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Inductive fixture hardening and tempering: A big step forward in gear manufacturing

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Fixture-hardening, also known as quench-press hardening, is a widespread process mainly for the automotive industry. The presentation introduces a new inductive hardening and tempering process that combines the known benefits of induction heating/hardening with the pros of a press hardening process. The main component is a new hardening machine with implemented fixture hardening assembly and integrated induction coil. The inductive energy can be used for heating up workpieces prior to fixture hardening and for tempering, which allows to simultaneously draw out the calibration mandrel with almost no abrasive wear on its surface.

KEYWORDS: INDUCTION HEATING, FIXTURE HARDENING, QUENCH-PRESS HARDENING AND TEMPERING, HEAT TREATMENT OF GEARS, SLIDING SLEEVES, CROWN WHEELS;

INTRODUCTION

IN RECENT YEARS A GROWING NUMBER OF WORKPIECES REQUIRE HIGHER ACCURACY for more and more sophisticated mainly automotive parts. To meet these increased requirements a press hardening process was developed. This presentation introduces the latest development in this field of applications.

EMA Indutec developed a quite new process that combines the known benefits of induction heat-ing/hardening with the advantages of a fixture or press hardening process.

Let us shortly sum up the well-known main benefits of induction hardening:

- heat created directly within a workpiece
- no transmission losses
- energy savings
- high production rates
- process/heating fast and easy to control
- no emissions.

HIGHLY DIMENSIONALLY PRECISE WORKPIECES REQUIRED

Deformations while hardening

Due to heating up to about 900-950 °C there are some adverse effects such as:

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- thermal expansion causes changes in dimension and shape
- distortions due to asymmetric shapes

and in combination with hardening:

- distortions due to asymmetric hardness patterns
- volume expansion due to martensite structure (approx. 1%)
- and mostly combinations of the above

and not to forget:

- tensions inside the workpiece due to machining and fabrication steps prior to hardening.

All pre-existing internal tensions are released during heating and hardening especially in thin walled work-pieces. Eliminating all these almost unavoidable effects requires a very time-consuming and therefore expensive rework. To complicate matters further the rework (such as grinding and straightening) has to be carried out on hardened surfaces.

INDUCTIVE CALIBRATION HARDENING PROCESS

To overcome all these almost unavoidable and unwanted effects EMA-Indutec has delivered a lot of induc-tion fixture hardening machines, mainly for round and cylindrical workpieces such as "sliding sleeves". The common process for carburized parts is demonstrated in Fig.1.

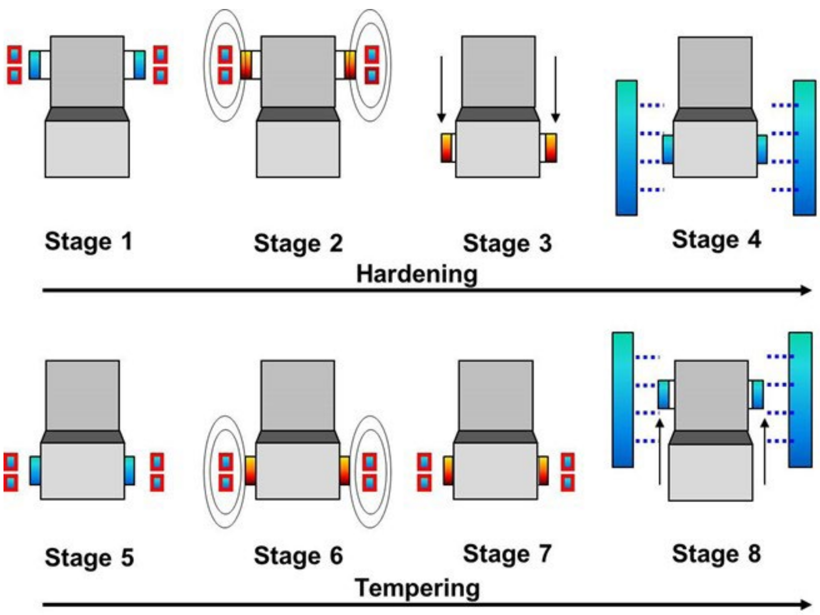


Fig.1 - Inductive calibration hardening process of sliding sleeves on a mandrel.

An oval or non-circular sliding sleeve is placed onto a non-conductive centering and holding device (stage 1) and heated up to about 900 °C inductively (stage 2). After a certain dwell time to achieve a uniform and homogeneous temperature the workpiece is driven onto the calibration mandrel (stage 3) immediately followed by extensive cooling with a polymer-based quenching liquid (stage 4). Stages 1 to 4 illustrate the inductive hardening process resulting in a cool workpiece, which is shrunk onto the calibration mandrel, made from stainless steel.

The following stages make up the tempering process. The inductor is placed around the assembly of sliding sleeve and calibration mandrel (stage 5) and generates tempering heat inside the workpiece (stage 6). With increasing temperature the sliding sleeve expands marginally. A minimal gap appears (stage 7) that allows to redraw the sleeve from the plug without effecting the very precise and accurate surface of the calibration mandrel - a spring driven force is sufficient (stage 8). At the end of the complete hardening and tempering procedure the sliding sleeve can be cooled down to room temperature again.

NEW INDUCTIVE FIXTURE HARDENING AND TEMPERING PROCESS

The new process has been developed also for helical gears and crown wheels without being limited to those. All workpieces requiring flat and even surfaces (Fig. 2) may thus be corrected to very accurate final dimensions while hardening.
In principle the new device works in a similar manner as a conventional machine (see above). But in addition there is a strong bottom fixture and a upper fixture which acts on the hot workpiece and presses it while quenching.

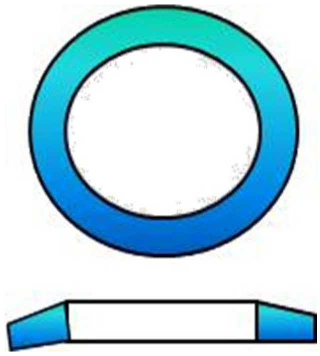
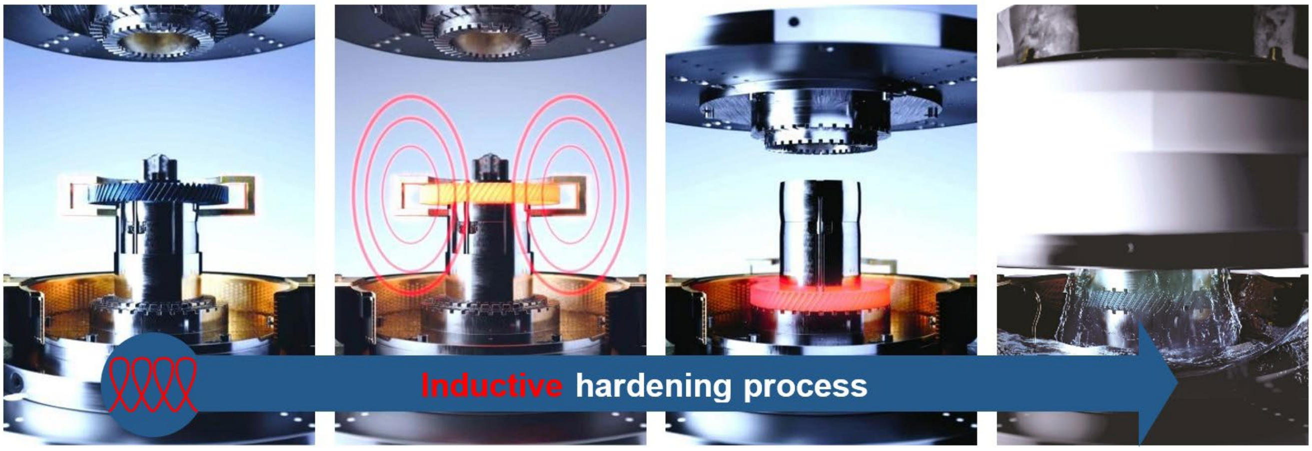


Fig.2 - Irregular crown wheel.



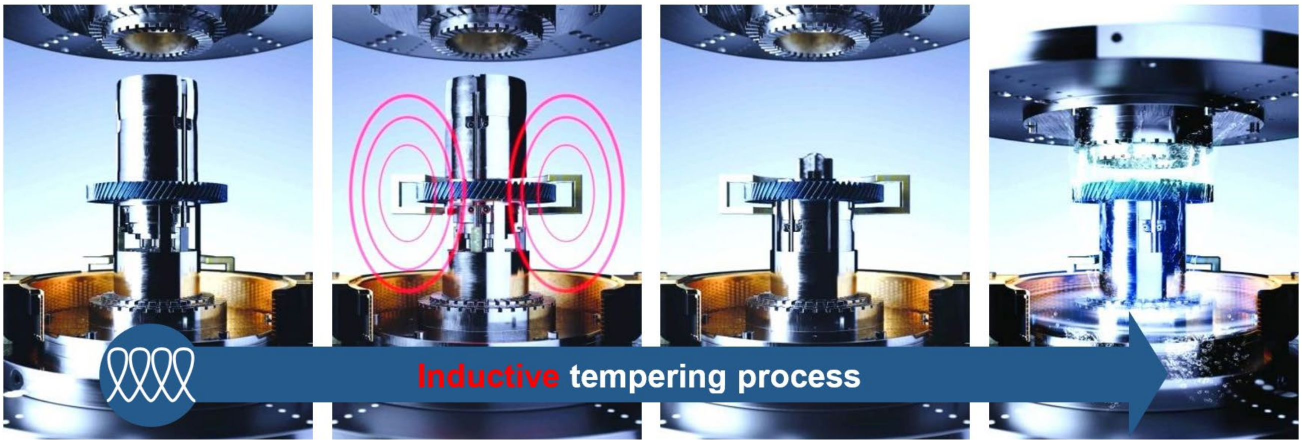
Stage 1
The workpiece is clamped into non-conductive brackets and moved into heating position.

Stage 2
An induction heating or re-heating to hardening temperature follows.

Stage 3
The workpiece drives onto the mandrel and the bottom fixture is lowered.

Stage 4
Quenching is performed while the workpiece is pressed and the workpiece shrinks onto the mandrel.

Stages 3 and 4 of fig. 3 show the additional fixtures. After quenching (stage 4) the fixtures are no longer necessary and removed to allow following tempering process (stages 5 and 6).removed to allow following tempering process (stages 5 and 6).



Stage 5
The fixture is opened again.

Stage 6
The inductor heats the workpiece to tempering temperature.

Stage 7
The workpiece is stripped off the mandrel without any force.

Stage 8
If necessary, further induction tempering can continued, followed by cooling.

Fig.3 - TInductive fixture hardening and tempering process.

MACHINE BENEFITS

As compared to conventional fixture hardening the new machine provides two relevant and remarkable differences:

1. In most conventional processes, workpieces are heated up in a gas fired rotary hearth furnace and subsequently transported into the press. During the transfer period the parts cool down, whereas the inductor in the new machine allows heating up – from room temperature if necessary or to compensate temperature losses during the transfer. The time span from end of heating to "first quench" which is relevant for quality is minimized.

2. Also the quenching technique is different. We use four separately controllable quench circuits: Through the bottom fixture (1st quench), through the upper fixture (2nd quench), through the calibration mandrel (3rd quench) and from the outside (4th quench). These four quenching options (Fig. 4) allow shape corrections via cooling conditions such as various flow rates and different starting times, resp. dwell times. All quench systems are controlled individually by flow meters.

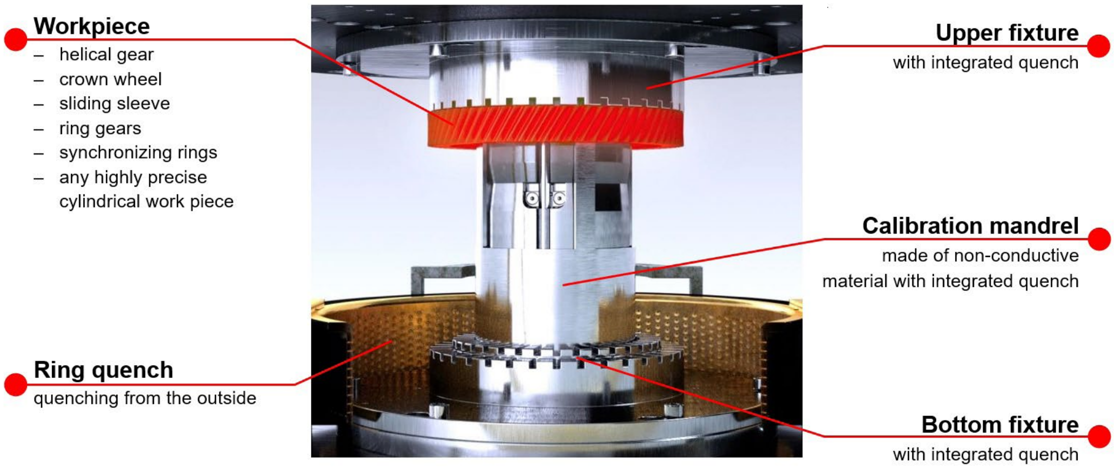


Fig.4 - Four (4) individually controllable quenches for individual shape corrections.

PROCESS BENEFITS

By means of the above device and process EMA INDUTEC combines the advantages of induction hardening with the pros of fixture hardening:

- Process can be integrated in line directly
- One-piece-flow
- No delay on process's start - no long term heating up of a furnace
- Energy savings due to short term heating
- Excellent reproducibility due to good control options
- Highest precision of final workpiece dimensions
- Minimization of dimension failures and scrap
- Minimization of rework

Nevertheless the process is based on carburized workpieces. So, it is not necessary to change materials to carbon-containing steels. The hardness patterns are not changed and therefore the qualifying procedure is less cost-intensive as compared to entirely new parts made from other material and complete approval for a totally different process.

PLANT DESIGN WITH ROTARY HEARTH FURNACE STATE OF THE ART LAYOUT

A layout of a conventional furnace is shown in the schematic of in Fig. 5 Main components are the rotary hearth furnace for carburization followed by a conventional fixture hardening machine for already heated workpieces. As conventional machines use oil as a quenchant the next big component has to be a washing machine to clean the parts from oil. After this a (mostly) gas fired tempering furnace is connected. Between all components individually controllable transport systems are necessary.

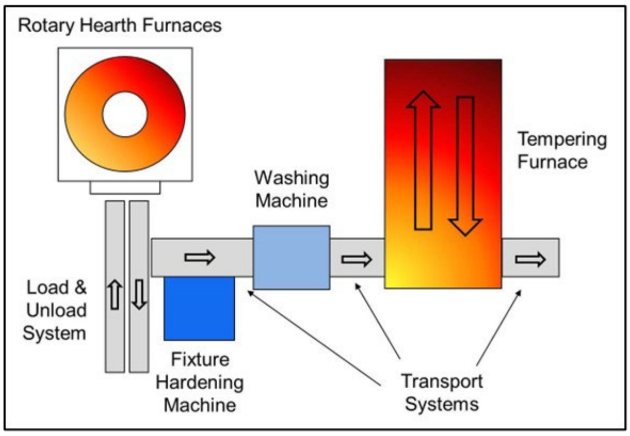


Fig.5 - Conventionel production plant.

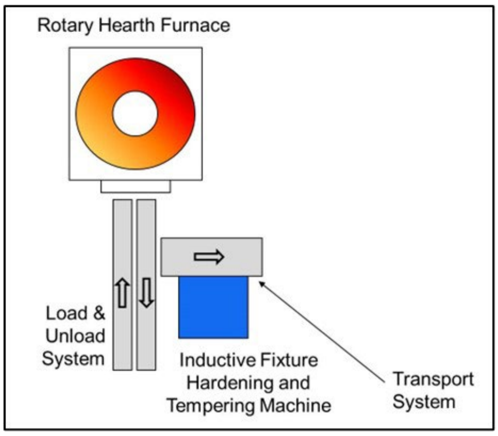


Fig.6 - Inductive production plant.

INDUCTIVE PRODUCTION PLANT LAYOUT

It is evident at first glance that the number of components is drastically reduced (Fig. 6). Only the rotary hearth furnace and the new inductive fixture remain. The washing machine is super-fluous because inductive hardening usually works with liquid quenchants on a water basis so that there is no need for a subsequent washing of the heat treated workpieces. The second component which is eliminated is the huge and expensive tempering furnace. Tempering is now integrated in the new process – and no separate and/or additional energy is required. The inductor inside allows heating up for hardening purposes as well as for tempering without any change - except power level.

Thus, the number of components diminished as well as the number of intermediate transport systems resulting in a considerable reduction of programming, malfunction sources of and maintenance.

COMPLETELY NEW MACHINE FOR INDUCTIVE FIXTURE HARDENING AND TEMPERING PROCESS

With this paper, we are introducing a newly developed inductive hardening and tempering ma-chine, which combines the known benefits of inductive heating/hardening with the advantages of a press resp. fixture hardening process.

In contrary to most of the conventional (hydraulic) press devices, the new press is driven by electric motors which ensure a very exact and repeatable positioning of the press stamps as well as an accurate dosage and as a result high reproducibility of the pressing forces.

Removal of the work piece from the calibration mandrel will start after an inductive re-warming and resulting expansion, leaving the mandrel almost free of wear.

The whole heat treatment process is carried out under protective atmosphere in order to pre-vent scale.

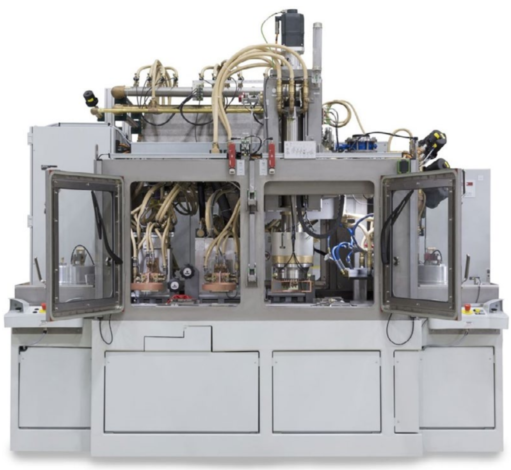


Fig.7 - Completely new inductive fixture hardening machine. Available with and without tempering process.

POSSIBLE WORKPIECES

- Sliding sleeves
- Ring gears
- Synchronizing rings
- Crown wheels
- Coupling bodies
- Any highly precise cylindrical workpieces

CONCLUSION

This paper introduces a quite new process which combines the benefits of induction heating and hardening with the advantages of fixture hardening to obtain highly precise workpieces with enormously reduced or even without rework.
The main component is a new hardening machine with implemented fixture hardening assembly and integrated induction coil. The inductive energy can be used for heating up workpieces prior to fixture hardening and for tempering, which allows to simultaneously strip off the calibration mandrel with almost no abrasive wear on its surface.

The whole plant and/or production line needs no washing machine and no separate tempering furnace.

Tempra e rinvenimento ad induzione in spina: un grande passo avanti nella produzione di ingranaggi

La tempra in spina, nota anche come tempra in pressa, è un processo diffuso soprattutto nell'industria automobilistica. La presentazione introduce un nuovo processo di tempra e rinvenimento induttivo che combina i noti benefici del riscaldamento/tempra a induzione con i vantaggi di un processo di tempra in pressa. Il componente principale è una nuova macchina di tempra con un gruppo di tempra implementato e una bobina a induzione integrata. L'energia induttiva può essere usata per riscaldare i pezzi prima della tempra in stampo e per il rinvemnimento, il che permette di estrarre contemporaneamente il mandrino di calibratura senza quasi alcuna usura per abrasion sulla sua superficie.

PAROLE CHIAVE: RISCALDAMENTO A INDUZIONE, INDURIMENTO DELL'ATTREZZATURA, TEMPRA E RINVENIMENTO A PRESSIONE, TRATTAMENTO TERMICO DI INGRANAGGI, MANICOTTI SCORREVOLI, RUOTE DENTATE;