DIN - DEPARTMENT OF INDUSTRIAL ENGINEERING

PhD Course in Mechanics and Advanced Engineering Sciences (DIMSAI)

PHD STUDENT POSTER - AY *2016/2017* Curriculum number *1* Cycle *XXXI*

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Study on Optimization of the Die Assisted Oil Quenching (DAOQ) process

1. General Overview: Issues

Heat treatment of steel typically **modifies** the **microstructure,** producing the **highest mechanical properties** of the materials if the heat treated process is a quenching.

Quenching Process ⟹ Performance of material ⟹ Martensite ⟹ Increase of Specific Volume ⟹ Changes of the treated parts

Distortions

In Heat Treatment due to:

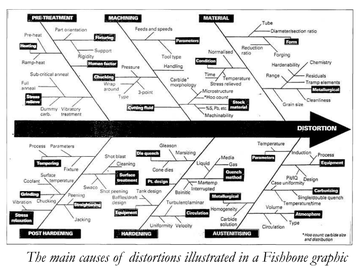
Thermal Gradient and **Phase Transformation**

Solution:

Minimizing distortions means to define the most efficient process route in order to maintain a **uniform temperature** throughout the part during the whole process.

How could we work/think/..?

-An **unavoidable effect** of the quenching process;
-Dependent on a **huge number of factors:** cooling rate and methods of cooling, thermal history of the components and the critical tempera.
-The evolution of this phenomena is still **uncontrolled.**



The main causes of distortions illustrated in a Fishbone graphic

dimensions of the part ⟸ design requirements ⟹ mechanical characteristics

Quenching process

⇩

Remachining operations ⟸ Machining allowance ⟸ Distortions must be Compensated or Reduced ⟹ Controllable process ⟹ Die-Assisted Quenching

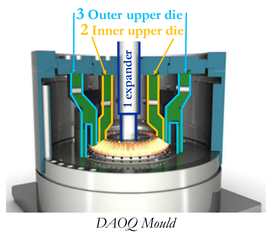
2. General Overview: Process

«Heating a part to the austenitic conditions and then immersing the same into a liquid to achieve metallurgical transformation, while at the same time forcing the part to hold size and shape»

Advantages
-***Controlled Process:*** part undergoes individually the quenching process;
-**Uniform cooling**: thermal gradients are reduced inside the parts;
-***Reduction of Deformations:*** due to the usage of specific equipment;

Disadvantages
-**Setting parameters** during the quenching process;
-**Mould** must be designed in order to control the critical part of the piece;
-**Size of the treated pieces** are linked to the press dimensions

Hydraulic Press for DAOQ process



DAOQ Mould

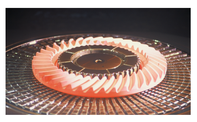
The **die** has typically three main parts:

1 **centre expander cone** that controls the inner hole of the parts;

2 **Inner upper die** that reduces the flatness of the part;

3 **Outer upper die** that controls the external diameter and planarity of the components;

3. Case study: the differences between DAOQ and Open Tank Oil Quenching (OTOQ) in terms of technological cycle.



Conical crown used for the case study

5 €/pz ⟵ Direct Quenching ⟵ **OTOQ** ⟵ -1Carburizing, **-2Quenching**, -3Rilieving Tempering ⟶ **DAOQ** ⟶ Indirect Quenching ⟶ 6.5 €/pz

0.2-0.4 mm ⟶ *Necessary & Difficult* ⟶ **-4Grinding** -5Run in stage -6Assembly ⟵ *Grinding Operations can be avoided* ⟵ 0.08-0.15 mm

Changing the **quenching process** changes the **technological cycle**

What exactly is the ***difference*** between DAOQ and OTOQ?

Die Assisted Oil Quenching:
-**extends** the technological cycle;
-**costs more** than the OTOQ;
but

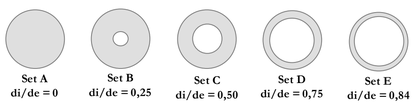
reduction of machining allowance; ⟵ **-controls** distortion in quenching process; ⟶ **No** Grinding operation;

It implies:

1 **smaller** amount of raw material
2 **simplification** of the part design
3 **wasting less** high value material
4 **save** energy

4. Experimental Activity:

Factor1: Geometry – (5 sets & 3 replications)
Factor2: Different materials: 100CrMo7, 20MnCr5 18NiCrmo5



Factor3: Technological cycle

-Op01 Machining 1st
-*Op02 OTOQ* 2nd
-Op03 Relieving Tempering 3rd
-Op04 Spheroidizing Annealing 4th
-*Op05 DAOQ* 5th
-Op06 Relieving Tempering 6th

CMM adopted for experimental activity

Definition of a **standard** for the measurements
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-technological phase
-same **positioning**
-same **measurement** programme
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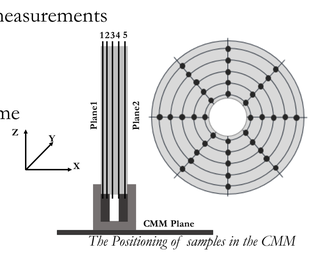
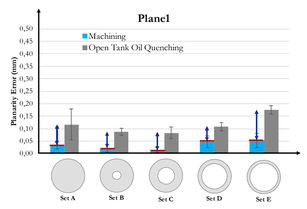
Evolution of Sample
DIMENSION

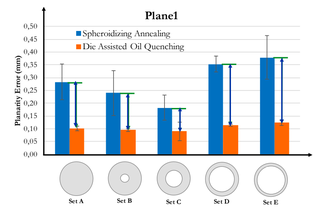


The Positioning of samples in the CMM

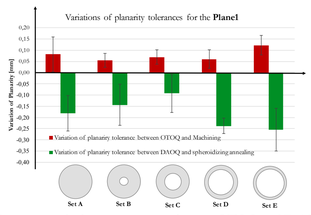
Analysis of planarity Tolerances



Comparison of planarity tolerance between Machining and OTOQ

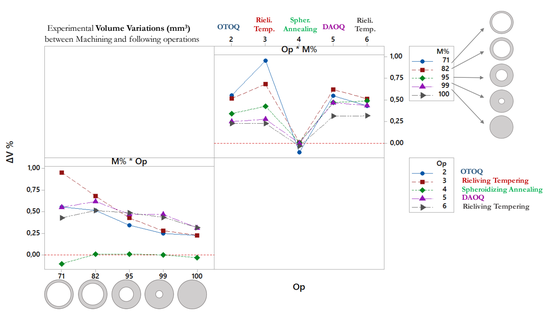


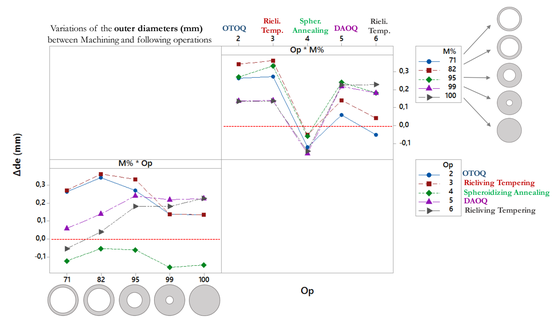
Comparison of planarity tolerance between Sph. Annealing and DAOQ

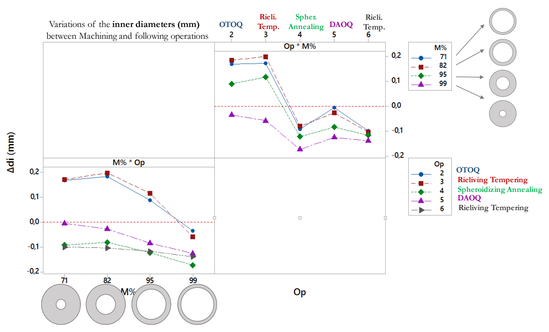


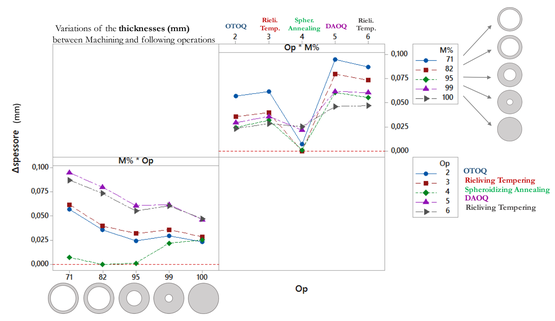
Comparison of planarity variations between OTOQ and DAOQ

ANOVA Analysis

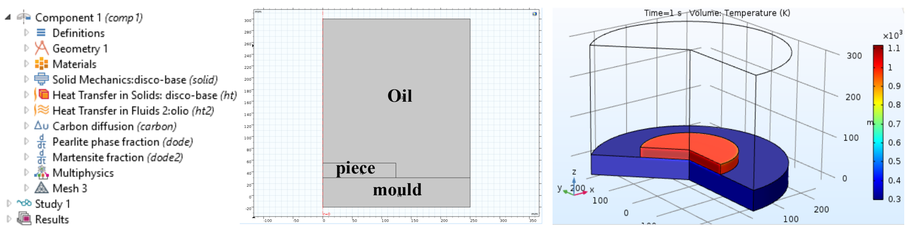








5. Modelling



The main causes of distortions illustrated in a Fishbone graphic

Aim: the simulation of DAOQ process through a multi-physics software.

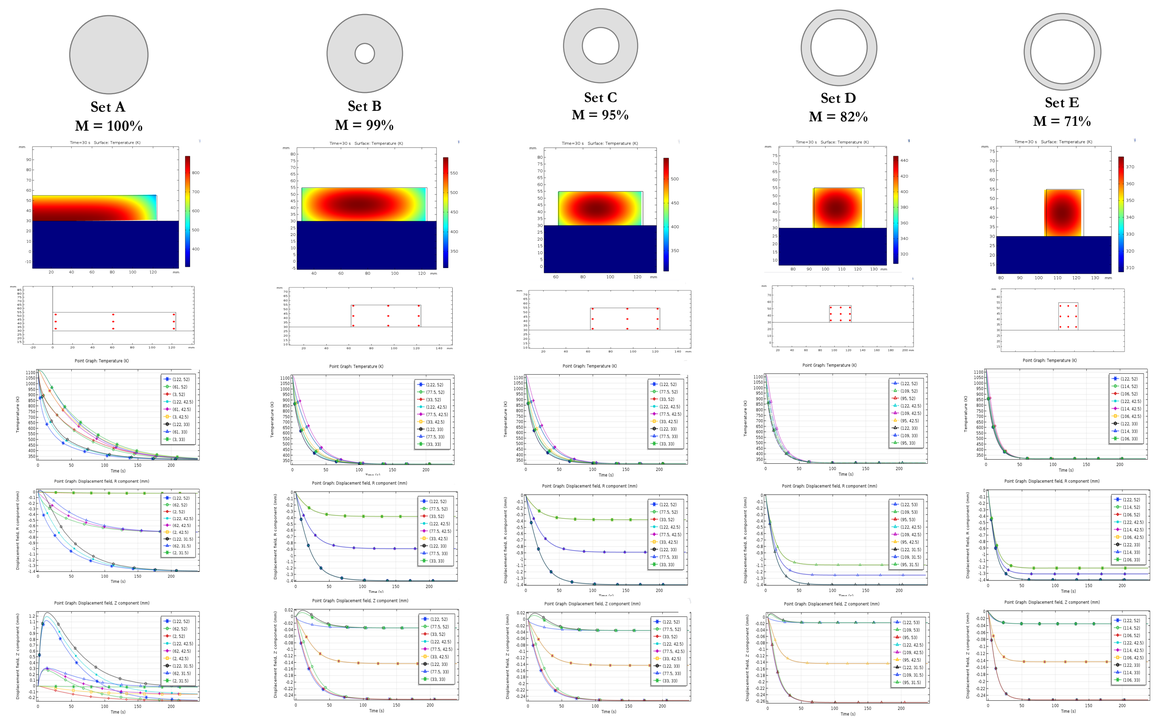
-Geometry: 2D axy-symmetric representation due to the axial-symmetry condition of the press, mould and mechanical parts;

-The physics implemented: thermal, mechanical, microstructural and diffusional mathematical model in order to describe the DAOQ process behaviour.

The hot piece is located on the lower part of the die and the quenchant surrounds the part, expels the heat producing metallurgical transformations and the assessment of the deformations induced by the cooling.

The validation of the model will be done with the experimental measurements carried out on real mechanical components.

Result of Modelling



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