START

EFFECT OF PREHEATING ON STRESS AND DISTORTION IN INDUCTION HARDENING APPLICATIONS

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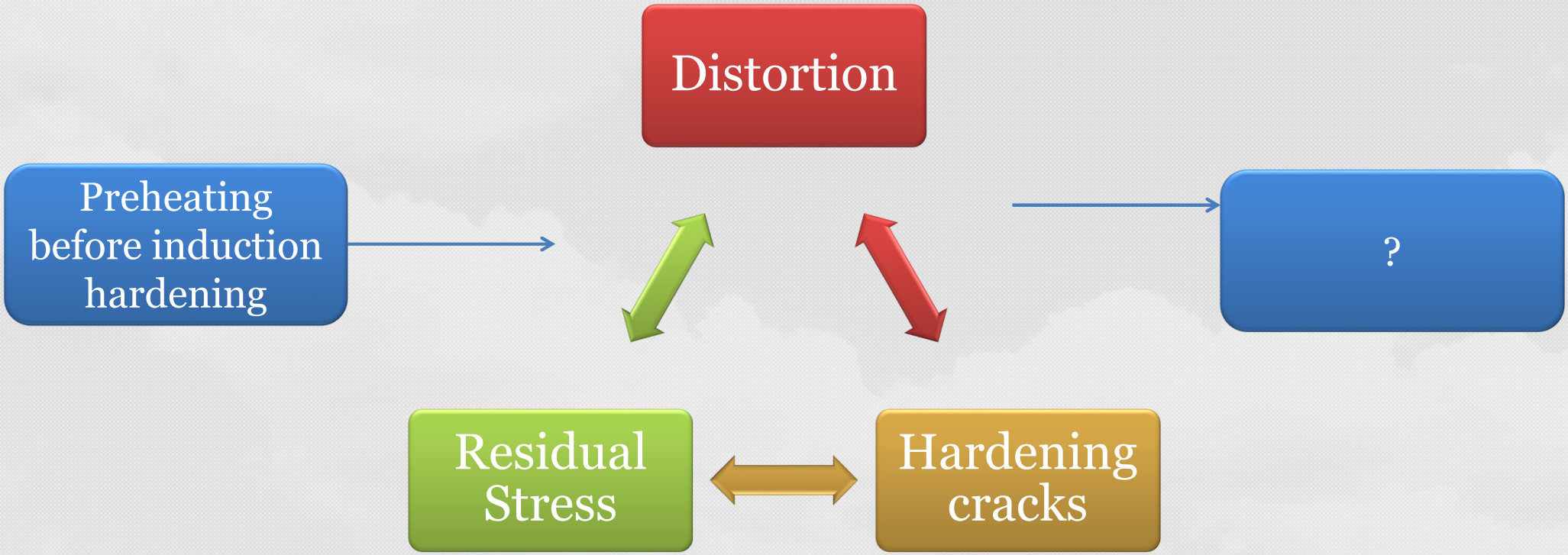
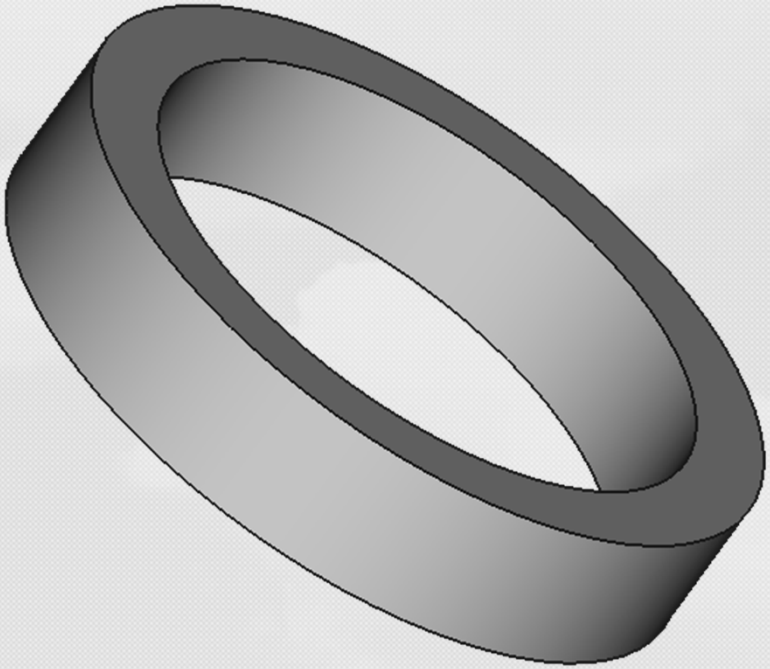
INTRODUCTION

STRESS AND STRAIN RELATED PROBLEMS IN INDUCTION HARDENING APPLICATIONS

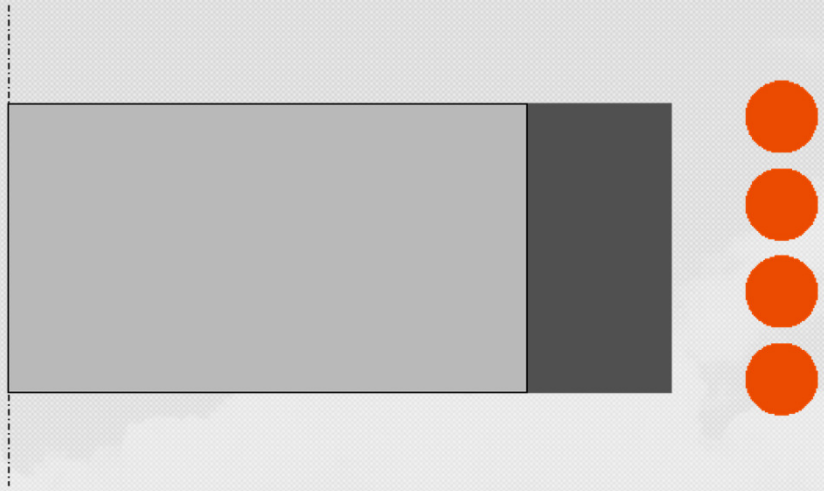


HARDENING OF RING

GEOMETRY AND HEATING SYSTEM



IR = 4 cm, OR = 5 cm, H = 2 cm

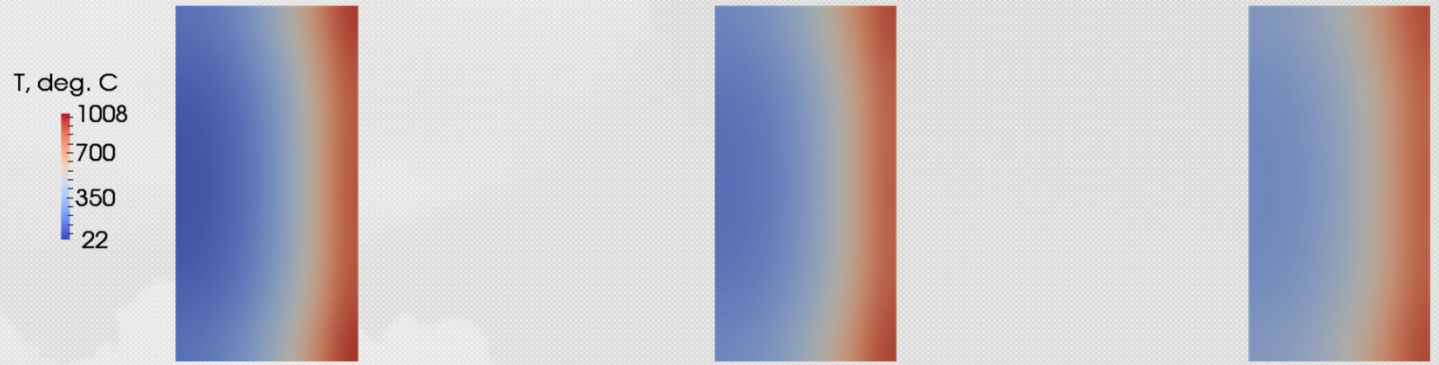


4-TURNS INDUCTION COIL, AIR GAP = 0.5 cm

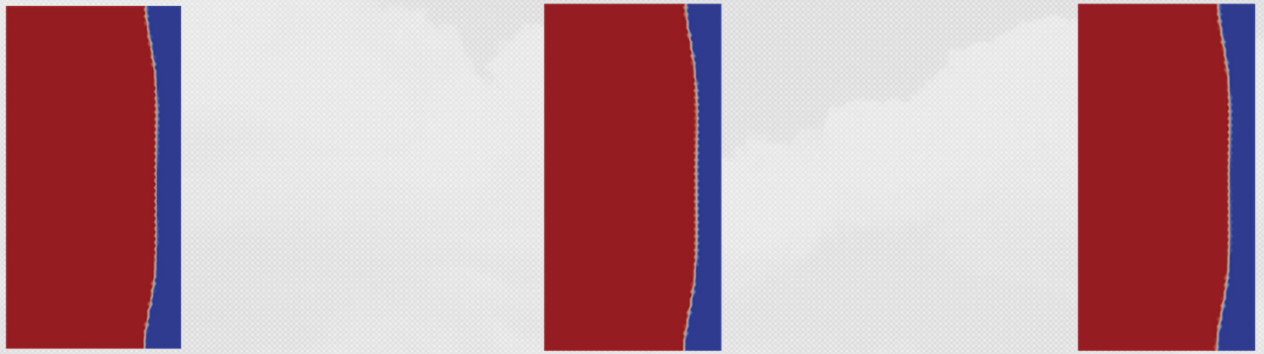
HARDENING OF RING

PROCESS VARIATIONS: FIXED HEATING TIME, EFFECT IS ADJUSTED TO GET THE SAME HARDENING PATTERN

TEMPERATURE AFTER HEATING



AUSTENITIZATION ZONE (BLUE AREA)



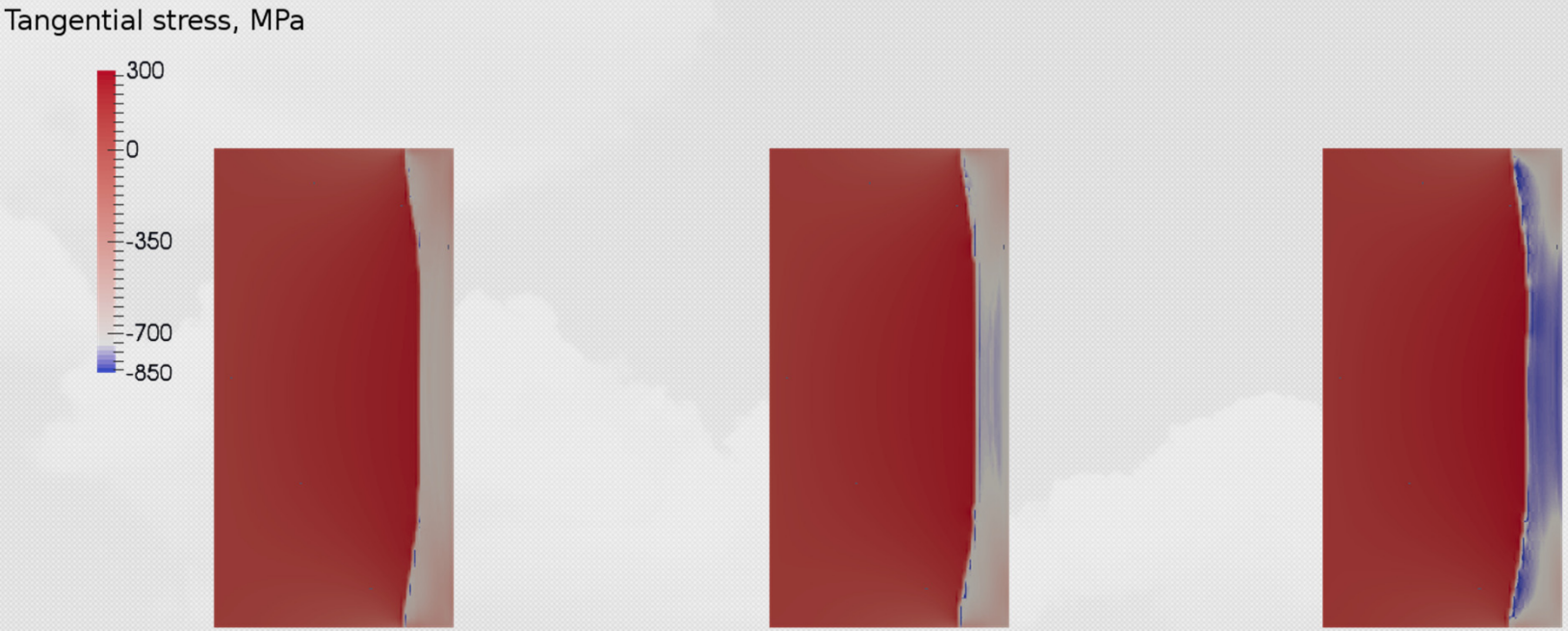
Ti = 20 °C

Ti = 120 °C

Ti = 220 °C

HARDENING OF RING

RESIDUAL STRESS DISTRIBUTIONS

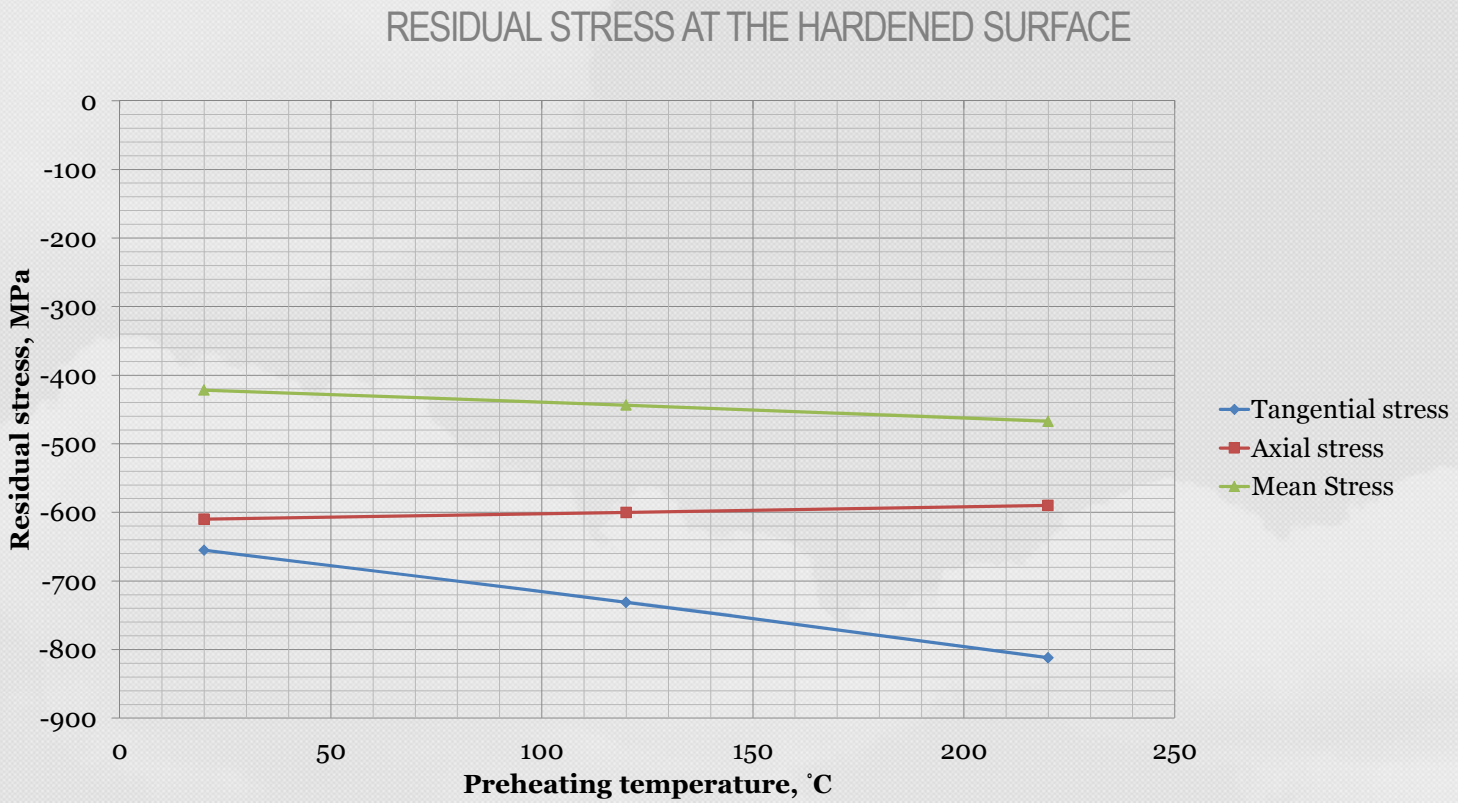


Ti = 20 °C

Ti = 120 °C

Ti = 220 °C

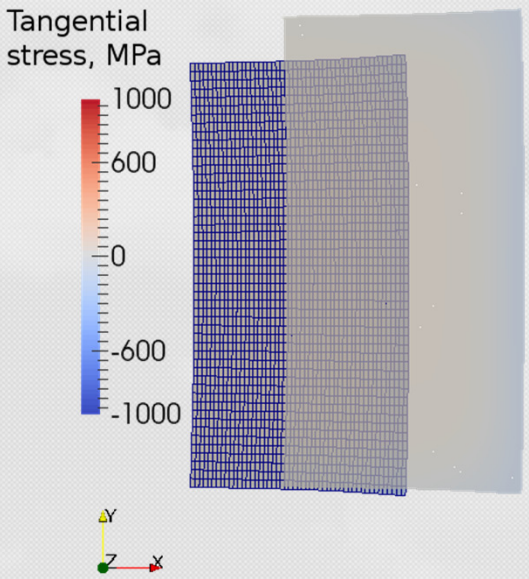
HARDENING OF RING



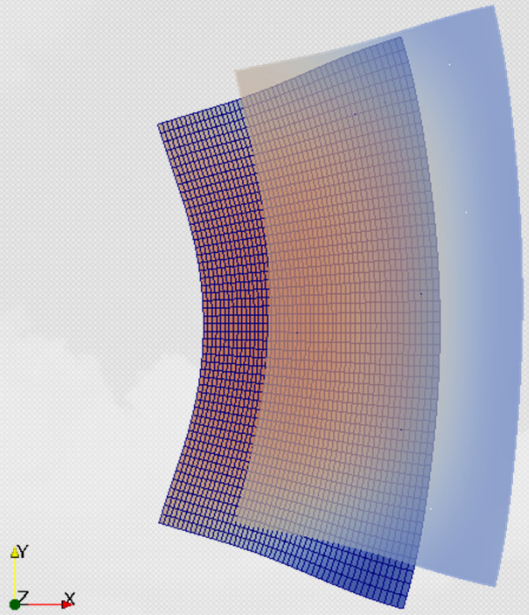
HOW PREHEATING AFFECTS RESIDUAL STRESS

STRESS AND DISTORTION AT DIFFERENT STAGES DURING THE PROCESS

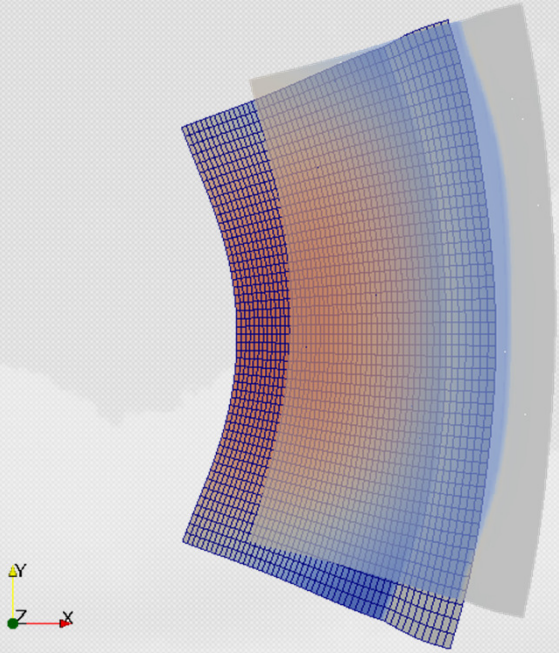
TRANSPARENT PART – PREHEATED TO 220 ˚C RING; PART WITH A GRID ON TOP – RING WITHOUT PREHEATING



CLOSE TO START OF HEATING



JUST BEFORE AUSTENITE TRANSFORMATION

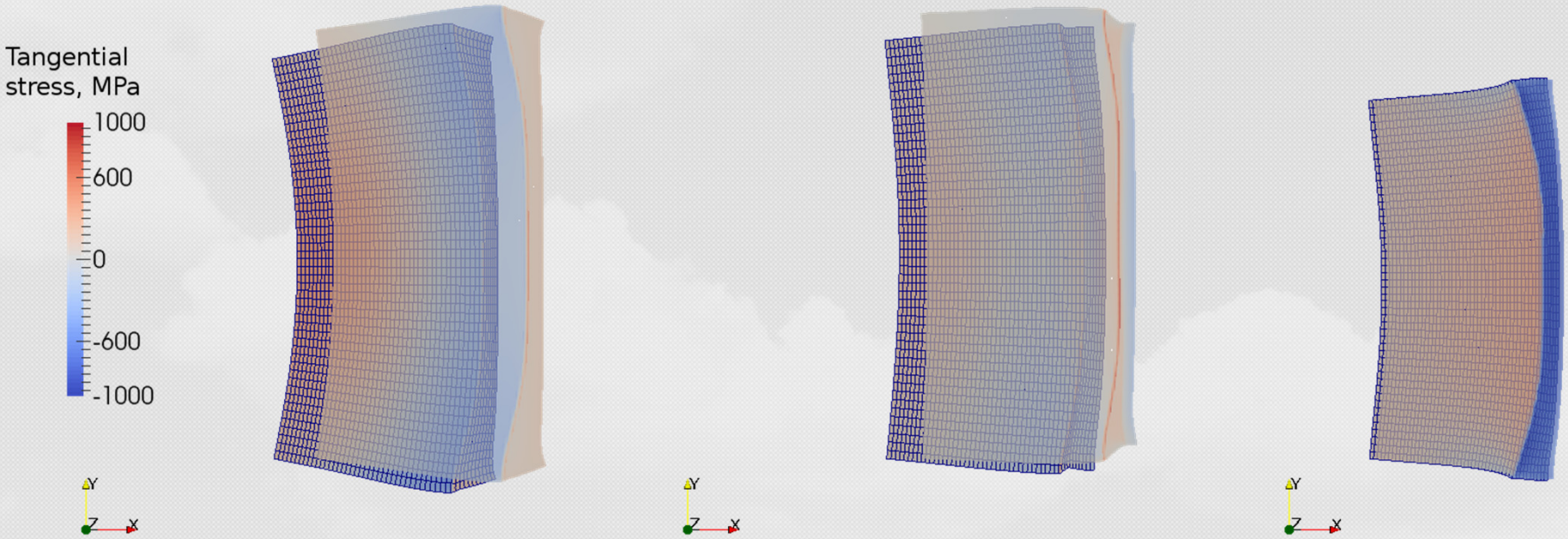


END OF AUSTENITE TRANSFORMATION

HOW PREHEATING AFFECTS RESIDUAL STRESS

STRESS AND DISTORTION UNTIL THE END OF TREATMENT

TRANSPARENT PART – RING PREHEATED TO 220 °C; PART WITH A GRID ON TOP – RING WITHOUT PREHEATING

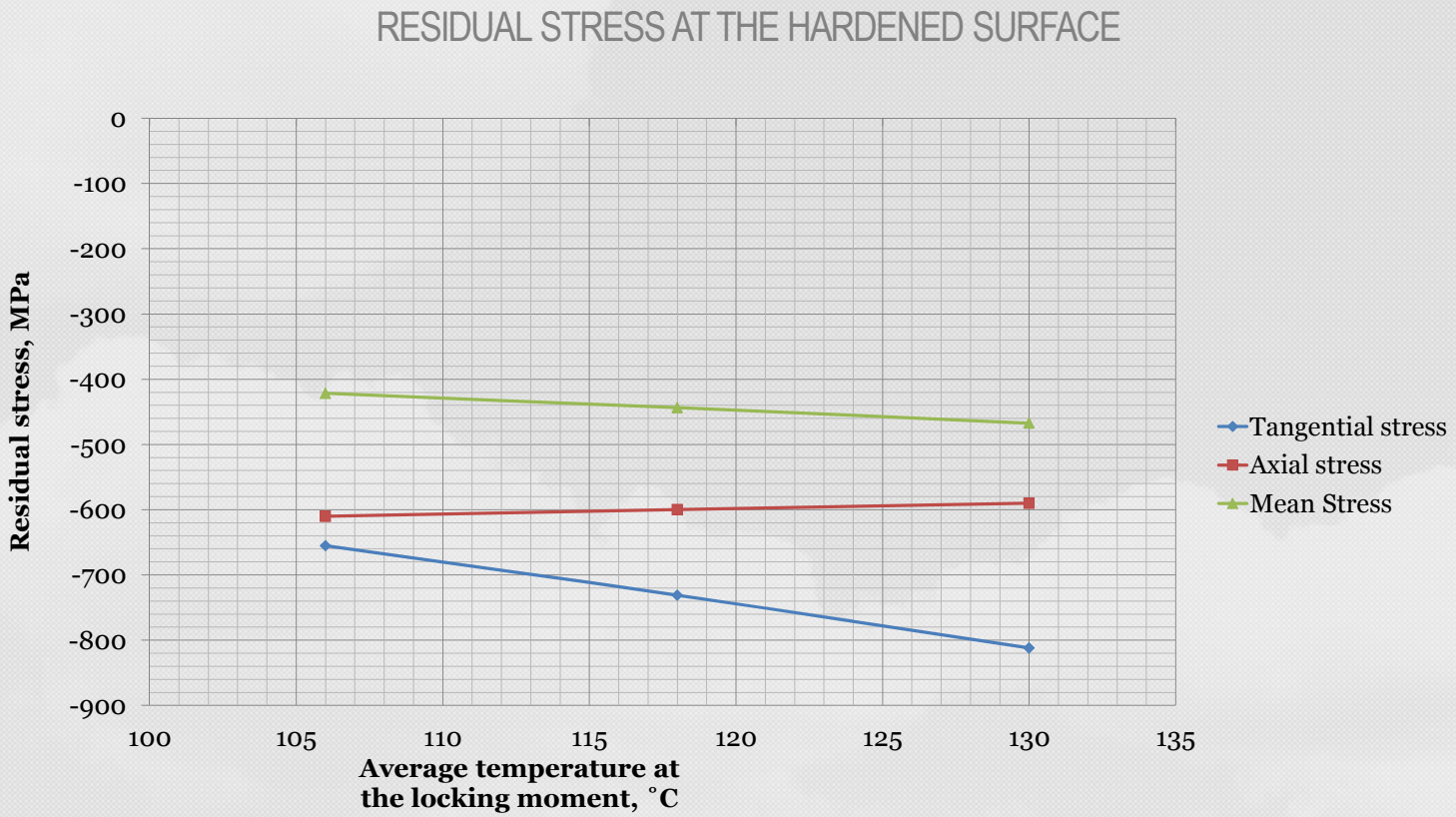


JUST BEFORE A SURFACE LOCKING

JUST AFTER THE SURFACE LOCKING

RESIDUAL STATE

HARDENING OF RING

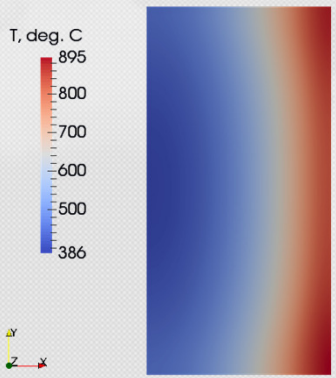


WHEN PREHEATING DOES NOT WORK

PROCESS VARIATIONS: FIXED SURFACE HEATING POWER, HEATING TIME IS ADJUSTED

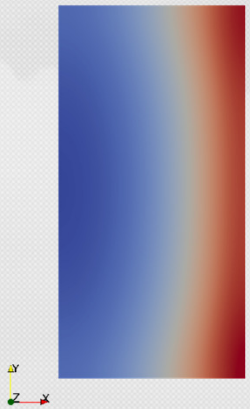
THE “THERMAL PENETRATION DEPTH” OF COMPONENT IS BIG – COMPONENT CONSIDERED AS “SMALL”

Heating Time = 5s



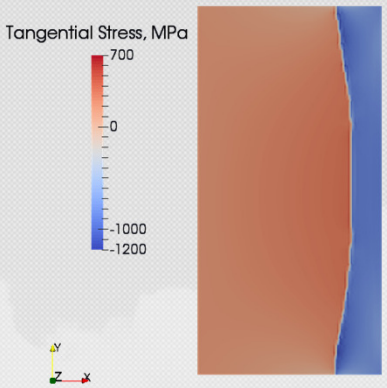
Ti = 20 ˚C

Heating Time = 3.2s

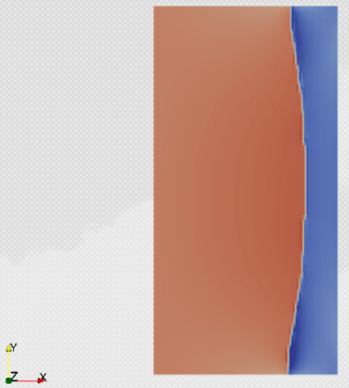


Ti = 220 ˚C

Residual stress



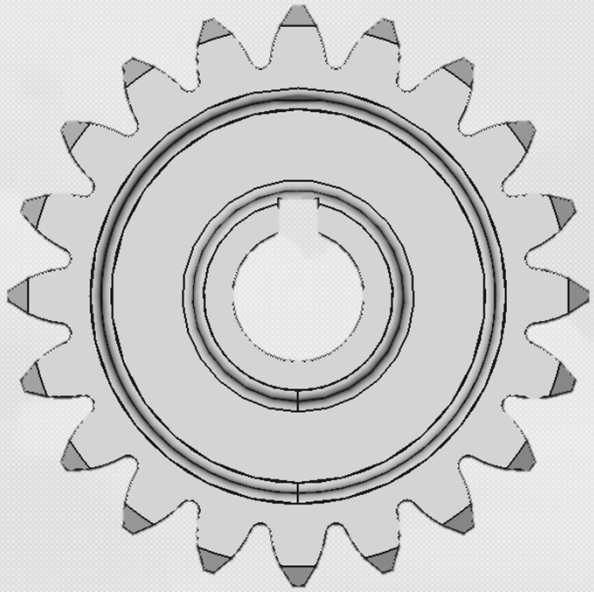
Ti = 20 ˚C

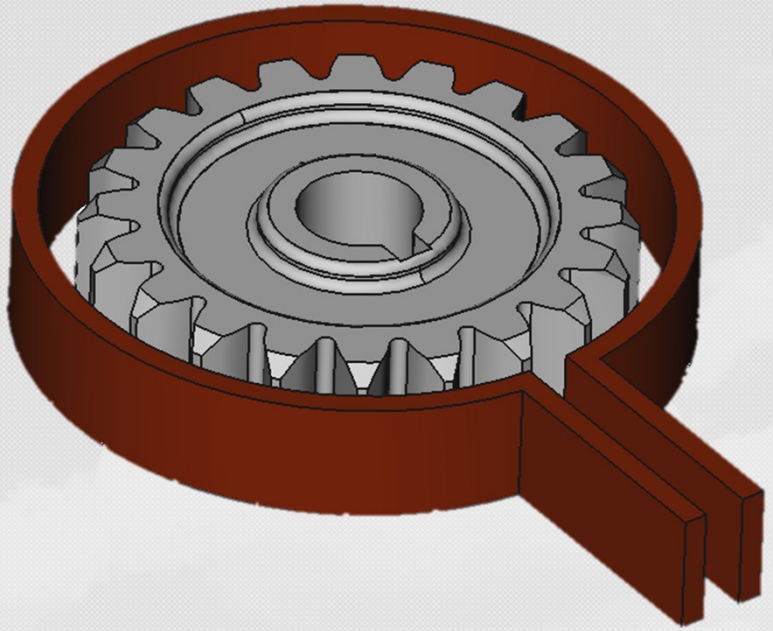


Ti = 220 ˚C

GEAR HARDENING. SINGLE SHOT

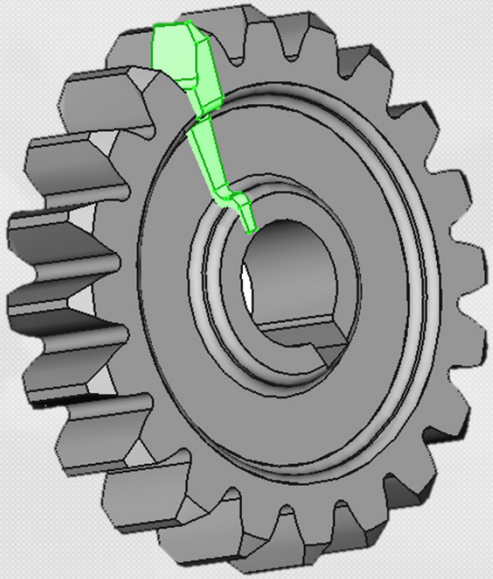
CONSIDERED SYSTEM

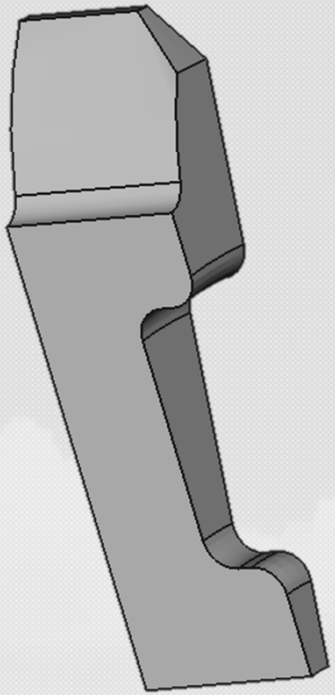


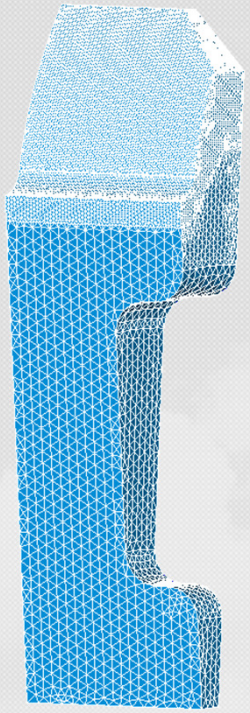


GEAR HARDENING. SINGLE SHOT

GEOMETRY AND MESH PREPARATION



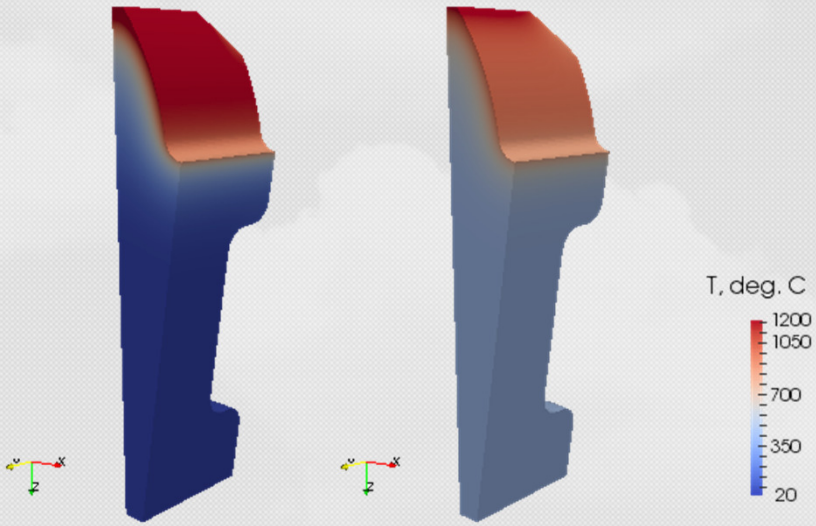




GEAR HARDENING. SINGLE SHOT

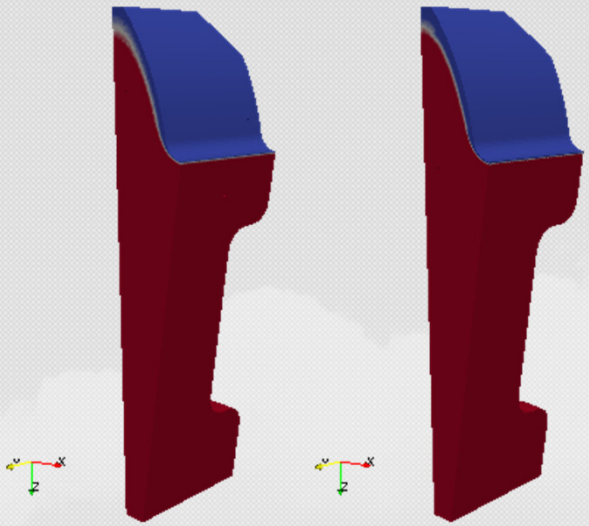
PROCESS VARIATIONS

TEMPERATURE AT THE END OF SHOT



NO PREHEATING PREHEATING 400 ˚C

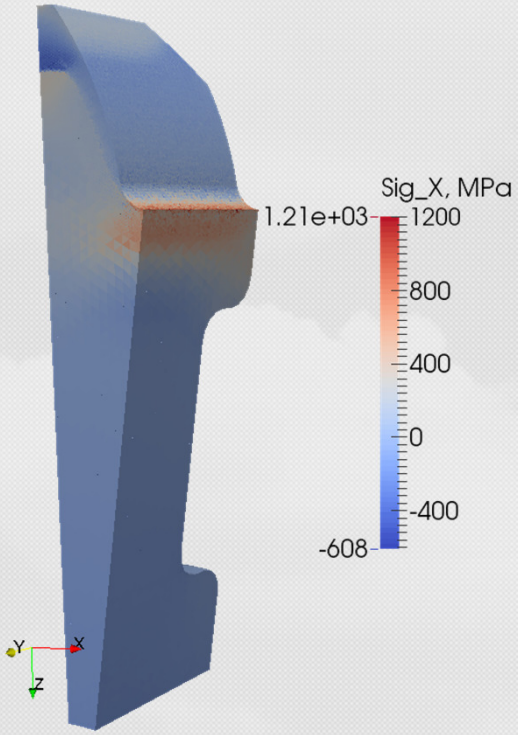
AUSTENITE DISTRIBUTION BEFORE QUENCHING



NO PREHEATING PREHEATING 400 ˚C

GEAR HARDENING. SINGLE SHOT

COMPARISON OF X-COMPONENT OF RESIDUAL STRESS



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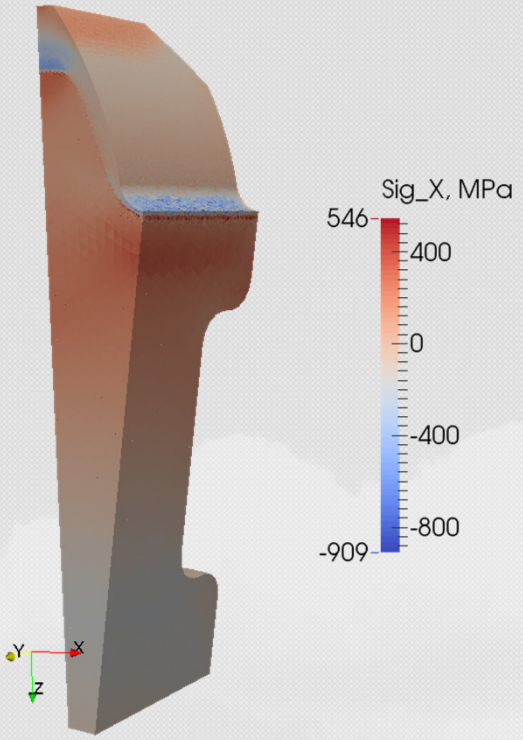
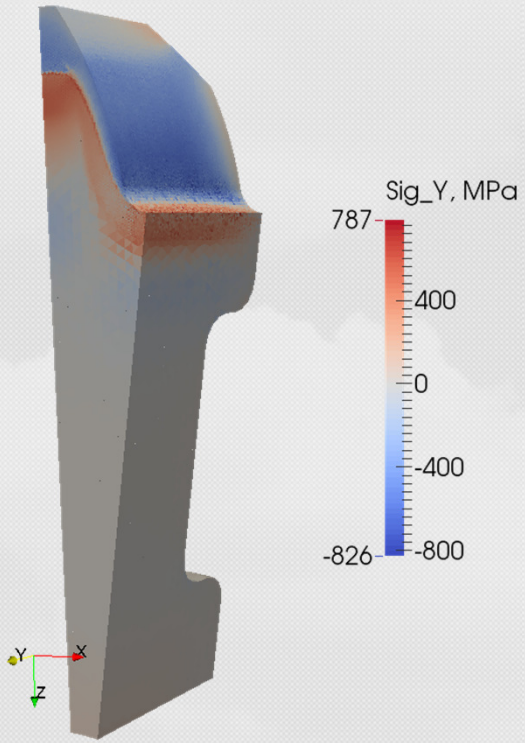


PREHEATING 400 ˚C

GEAR HARDENING. SINGLE SHOT

COMPARISON OF Y-COMPONENT OF RESIDUAL STRESS



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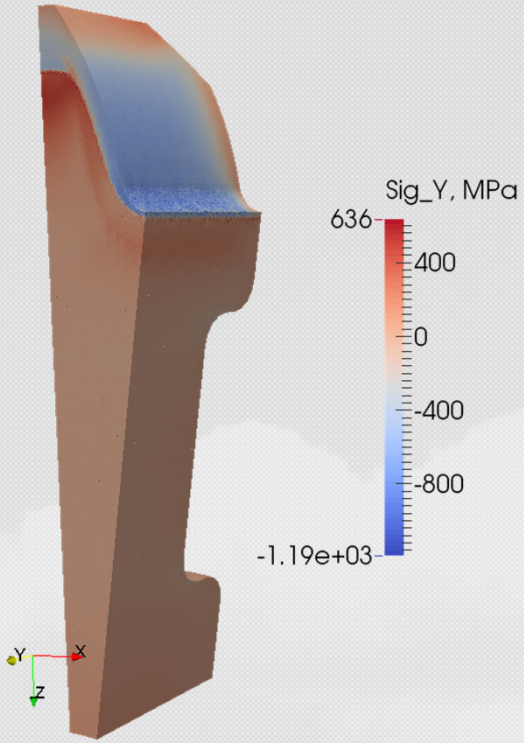
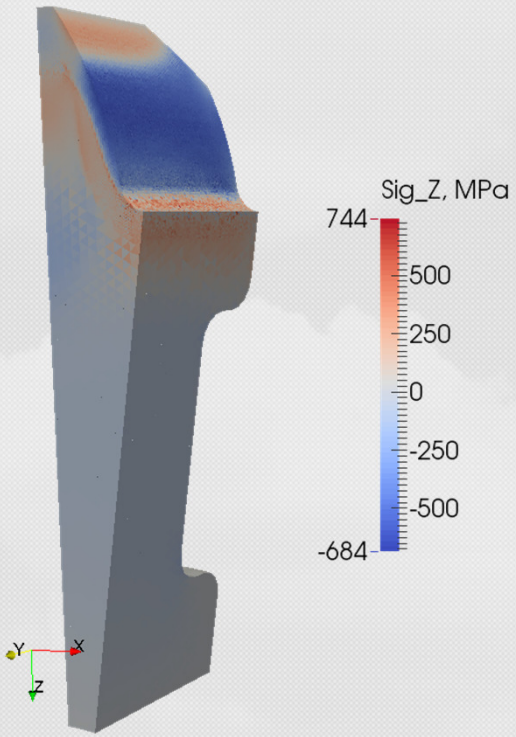


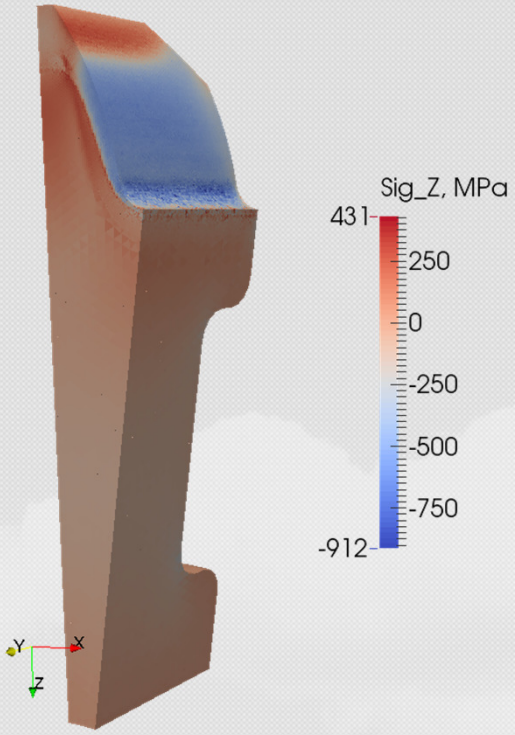
PREHEATING 400 ˚C

GEAR HARDENING. SINGLE SHOT

COMPARISON OF Z-COMPONENT OF RESIDUAL STRESS



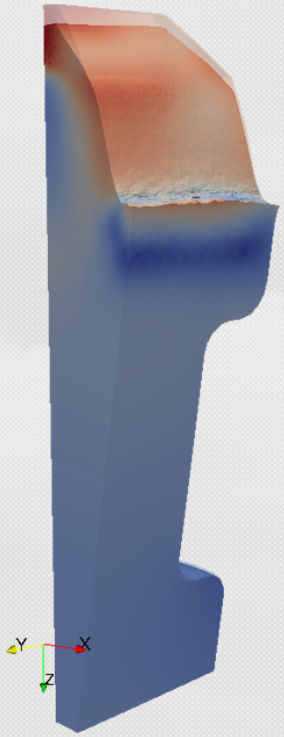
NO PREHEATING



PREHEATING 400 °C

GEAR HARDENING. SINGLE SHOT

COMPARISON OF DISTORTION. DISPLACEMENT MAGNIFIED X50



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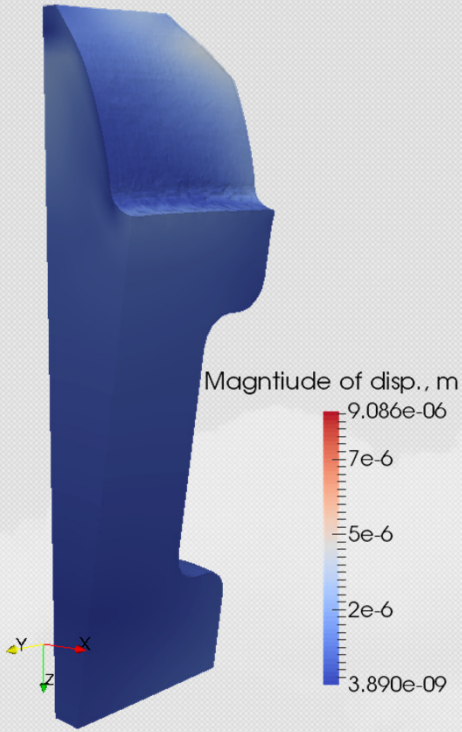
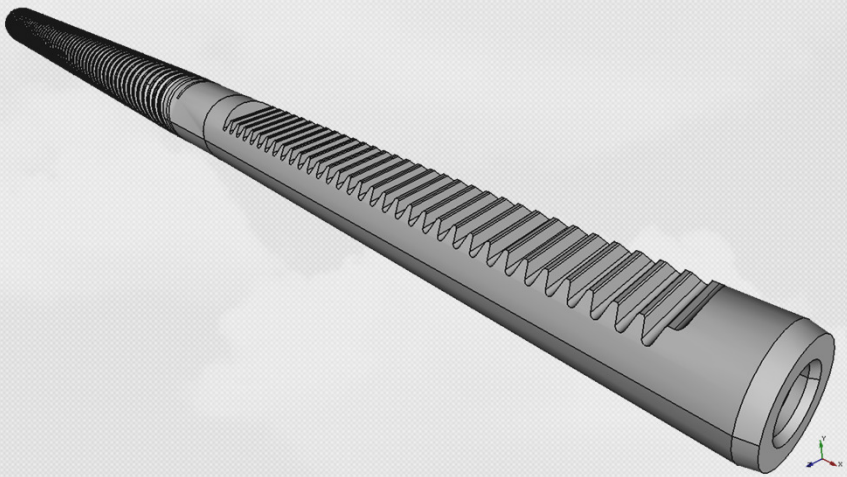


PREHEATING 400 ˚C

STEERING RACK HARDENING. SCANNING

GEOMETRY AND PROCESS VARIATIONS



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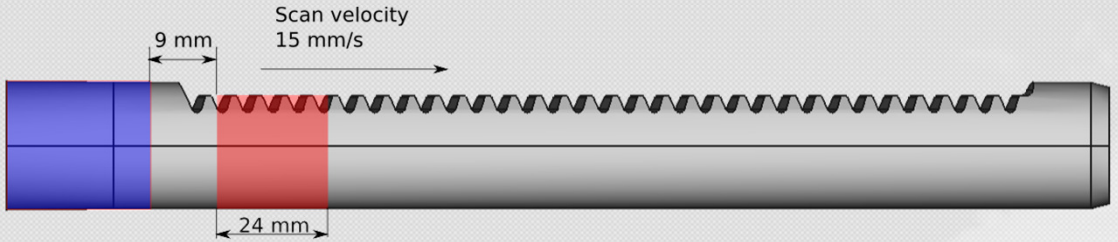
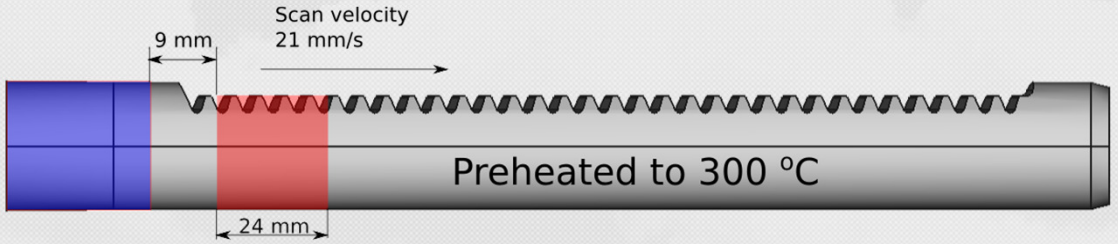
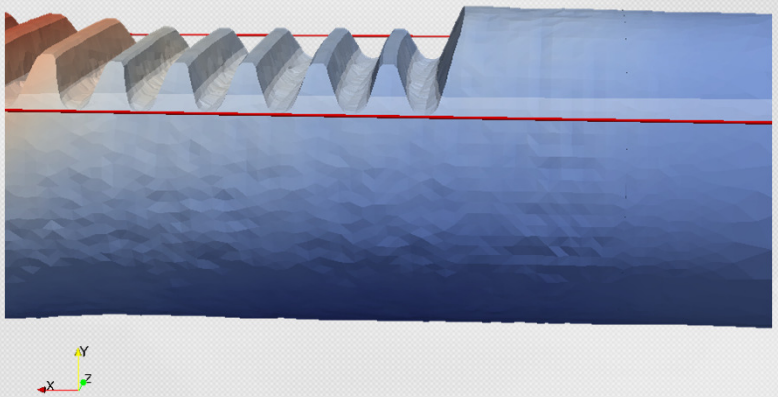


PREHEATING 300 ˚C



STEERING RACK HARDENING. SCANNING

ESTIMATION OF BULGING FROM SIMULATION

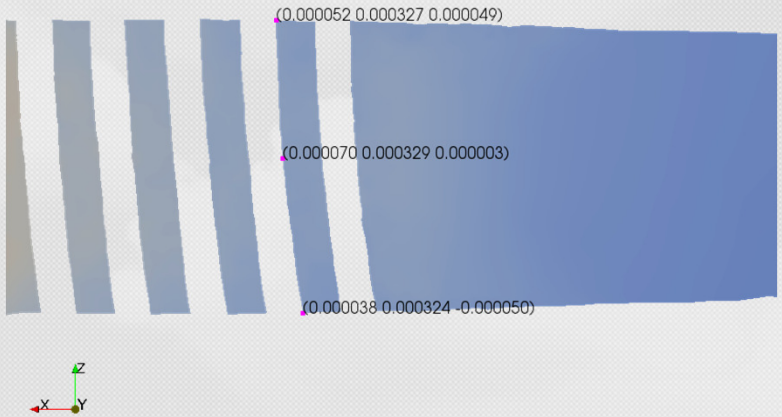


SCANNING DIRECTION

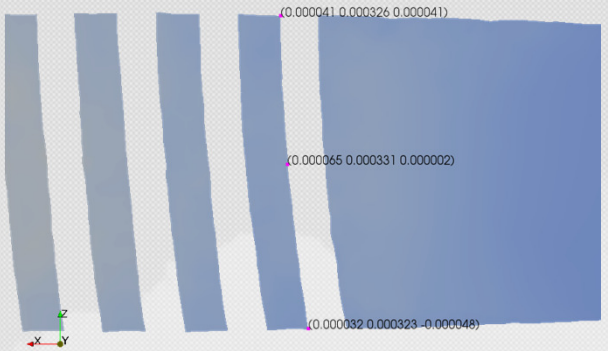
STEERING RACK HARDENING. SCANNING

PROBLEM – EXCESSIVE BULGING OF TEETH IN THE CASE OF NO PREHEATING

BULGING OF FRONT OF TEETH ≈32 µm



BULGING OF REAR SIDE OF TEETH≈33 µm

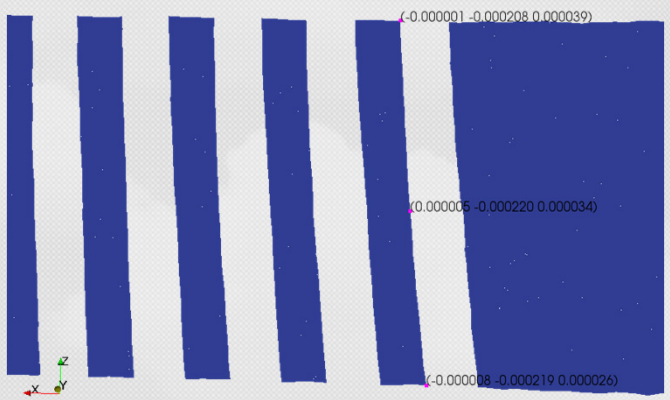


SCANNING DIRECTION

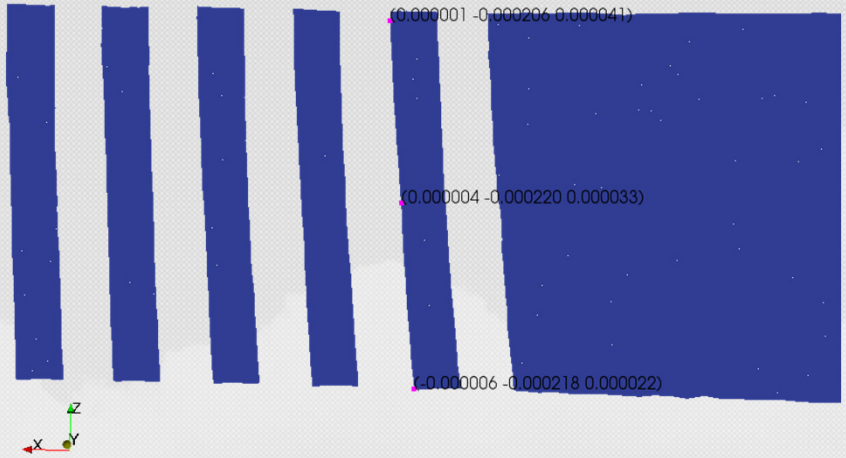
STEERING RACK HARDENING. SCANNING

BULGING IN CASE OF PREHEATING 300 ˚C

BULGING OF FRONT OF TEETH ≈13 µm



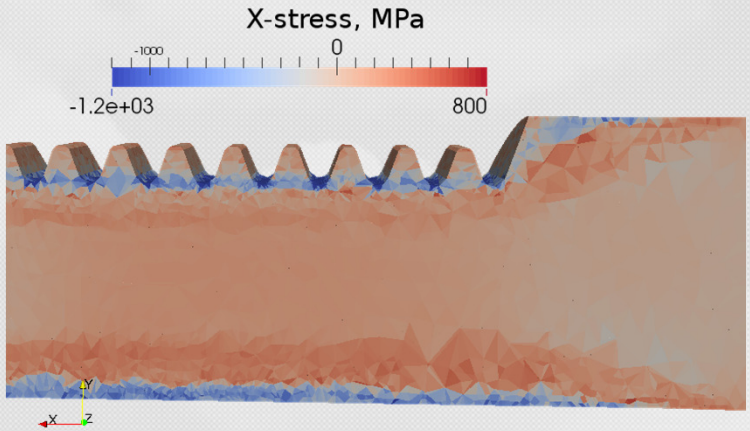
BULGING OF REAR SIDE OF TEETH≈10 µm

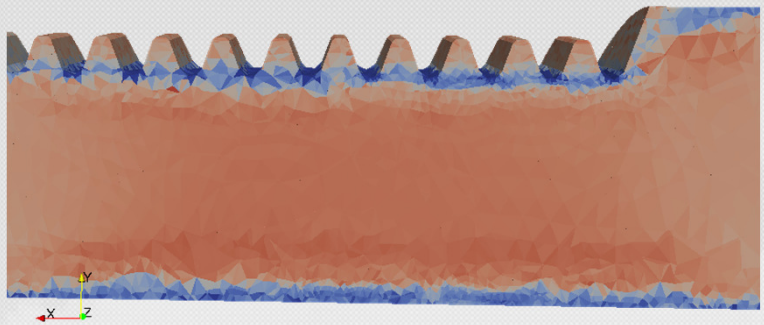


SCANNING DIRECTION

STEERING RACK HARDENING. SCANNING

COMPARISON OF X-COMPONENT OF RESIDUAL STRESS



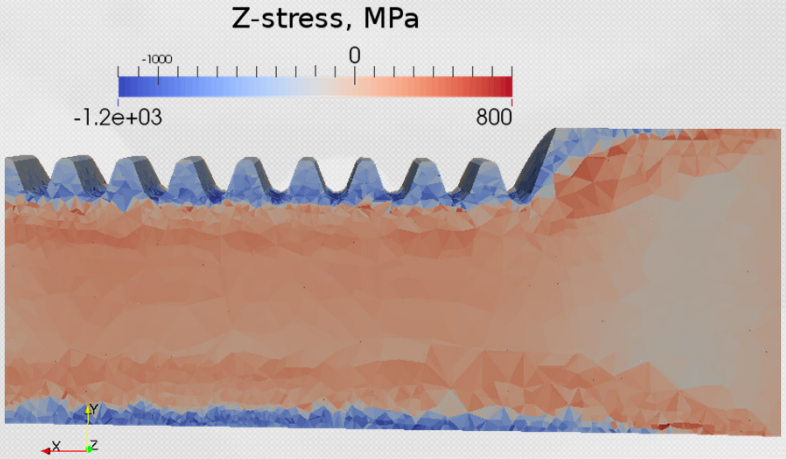


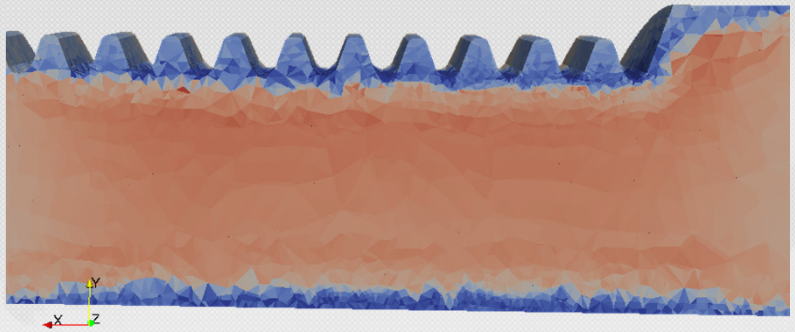
NO PREHEATING

PREHEATING 300 ˚C

STEERING RACK HARDENING. SCANNING

COMPARISON OF Z-COMPONENT OF RESIDUAL STRESS





NO PREHEATING

PREHEATING 300 ˚C

EFD INDUCTION

Putting the smarter heat to smarter use.