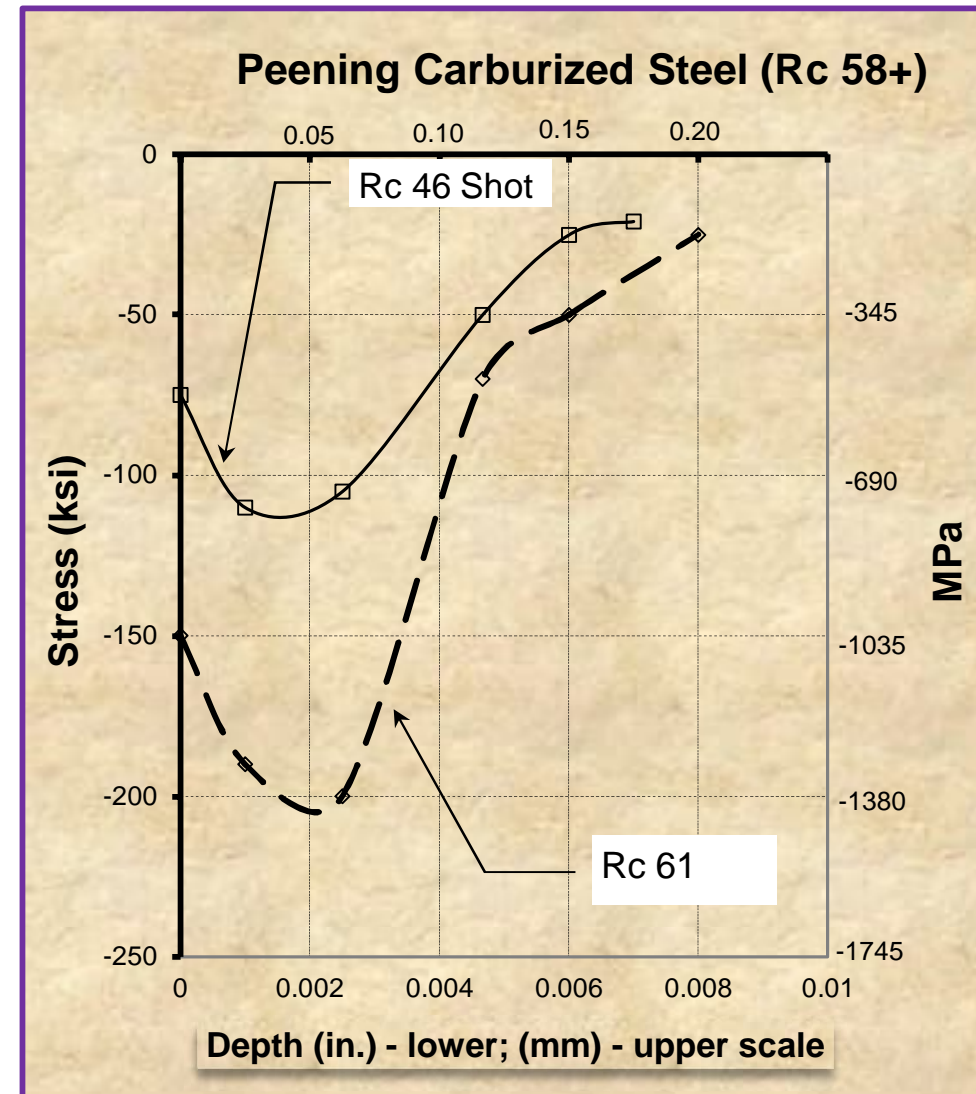
- ✓ Carburized & ground
- ✓ Tooling masks finished surfaces
- ✓ **Regular** hardness shot (45-52 HRc)
  - *Better alternatives?*



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

## Compare Residual Stress:

- ✓ Solid Line – Regular Hardness Shot
  - 45-52 HRc
  - *Carburized gear surface is harder than shot*
- ✓ Dashed Line – Hard Shot
  - 55-62 HRc
  - *Significant improvement in residual stress and up-rating of gear*



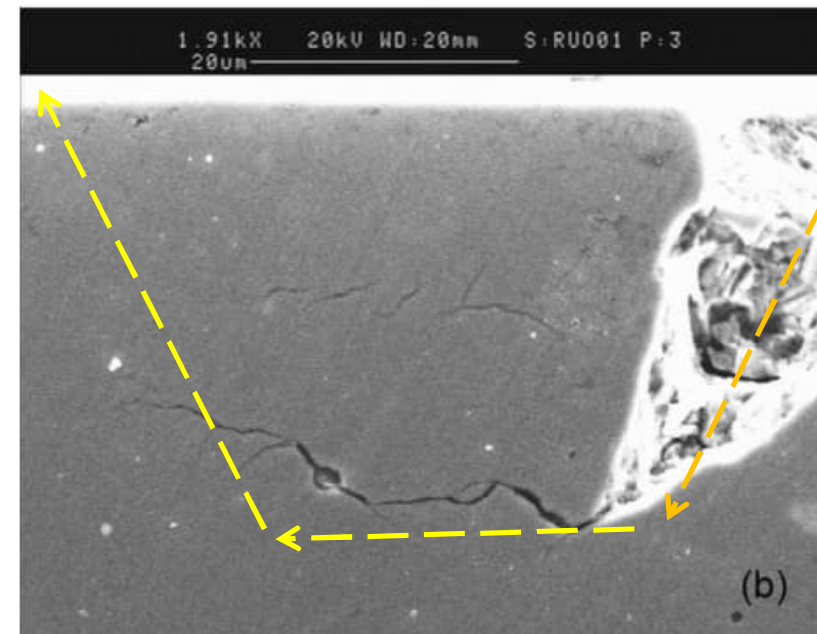
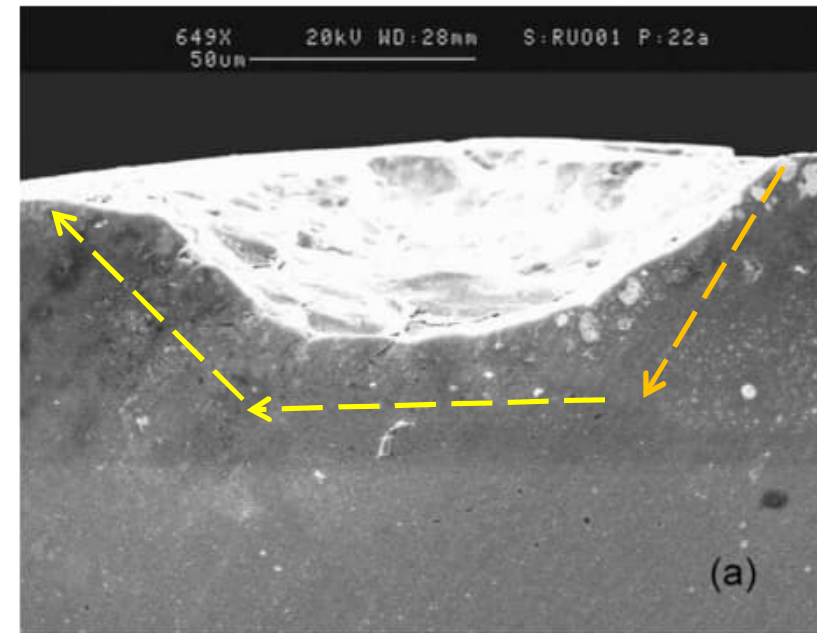


## STAGES OF MICROPITTING

1. Micro-cracks grow in downward direction
  - Compressive stress is beneficial
2. Crack changes direction and moves parallel to surface
  - Hydrostatic oil pressure advances crack
3. Crack moves toward surface
  - Material breaks away

### Additional Comments:

- ✓ 15-20% uprating of tooth flank durability
  - Not a lot of published data
- ✓ Dedendum (near pitch line) is area most likely affected
  - Rolling & Sliding are in opposite directions



## STAGES OF MICROPITTING

1. Micro-cracks grow in downward direction
  - Compressive stress is beneficial
2. Crack changes direction and moves parallel to surface
  - Hydrostatic oil pressure advances crack
3. Crack moves toward surface
  - Material breaks away



# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?



## Industrial gears:

- ✓ Carburized
- ✓ Steel shot peened (no masking)
- ✓ After peening grind teeth, avoid grinding roots
- ✓ Least expensive way to shot peen

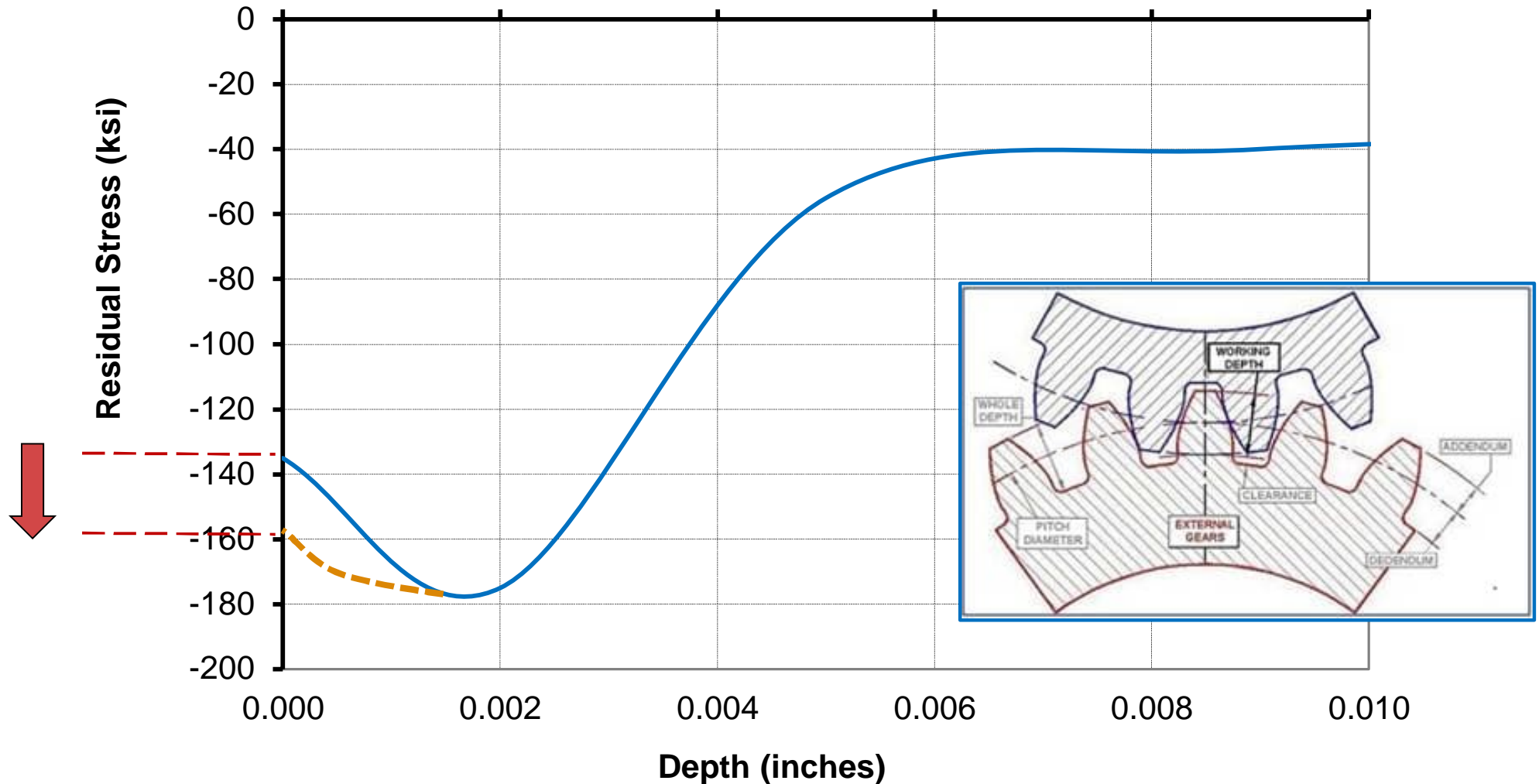
## Energy exploration gears:

- ✓ Carburized
- ✓ Steel shot peened (no masking)
- ✓ Grind teeth, avoid grinding roots after peening
- ✓ Least expensive way to shot peen





# SHOT PEENING GEARING – SECONDARY PROCESSING



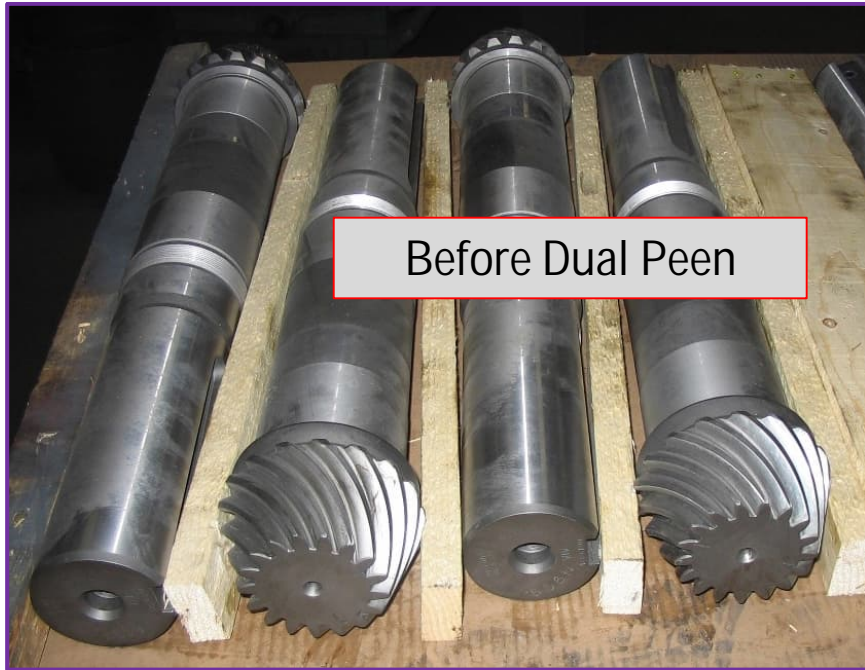
Secondary processing (bending & pitting fatigue improvement):

- ✓ Improve compressive stress at surface
- ✓ Improve surface finish

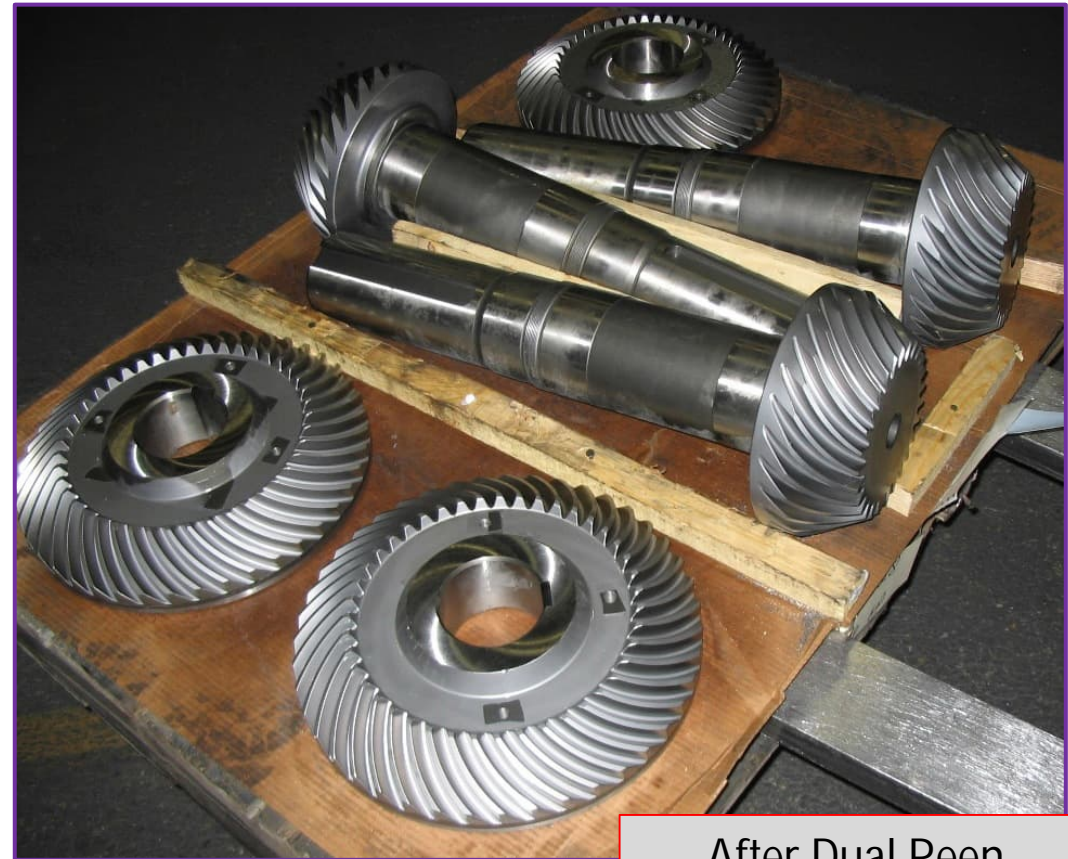


# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?



Before Dual Peen

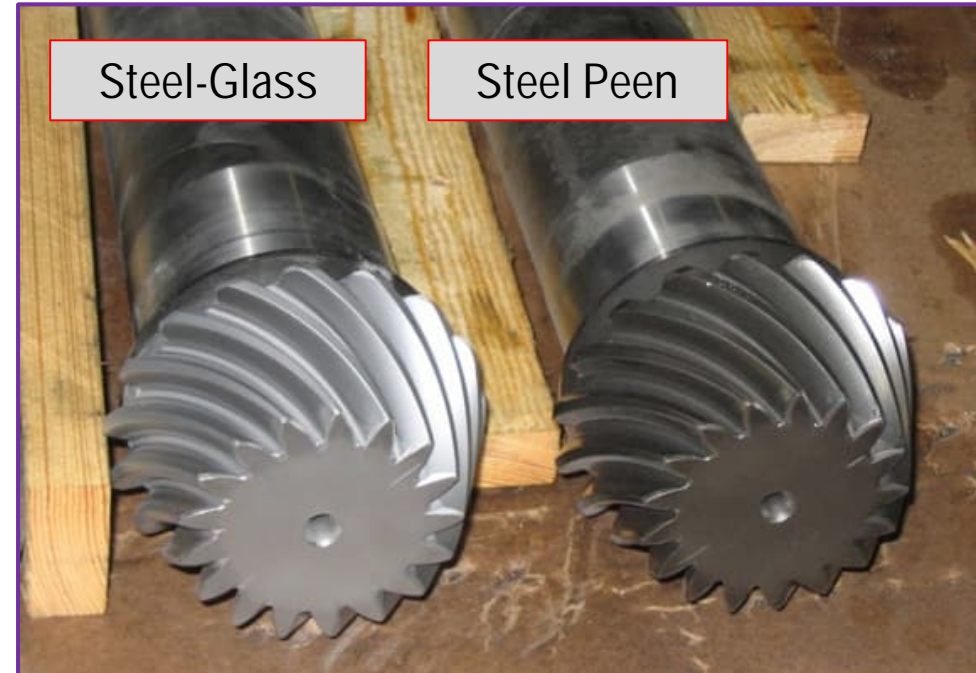
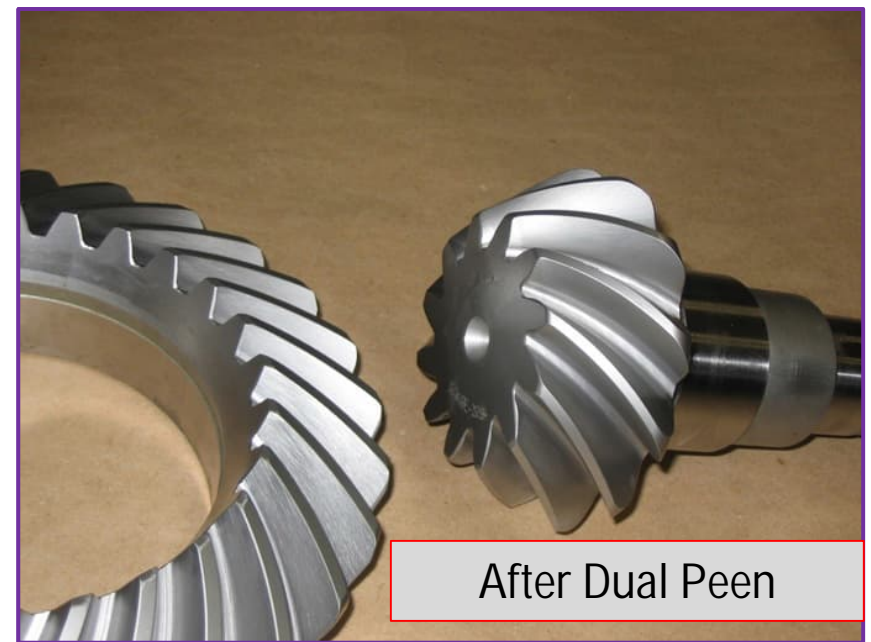
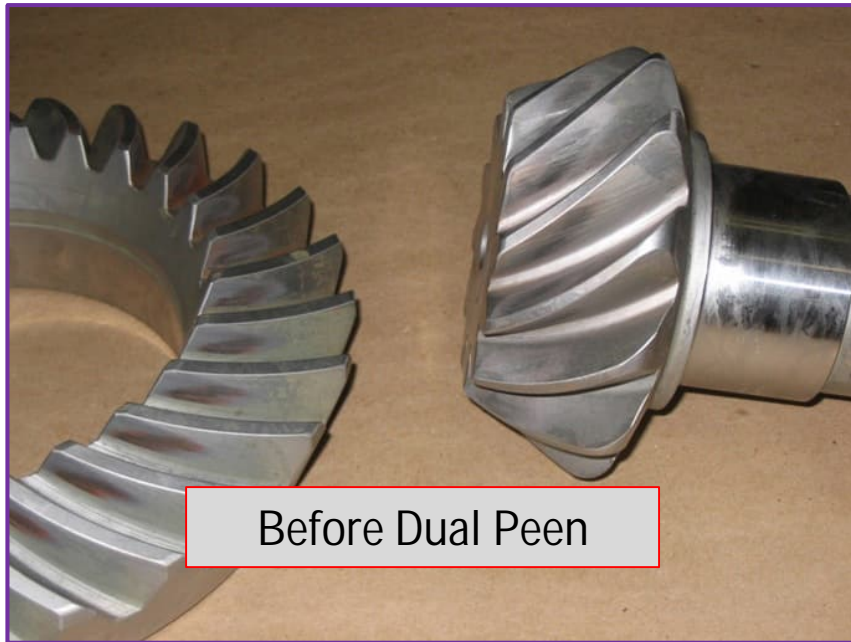


After Dual Peen

## Industrial gears:

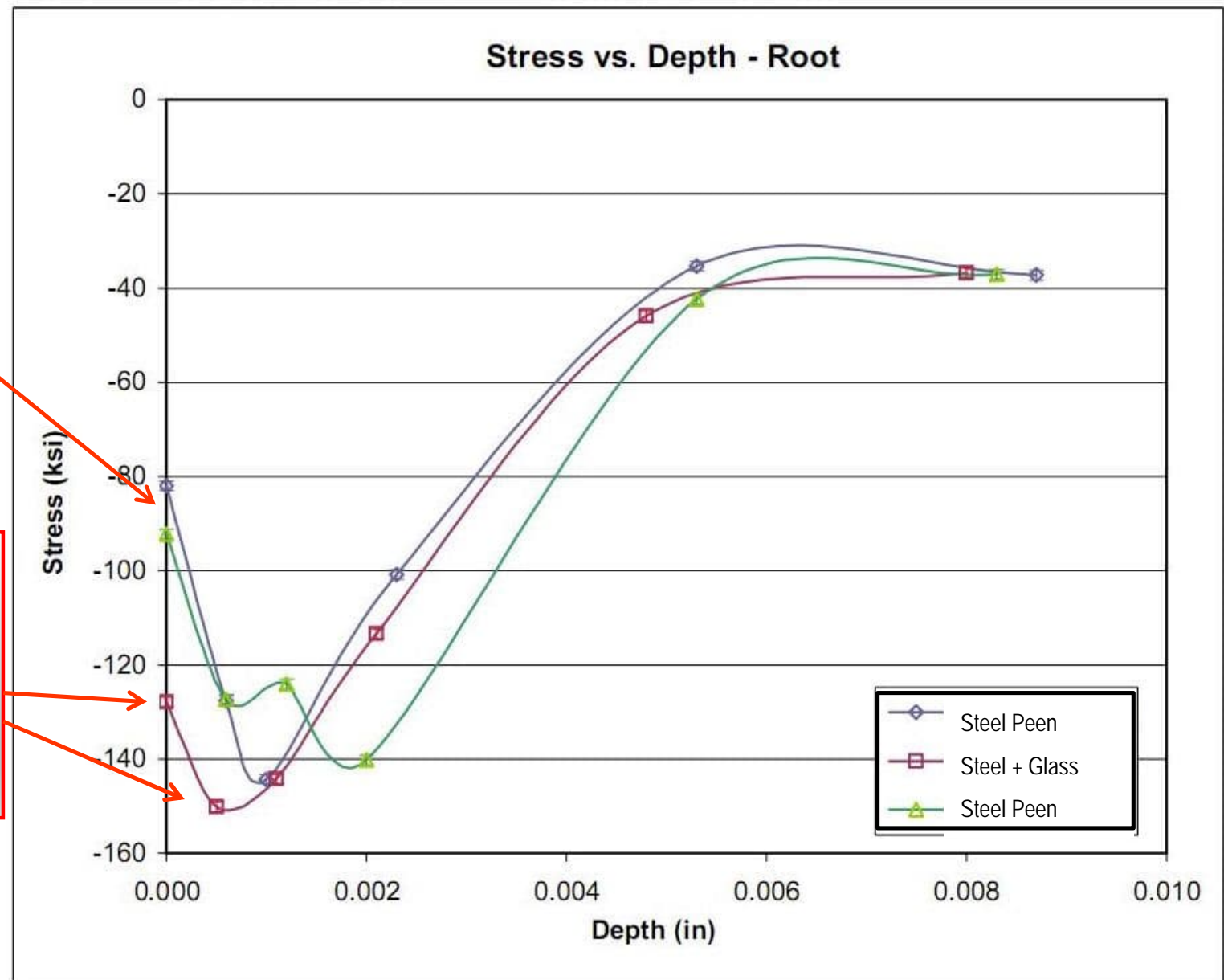
- ✓ Carburized & ground
- ✓ Dual shot peened (steel then glass)
- ✓ Premium shot peen, offers improvement in bending & tooth flank contact fatigue

## More steel-glass dual peening photos





# SECONDARY PEENING – RESIDUAL STRESS ENHANCEMENT (INDUCTION HARDENED GEARS)



Hard Shot Peened

Hard Shot + Glass  
Beads:

- Better surface compression
- Increased Max compression
- Better Surface Finish

# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?

## Agricultural Tractor:

- ✓ Engine was updated ~ 20%
- ✓ FWD gear set was failing on the flanks
- ✓ Steel-Glass dual peen allowed same gears to be updated
- ✓ No re-design of gears, bearings, etc... required
- ✓ Multiple tractors benefitted



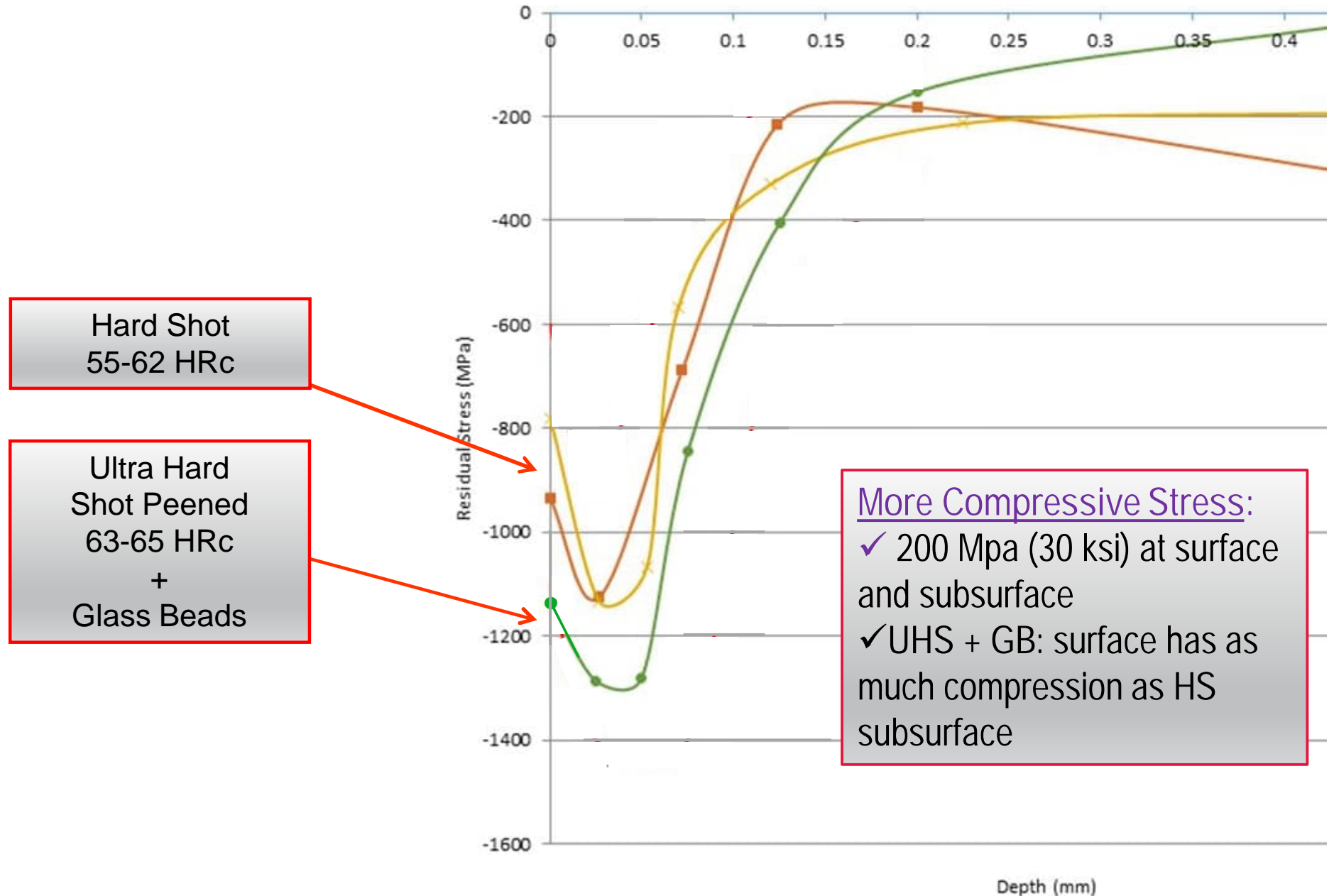
## Carb & Ground Bevel Gears:

- ✓ Steel + Glass Dual Peen
- ✓ Uprate Tooth Roots & Flanks





## AS CARBURIZED GEARS GET HARDER: ULTRA HARD SHOT VS HARD SHOT



## SHOT PEEN BEFORE SUPER FINISHING (OR GLASS BEADING)

The above discussion applies only to bending fatigue resistance and caution should be exercised regarding shot peening and Hertzian fatigue resistance. The tooth flanks should not be shot peened because their surfaces will be made somewhat harder and rougher, and the flanks might create micropitting on the mating gears. To prevent this problem, the shot peened flanks can be super-finished. Generally, shot peened flanks that are super-finished after shot peening have maximum micropitting and macropitting resistance.

**Robert L. Errichello** heads his own gear consulting firm, GEARTECH ([geartech@mt.net](mailto:geartech@mt.net)), and is founder and creator of GEARTECH software, Inc. He is a technical editor for Gear Technology magazine and STLE Tribology Transactions. Bob is also a recipient of the AGMA TDEC, AGMA E.P. Connell, AGMA Lifetime Achievement, STLE Wilbur Deutch Memorial, and AWEA Technical Achievement Awards.



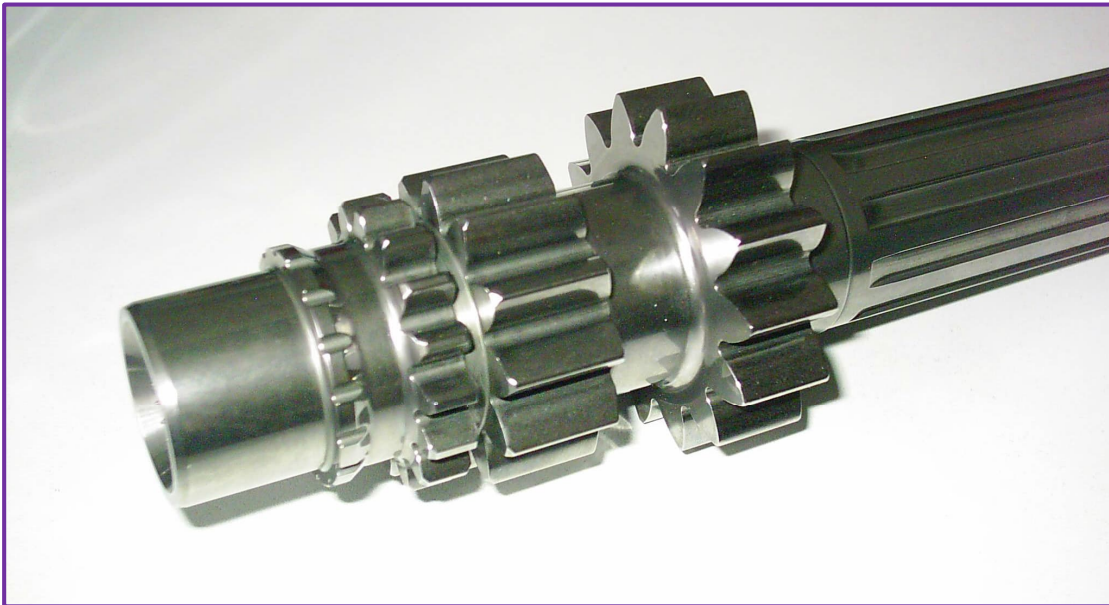
[[www.geartechnology.com](http://www.geartechnology.com)]

# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

What types of gears does MIC process?

## Precision gears:

- ✓ Carburized & ground
- ✓ Isotropic finishing (after peening)



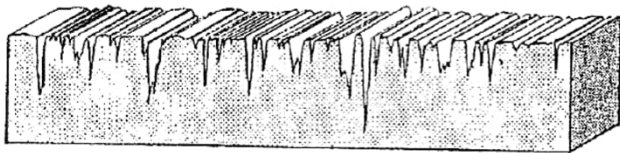


## MIC SUPER FINISHING – CENTER OF EXCELLENCE; ROMULUS, MI

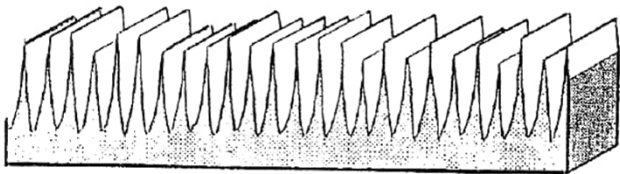




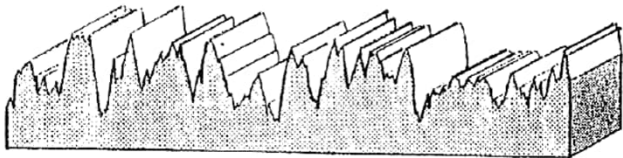
# SURFACE FINISH CONSIDERATIONS



$R_a = 2,4 \mu\text{m}$

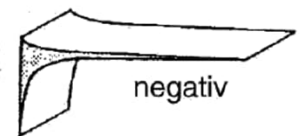
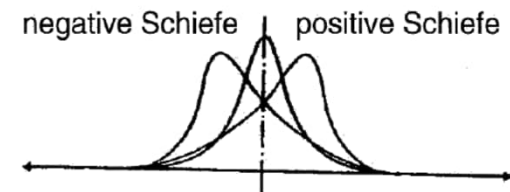


$R_a = 2,5 \mu\text{m}$

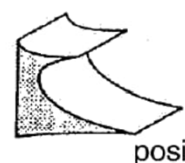
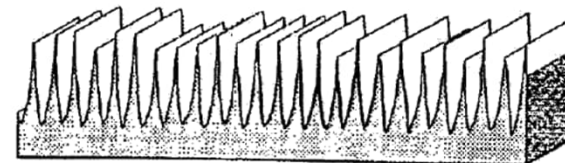


$R_a = 2,4 \mu\text{m}$

Similar  $R_a$  values  
Different peak pressures



negativ



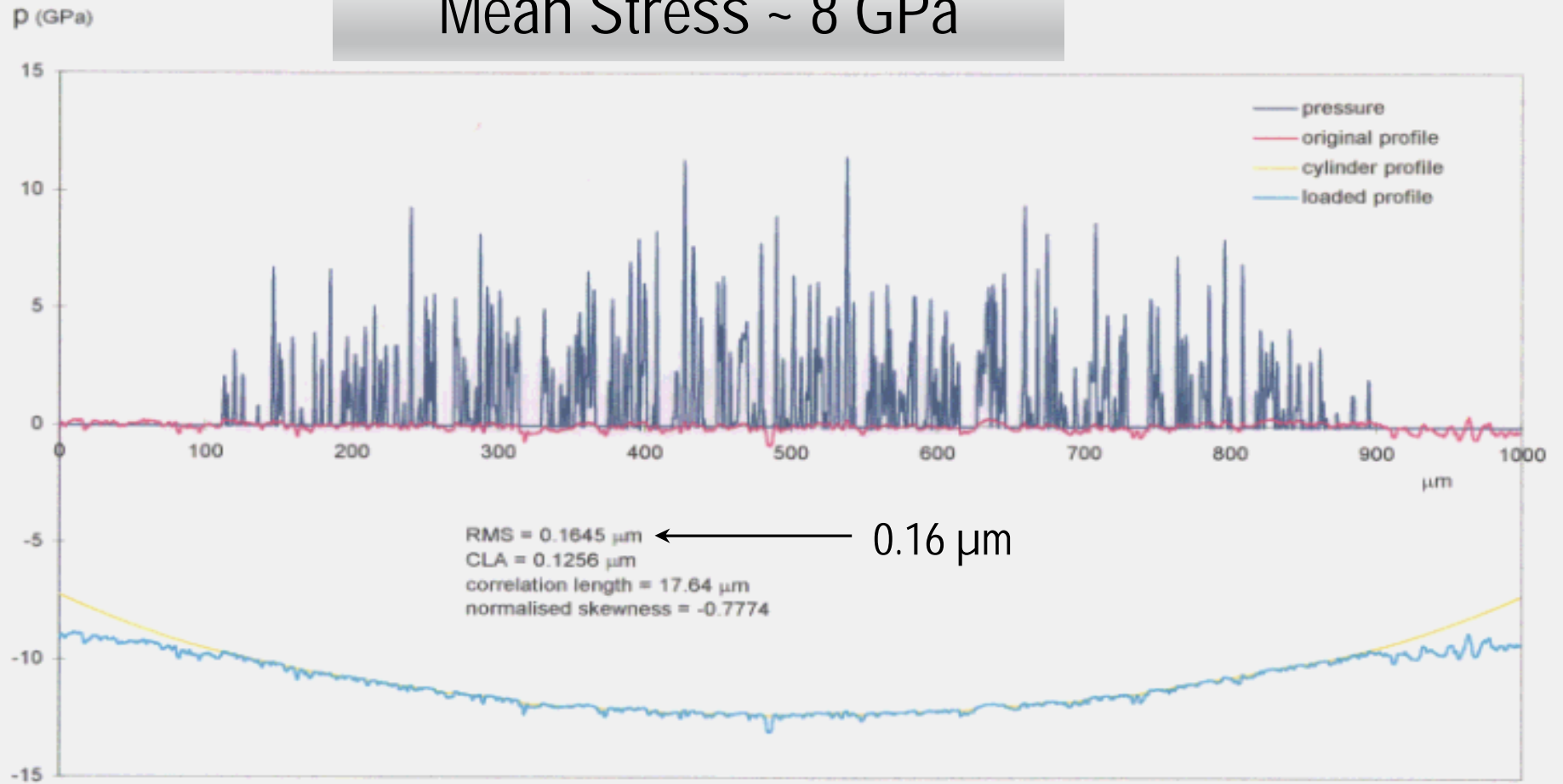
positiv

Surface Profile Skew ( $R_{sk}$ ) is  
Very Important (negative is desired)

# CONTACT STRESS COMPARISON

## 'As Ground' Surface

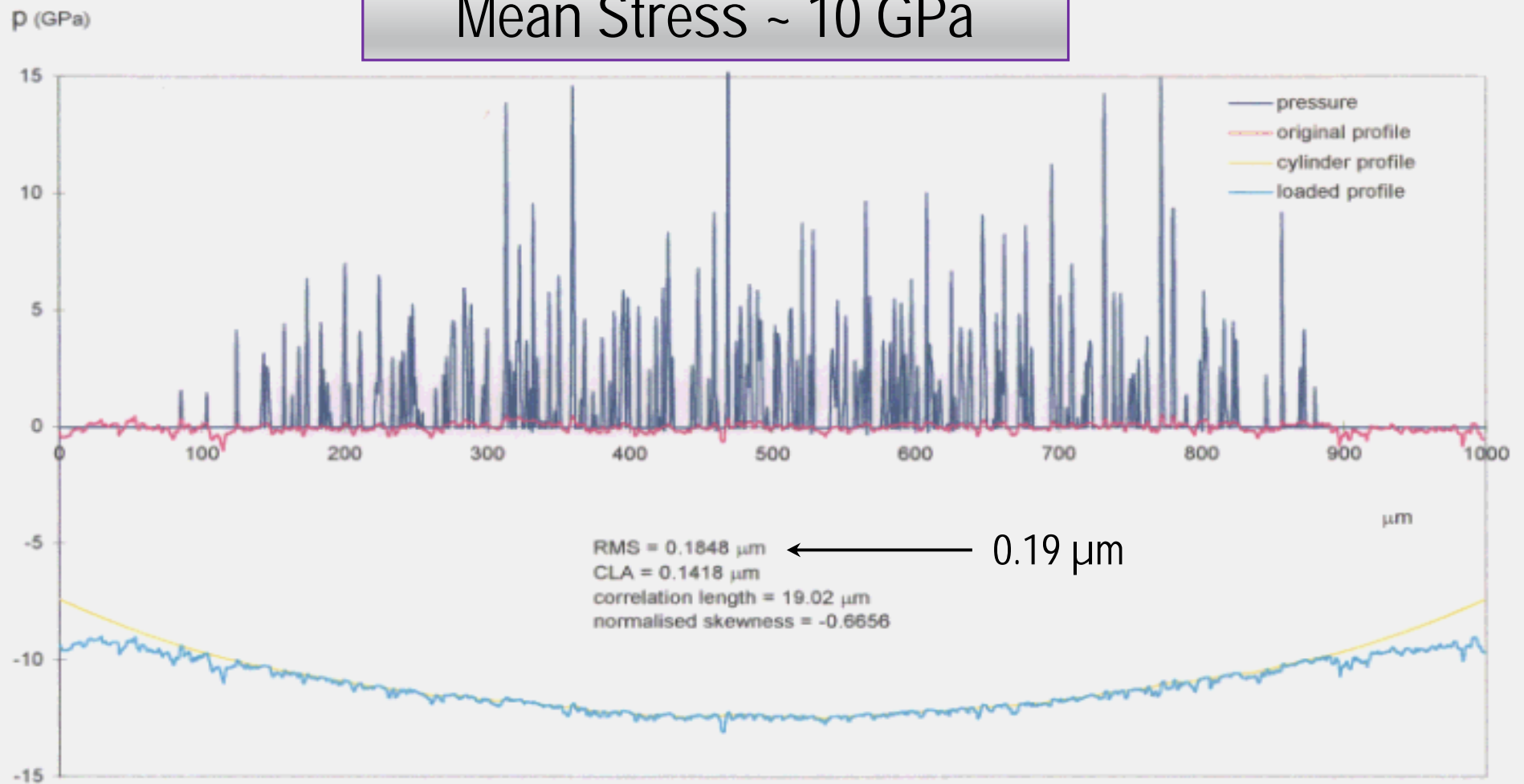
Mean Stress ~ 8 GPa



# CONTACT STRESS COMPARISON

## Ground & Shot Peened

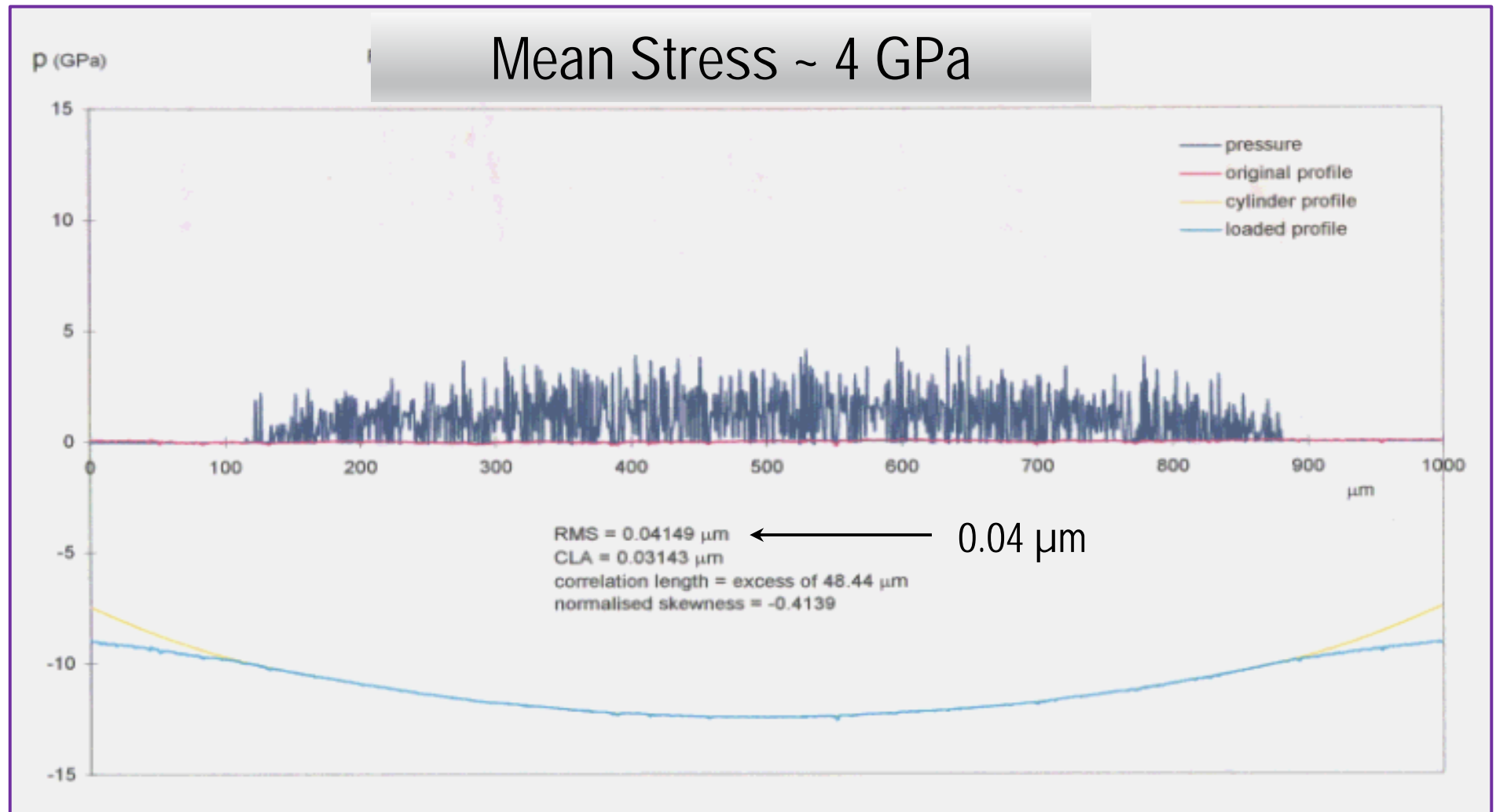
Mean Stress ~ 10 GPa





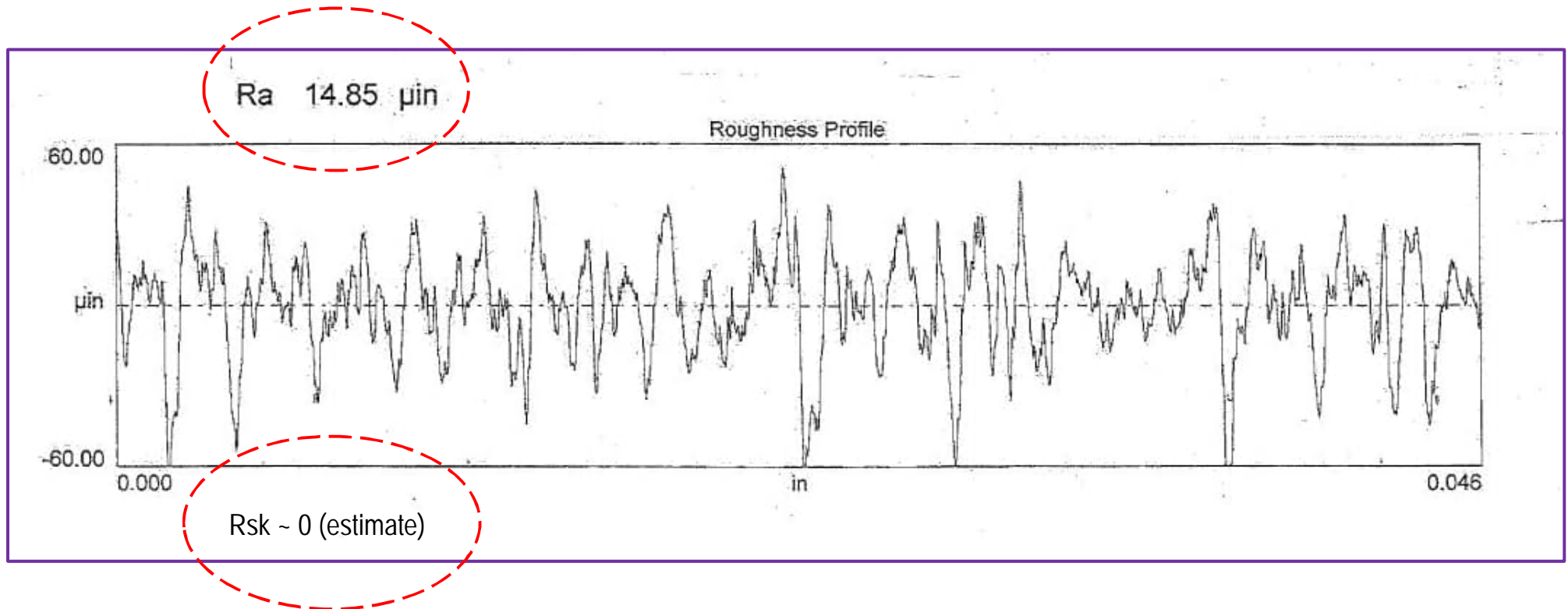
# CONTACT STRESS COMPARISON

## Ground, Shot Peened & Super Finish



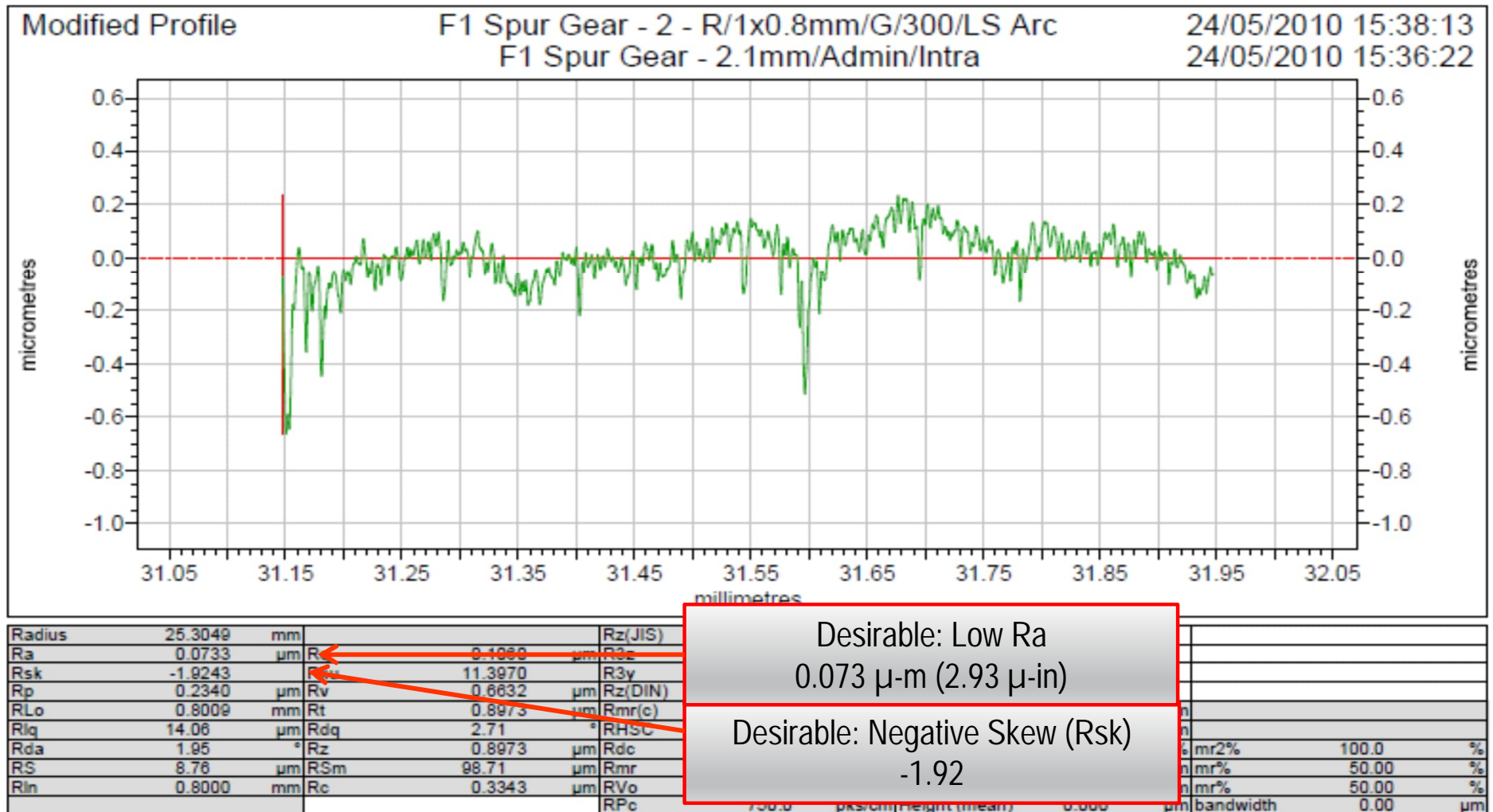
# SHOT PEENED

## Surface Finish of Carburized & Ground



# SHOT PEENED & SUPER FINISHED

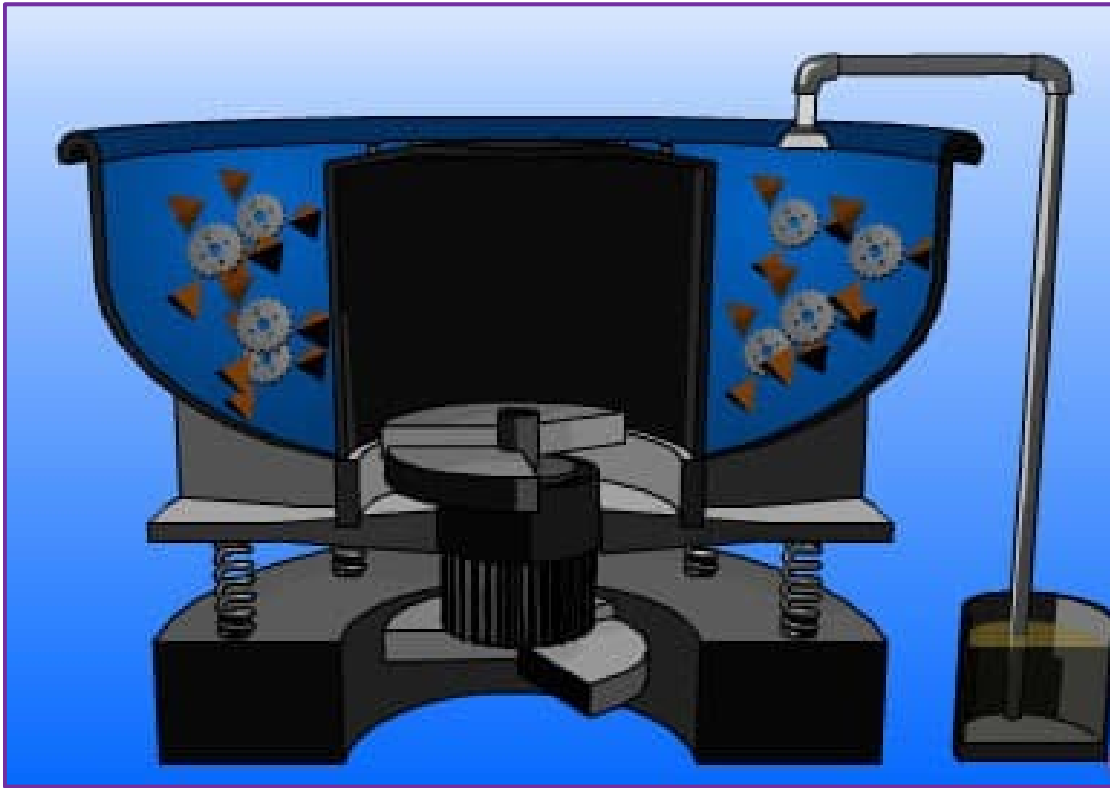
## Surface Finish of Carb, Ground & Super Finished





# GERMAN GEAR ASSOCIATION (FVA)

## Optimization of Flank Load Capacity



### PITTING RESISTANCE (2009 Study)

Baseline: As Ground  
100%

Super Finished  
111%

Shot Peen + Super Finish  
121%

# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

## THINGS TO AVOID (there are no set rules you will find):

You should be able to find many case studies and reports on shot peening of gearing. However, you will have a hard time finding a standard set of guidelines on how to apply shot peening to various gear applications.

- High Intensity Shot Peening (on precision gears):
  - This is relative to shot diameter. A 0.012" A intensity is a high shot peen callout for a 0.011"Ø (110) shot, however, this is not a high callout for a 0.023" Ø (230) shot as the larger shot requires less velocity to have the same shot stream energy ( $KE = \frac{1}{2} mv^2$ )
  - The main problems will be
    - ✓ Rougher surface finish on the tooth flanks
    - ✓ Less desirable surface compressive stress
    - ✓ Burrs on tooth tips.

# CUSTOM APPLICATION OF SHOT PEENING TO GEARING

## THINGS TO AVOID (continued):

- Regular Hardness Shot (45-52 HRc) (on case hardened gears):
  - The shot should be as hard or harder than the material it is peening. Regular hardness shot will produce about half the amount of residual compressive stress if the shot is less hard than the surface it is peening (~ 100 ksi instead of 200 ksi for carburized gears).
- Concerns about rougher surface finish can be addressed by:
  - ✓ Reduce the intensity of the "Hard" media.
  - ✓ Subsequent processing:
    - Glass Beads, Ceramic, Vibe SF
    - All further improve surface finish and RS from initial peening.
    - Tooth flank contact fatigue properties can be 'uprated' when using these secondary processes.



## RECOMMENDED READING:

### AGMA 938-A05 Shot Peening of Gears:

- ✓ This document was generated due to the lack of available information on shot peening for gear engineers.
- ✓ AGMA did not allow any 'up-rating' in the document as they wanted each application to be up-rated by the gear designer.

