

Improvements on Induction Fixture Hardening

W. Goy, J. Kern

Fixture-hardening, also known as quench-press hardening, is a widespread process mainly in the automotive industry. Since many years Induction Fixture Hardening and Tempering of single sliding sleeves and crown wheels has been state-of-the-art. The article introduces an improved 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 work pieces prior to fixture hardening and for tempering, which allows to simultaneously draw out the calibration mandrel without any abrasive wear on its surface.

KEYWORDS: INDUCTION HEATING - FIXTURE HARDENING - QUENCH-PRESS HARDENING AND TEMPERING - CROWN WHEEL HARDENING - PROTECTIVE ATMOSPHERE

INTRODUCTION

Due to increasing necessities for higher production rates and "green" products, lightweight work pieces and their miniaturization are becoming more and more important. In conjunction with the challenge to reduce hard machining (on prior hardened surfaces) work pieces need to be produced very close to their final dimension.

Against this background EMA Indutec GmbH improved related machines in order to achieve higher production rates and accuracy.

Shortly summarized, the main benefits of the previous and especially the improved process are:

- heat created directly within a work piece,
- no transmission losses,

- energy savings,
- high production rates,
- process/heating fast and easy to control,
- mandrels with inlays for specific work pieces,
- lower induction frequency at removal from calibration mandrel and tempering of sleeves,
- double production by heat treating of two work pieces at the same time (vertically arranged),
- eliminating rotation of the work piece,
- heat treatment under protective atmosphere,
- no emissions.

HEAT TREATMENT UNDER PROTECTIVE ATMOSPHERE

In the past, the scaling of ferrous materials has often been studied; a lot of principles for scale growth and the increase in layer thickness have been developed. However, all these studies always aimed at the investigation of scale growth behaviour in "long-term processes", such as heating up for forging.

For inductive heat treatment processes with their characteristic very short heating times, no such information is available. For this reason, EMA Indutec GmbH performed corresponding experiments in order to basically determine whether and in which period of time significant scale layers are generated.

In this test, a sandblasted work piece was heated up inductively as quickly as possible to the desired temperature, which was then kept constant at reduced (holding) power. After the desired dwell times at different temperatures, the work piece was quenched with a polymer liquid, as in conventional induction hardening processes. Quenching was also necessary in order to not falsify the results due to long cooling-down periods. The evaluation of the formed scale layers was carried out with an ordinary transparent adhesive tape.

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The result is shown in Figure 1.

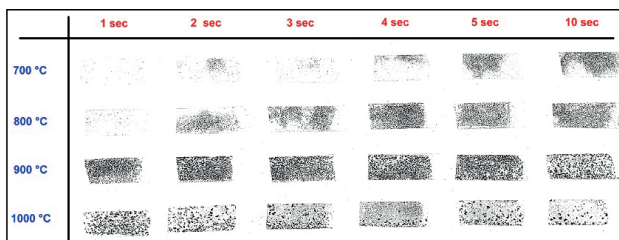


Fig. 1 - Remaining scale on adhesive tape vs. temperature and dwell time

As can be clearly seen, a significant proportion of releasable scale on the work piece surfaces at very short heating times, starting at about 700 °C, has developed. At common inductive hardening temperatures (900 °C), a notable oxide formation started within one second.

Once the temperature reaches 900 °C, with a holding time of five seconds, the typical plate-like structure of the scale is visible. The same characteristic can be found at a temperature of 1000 °C after one second! The fact that the scale layer adheres only loosely to the surface of the work piece, is backed up by the fact that at these high temperatures and increasing process times already relatively "large" scale particles are removed (washed away) with the quenching liquid - to be seen in the two tape prints bottom right (1.000 °C - 5 and 10 s).

If the manufacturer wants to avoid a costly and time-consuming rework, the only option - especially for selected driveline components - is to carry out the whole process under an inert gas atmosphere.

COMPLETELY CLOSED MACHINE

Due to upcoming requirement for heat treatment under protective atmosphere (nitrogen) a completely closed machine was developed. The whole working area, the complete inside of the machine, needs to be flooded and held at a certain overpressure to guarantee an oxygen-free atmosphere embracing the whole duration of the heat treatment. This state-of-the-art-type of machines was continually improved over the years and guarantees meanwhile a very reliable and stable production.

Of course, this also means that after each opening of the machine (for new process setups and/or any repair and adjustment works) the whole process chamber must be flushed twice (at minimum) to eliminate any oxygen inside which clearly requires some time.

A completely closed machine is shown in figure 2. In front of the closed working room, there is a lock system for loading two parts at the same time. The work pieces will be placed on a fixture and the lids will close. The interior of the locks will be flooded and the parts will be driven into the chamber by means of a turntable system. Two treated parts will come out and the lid will open again.



Fig. 2 - Completely closed machine

Due to the completely closed working room the interior of the machine can be tooled up very flexibly and is thus suitable for a large variety of work pieces.

Stack hardening

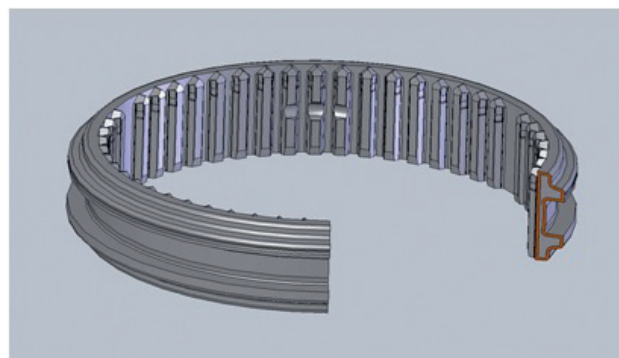


Fig. 3 - Sliding sleeve

In conventional fixture hardening of sliding sleeves it is common to calibrate up to seven parts at the same time. The work pieces are stacked. This assembly is heated up, fed on a mandrel, quenched and therefore calibrated completely.

Based on this (conventional way of) heat treatment the question arose, whether it would be possible to calibrate more than one part in induction machines also.

Due to the requirement of highly precise final dimension EMA started developing a fixture hardening device to simultaneously run two parts stacked aiming at the same level of accuracy as in one-part versions.

First of all, the temperature needs to be as homogeneous as possible, which requires a multiple turn inductor. The objective was to get a very homogeneous temperature distribution all over the stack while heating up and also while tempering including an easy removal from the mandrel. Just as in conventional tempering processes it is a must to adjust a temperature distribution of only a few kelvin-degrees difference over all work pieces.

The result of this process development is shown in figure 4.

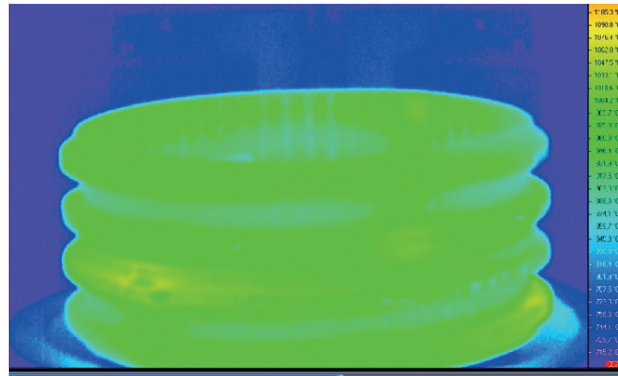


Fig. 4 - Temperature distribution in two stacked sliding sleeves during the hardening process

Irrespective of the fact that two work pieces are treated at the same time and the heated volume is thus doubled, it is not necessary to run the process with double power. Of course, the energy transmission losses on the way from power supply to the induction working head are a bit higher but not doubled. But on the other hand it is obvious that a multi turn inductor device will show a better efficiency than a single turn inductor.

For this reason we achieved a double production rate without doubling the energy consumption. The machine itself is the same as known from single parts treatment, but longer vertical driving ranges are needed.

Hardening without rotation

During the development of the process of two stacked parts the question came up, whether it would be possible to run the heat treatment of these (round) sliding sleeves without rotation or at least without a CNC-axis.

Theoretical presumptions were that the gap between the inductor feeding tubes needs to be as narrow as possible - two millimeters or better just one millimeter. The inductor should consist of even and plane rings with a stepped connection between the turns. A spiral-like inductor cannot generate horizontal induction current flows on no condition.

The plane rings have to generate strictly horizontally orientated induction currents in the work piece assembly. This is a prerequisite for the adjustment of a nearly even power generation and temperature distribution on a part assembly, consisting of sliding

sleeves with an inhomogeneous not uniform structure on the outer surface.

But physics helps:

Physically based induction currents inside the work pieces are flowing at the outer perimeter only. And all induction currents are flowing in a closed loop, defined by the inductor's design and layout. For this reason the narrow gap between the inductor feeding lines will not influence the flow of the induction current. In order to investigate this effect more closely, EMA Indutec performed several tests with and without rotation and compared the corresponding videos. There was no significant difference between the achieved temperature profiles. In both cases, the temperature profiles at the end of the heating stages were very similar to the temperature distribution shown in Fig. 4.

MANDREL WITH INLAYS

Normally most work pieces are hardened and shrunk onto round and strictly cylindrical calibration mandrels. This is currently the most common way. The work pieces need not be orientated in horizontal direction or in an angle.

Accuracy tolerances with less than 0,05 mm according to roundness/evenness and rectangularity are required today.

To meet these demands on higher accuracy regarding roundness on one hand and on more and more sophisticated work pieces (with recessed/shorter teeth and/or longer teeth for lock-in purposes) new designs of mandrels have been developed.

Figure 5 gives an overview of current mandrel designs.

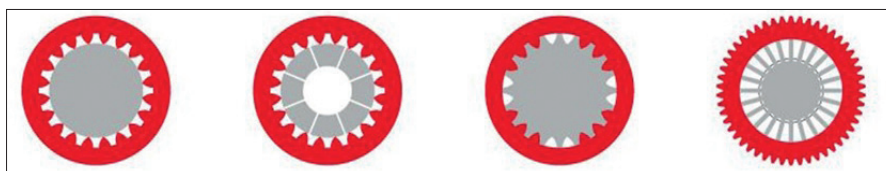


Fig. 5 - Typical designs and layouts of calibration mandrels (reference: HEES-website)

Today's work pieces can be hardened on smooth cylindrical mandrels - as fixed or expanding mandrels (furthermore, expanding mandrels (details picture 2 and 4 of figure 5) are very susceptible to fail) - or on toothed mandrels (detail picture 3 of figure 5), supporting tooth flanks or tooth bases. Latter mandrels are complicated and very difficult to manufacture, because of the

toothed surface, which has to align and adjust the roundness of work pieces, even it has window-like areas of missing teeth (two or three teeth wide). During process development a mandrel diameter and surface need to be adjusted in several steps, resulting in a time consuming and expensive rework.

Deformations of work pieces within ranges of missing teeth are not allowed.

Against this background EMA Indutec GmbH developed mandrels with inlays, which are screwed at the mandrel perimeter. Typically the periodicity is 120 degrees. The removal of inlays allows a better adjustment work on the base diameter of a mandrel: Removed inlays allow a simple rework of the diameter by turning machines.

Thicker inlays are designed to support areas of shorter toothing or even wide windows of totally missing teeth. These protruding inlays define a bigger diameter and are designed to let the bases shrink onto them.

Recessed inlays define a theoretically smaller diameter to allow support areas of longer teeth (lock-in-teeth).

Figure 6 shows a schematic of such a mandrel from EMA Indutec.

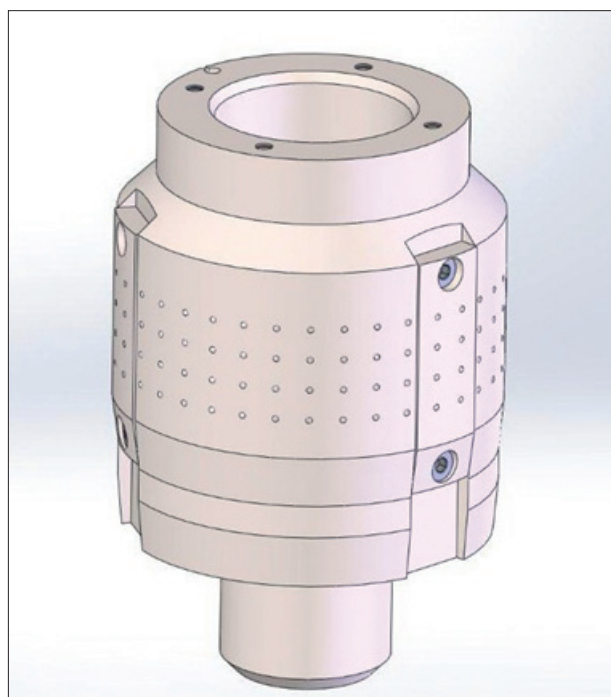


Fig. 6 - Mandrel from EMA Indutec with screwed inlays

It is obvious, that such mandrels are used with CNC-axis on the calibration machines to allow feeding in these prominent areas/ tooth ranges.

SUMMARY

With the described heat treatment package, consisting of a new machine for hardening and tempering (if necessary under protective nitrogen atmosphere), and together with a power supply of latest development, a new generation of hardening equipment (not only) for very precise components was established. It will set up a new milestone regarding accuracy of work pieces after heat treatment in combination with fixture hardening and tempering processes without extensive costs.

The new generation of machines is suitable to heat treat nearly all work pieces which need to be very precise and close to final dimension.

REFERENCES

- [1] Benkowsky, Günter: Induktionserwärmung, Verlag Technik GmbH, Berlin, 1990.
- [2] Rudnev, Valery; Loveless, Don; Cook, Raymond: Handbook of Induction Heating, Marcel Dekker Inc., 2003.
- [3] Schreiner, Alexander; Irretier, Olaf: Praxishandbuch Härtereitechnik, Vulkan-Verlag, Essen, 2013.
- [4] Nacke, Bernard; Baake, Egbert: Induktives Erwärmen, Vulkan-Verlag, Essen, 2014.
- [5] Thomas Streng: Qualitätsverbesserung und Kostenreduzierung in der Serienfertigung beim Härten von Getriebeteilen durch die Verwendung automatisierter Fixturhärteanlagen, HEES GmbH & Co KG, Lampertheim, 2008