UNLOCKING THE POTENTIAL OF RENEWABLE ENERGY COMPONENTS THROUGH OPTIMUM HEAT TREATMENT METHODS

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1. Introduction:

In recent years, the demand for heat treatment installations to process large gears has grown enormously. The range of applications of the large gears is very wide and diverse. After the strong growth in ship transmission systems over the last few years, the wind energy sector now appears to have the best growth potential. Earthmoving industry, through their construction machinery which requires large gears are also target consumers for such technology.

Union Budget 2023 has declared an allocation of ₹ 10,222 crores to the Ministry of New and Renewable Energy (MNRE), which is approx. 45% hike with respect to last fiscal year. This clearly indicates the switch towards renewable energy resources gradually in the coming years, which is obviously a great decision as far as sustainable development is concerned. So, in next few years, we can expect a boom in sectors related to this segment specifically wind & hydraulic energy and consequently the demand for large gears.

Looking at the heat treatment technology for large gears, one finds mainly pit furnaces in this area, largely due to the lack of capital cost viable alternatives. Pit furnaces therefore continue to be popular in spite of the disadvantages of eventual surface oxidation while being carried for quenching and the inherent problems in automating such processes.

Figure 1: Pit Furnace Installation

In the meantime, however, alternatives to pit furnaces have been developed, which are competitive with respect to heat treatment quality & costs and have already proven themselves in industrial use. They are therefore suitable for replacing pit furnaces in the foreseeable future.

The new furnace systems are:

- Box furnaces
- Sealed quench furnaces
- Vacuum furnaces

These purely horizontally loaded, fully automated furnace systems represent the state of the art in the automotive and aircraft industries, in mechanical engineering, tool making, the medical industry and others since a number of years.

Previously, this furnace technology was not used in large gear manufacture, simply because the furnace sizes needed for such applications were not available. New developments in the field of atmosphere furnaces and also in vacuum furnace technology permit today the heat treatment of large, heavy work pieces with load weights of up to 10 t (up to 5 t in Sealed Quench Furnace). Additionally, the handling and automatic horizontal transportation of such large heavy charges, is today no longer a problem.

In the following, therefore, the options available for using this new furnace technology for large gears are presented and compared with the conventional pit furnace installations.

Insights:

Box / Sealed Quench Furnace Installation

Vs.

Vacuum Furnace Installation

Vs.

Pit Furnace Installation

2. Comparison of various furnace designs:

A comparison of various furnace designs is only practical on the basis of a concrete case study. As the largest number of onshore wind turbines produced generate a power of 2 MW and as Ipsen has already supplied several heat treatment systems for the gears of such wind turbines, this type of a gearbox was selected for the system comparison.

Such a gearbox of a 2 MW turbine comprises a planetary gear section and a spur gear section, as shown in figure.

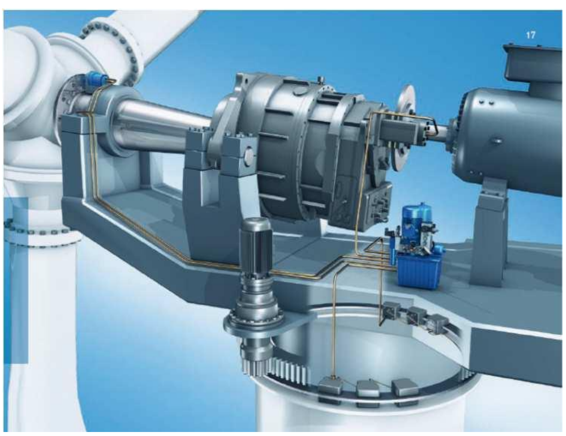


Figure: Power Transmission module of Horizontal Axis Wind Turbine (Source: Bosch Rexroth)

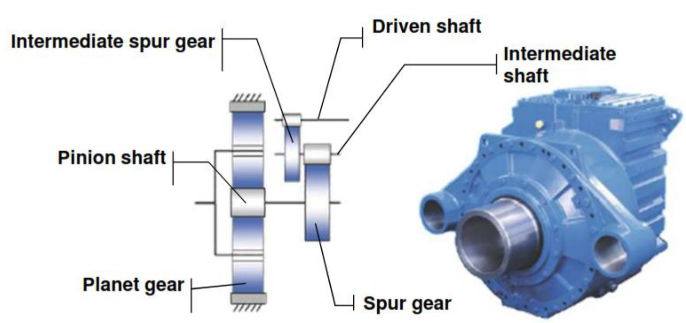


Figure: Main Gear Drive of an Onshore Wind Turbine

2.1 Design basis

Such a gearbox contains a total of 8 toothed gears and pits that are case hardened and has a total weight of 3.4 t.

Based on an annual output of 1,500 gearboxes per year and a production quantity of 32 gearboxes per week, assuming a production time of 47 weeks per year with three-shift operation (7 days per week), a comparison of 4 different heat treatment systems was carried out.

For each furnace design, the optimum furnace size was determined and for each component the optimum charge calculated. The cycle times are calculated for the usual hardness Cd 550 of 2.0, 2.5 and 3.0 mm, based on a carburising temperature of 950 °C for the atmosphere furnaces and 1050 °C for the vacuum furnaces. For the atmosphere furnaces used in the system comparison, direct hardening, the most frequently used process was employed, while for the vacuum furnaces, simple hardening was used because of the increased carburising temperature. With this data, it was possible to completely specify the scope of the plant for each furnace design.

2.2 Presentation of the furnace designs:

2.2.1 Pit furnace installation:

In this standard furnace design, carburising takes place in vertical retort pit furnaces. A crane system is used to manually load the charge into the furnace and to manually transport the charge through air for quenching in an oil bath. For complete removal of the resultant scale, a shot blasting machine is necessary.

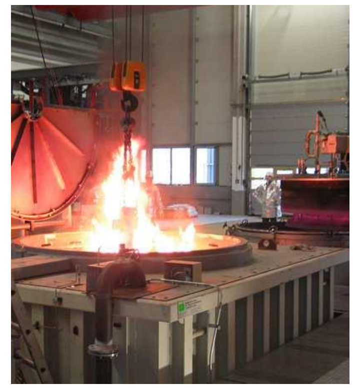


Figure: Material transportation in Pit Furnace

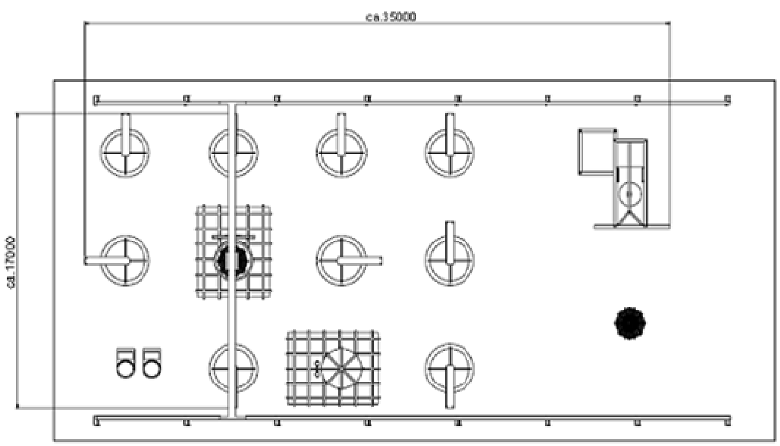


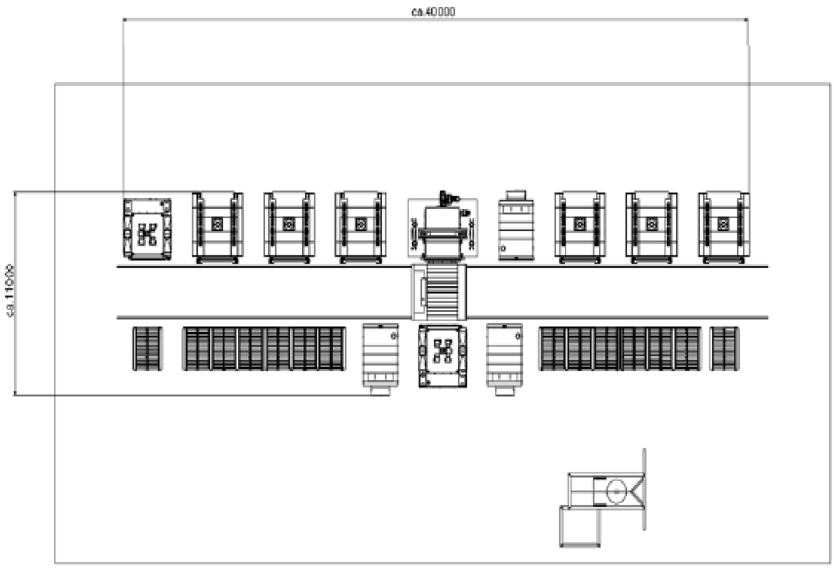
Figure: Tentative Layout of a Pit furnace installation

This installation comprises:

- 6 x pit furnaces (useful dimensions: ϕ 1,800 mm x L 2,000 mm)
- 1 x post-wash machine
- 2 x tempering furnaces
- Crane system
- Shot blasting machine

2.2.2 Box furnace Installation:

The box furnace BT-37-GRM consists of a horizontally loaded heating chamber. Using an automated, horizontally traversing transport system, the charges are loaded into the box furnace and removed from the box furnace through air into the centrally positioned quench bath. This also causes scale to be formed on the gears, which must be completely removed by blasting.



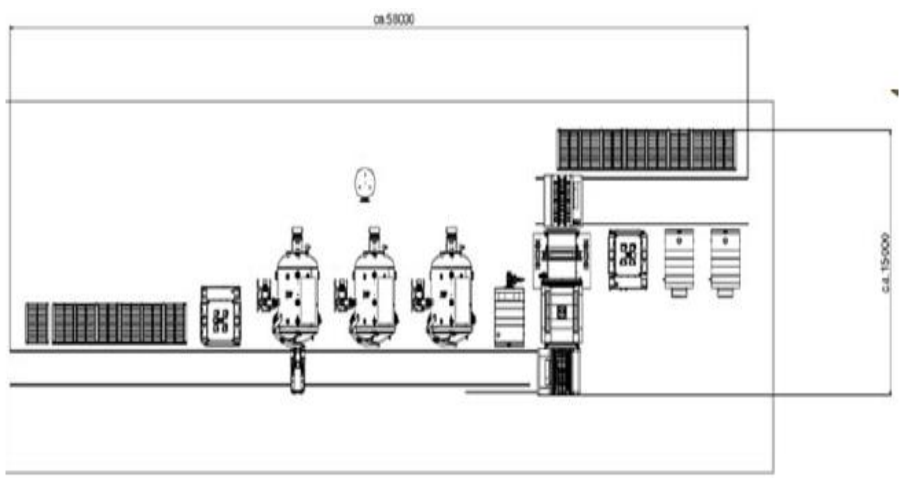
This installation comprises:

- 1 x pre-wash machine
- 1 x pre-heating furnace
- 6 x box furnaces BT-37-GRM (Useful dim.: 1,500 mm x 1,800 mm x 1,400 mm)
- 1 x quench bath
- 1 x post-wash machine
- 2 x tempering furnaces
- Transport system
- Load storage
- Automation
- Shot blasting machine

Figure: Tentative Layout of a Box Furnace Installation

2.2.3 Vacuum furnace line:

The carburising using the low pressure carburising process AvaC® takes place in horizontal, automatically charged vacuum furnaces of the type Turbo^{2}Treater. The cooling after the carburising is carried out under nitrogen gas. The load is reaustenitized in a sealed quench furnace TQ-37-GRM and quenched under protective atmosphere in oil.



This installation comprises:

- 1 x pre-wash machine
- 3 x low-pressure carburising furnaces Turbo^{2}Treater XXXL
- 1 x pre-heating furnace
- 1 x chamber furnace
- 1 x post-wash machine
- 2 x tempering furnaces
- Transport systems
- Charge storage
- Automation

Figure: Tentative Layout of a Vacuum furnace line

2.2.4 Sealed quench furnace line:

It is well known; the sealed quench furnace contains an integral oil bath. Therefore, the transport of the charge from the heating chamber to the oil bath takes place under protective atmosphere. Consequently, no scaling of the components occurs, while oxidation or decarburization of the component surfaces are also reliably avoided.

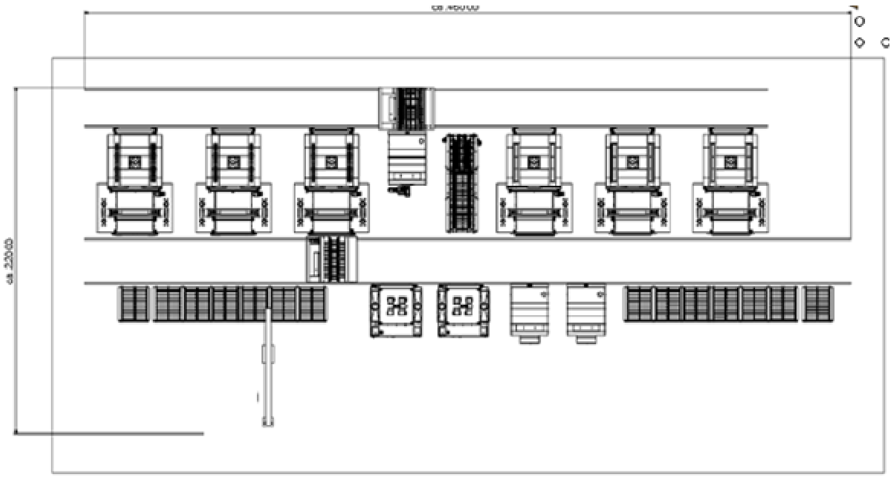


Figure: Tentative Layout of a Sealed quench furnace line

This installation comprises:

- 1 x pre-wash machine
- 1 x pre-heating furnace
- 6 x sealed quench furnaces TQ-37-GRM (Useful dimensions: 1,500 mm x 1,800 mm x 1,400 mm)
- 1 x quench bath
- 1 x post-wash machine
- 2 x tempering furnaces
- Transport systems
- Load storage
- Automation

3. Comparison of the furnace designs

Qualitative comparison of various aspects of the 4 plant designs

Particulars	Pit furnaces	Box furnaces	Sealed Quench furnaces	Vacuum furnaces
High heat treatment quality	o	o	+	++
Short cycle times	o	+	+	++
Simple atomization	o	+	+	+
Complete documentation	o	+	+	+
High safety level	o	+	++	++
Short investment payback period	o	+++	++	+
<u>High Heat Treatment Quality in Details</u>				
No scale formation	o	o	++	++
No inter-granular oxidation (IGO)	o	o	+	++
No Decarburization	o	o	++	++
Uniform Quenching	o	+	+	+
High core strength	o	+	+	+

3.1 Heat treatment quality

The sealed quench furnace and the vacuum furnace have the advantage that the component surfaces remain scale-free, oxidation-free and decarburizing free, thanks to quenching under protective atmosphere.

3.2 Cycle times

Due to the high carburising temperatures, the cycle times in the vacuum line are considerably shorter for the same case depth.

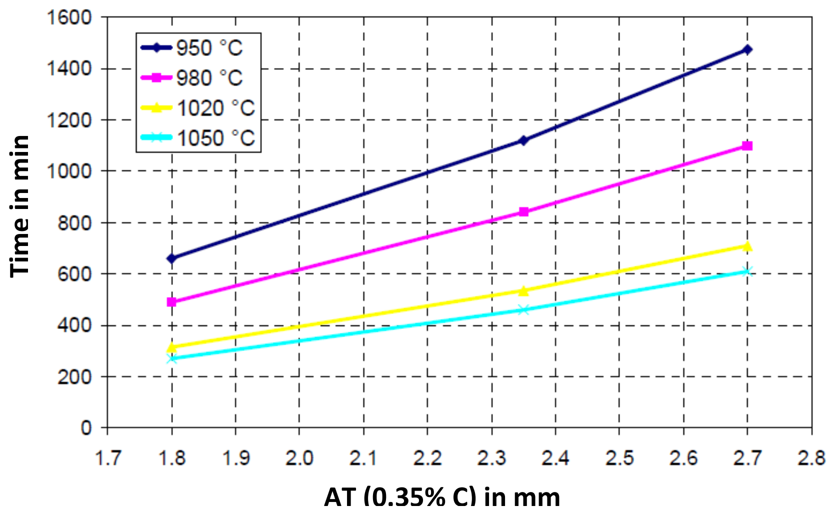


Figure: Comparison of cycle time in vacuum furnace with respect to temperature

3.3 Automation

The state of the art involves fully automatic operation of the complete heat treatment line. This applies for box furnaces as well as for sealed quench furnaces and vacuum furnaces.

3.4 Safety

- With respect to safety, the pit furnace system has a number of critical dangerous points. Open oil baths always present a safety risk. A burning oil bath is the meltdown-equivalent accident of any heat treatment shop.
- The lowering of the charge into the open oil bath produces several meter-high flash flames which require enormous vigilance during operation and place a number of requirements on the shop construction and exhaust system. Also the environmental impact resulting from the large quantity of oil fumes generated is considerable or results in the need for a very expensive filtering system.
- To minimize the danger of fracturing of a support pole, as the entire hot charge is suspended from it during transport, it must be continuously checked for cracks or deformation.

Figure: High flames during oil quenching in case of pit furnace installation

3.5 Surface decarburization /surface oxidation

- Transporting the load to the quench chamber and quenching in oil under protective atmosphere prevents surface decarburization and oxidation in the sealed quench furnace line and also in the vacuum furnace line.
- The use of acetylene in the AvaC®- process results the components, completely free from surface decarburization and intergranular oxidation (IGO) after low pressure carburising in the vacuum furnace.

3.6 Quenching

The use of SuperQuench® provides the possibility to select the optimum quench parameters for each charge and individually for each component. Here the main purpose is to minimize distortion.

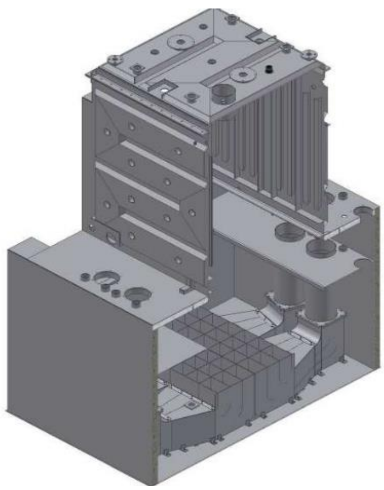


Figure: Ipsen SuperQuench® with full-honeycomb oil baffle

Technical Data

- 6 Agitators each with powerful 7.5 kW motors
- Honeycomb type Oil guide channel system
- All agitator motors with variable frequency drive
- Quench oil cycle programming via Carb-o-prof® 4.0 (Option)

3.7 Fixtures

With box, sealed quench and vacuum furnaces, the load is not lifted by a crane. It also does not have only a single mounting point as with pit furnaces but rather a flat and level support. Therefore, the load fixtures

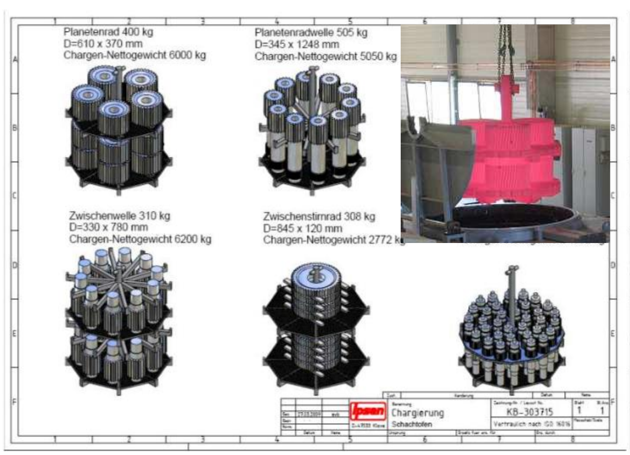


Figure: Tentative fixture arrangement suitable for pit furnace installation

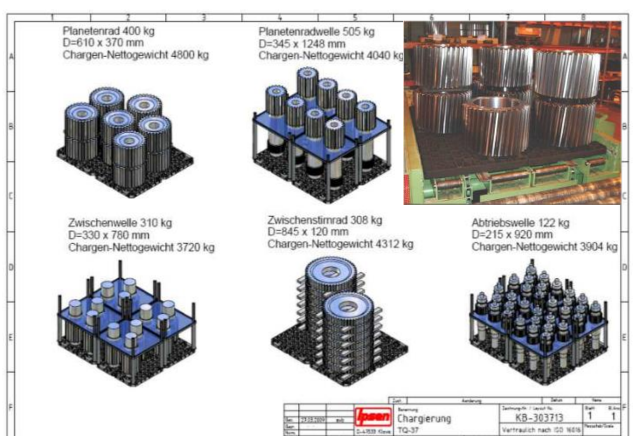


Figure: Tentative fixture arrangement suitable for box/ sealed quench furnace installation of all horizontal furnace types are much lighter and less costly. The consequent tare weight saving for the horizontally charged atmosphere and vacuum furnaces results in a significant reduction in heating costs and heating duration. In addition, the heavy fixtures of pit furnaces are significantly more expensive to procure and have, due to the single point mounting and the lack of support, a much lower service life with correspondingly high maintenance costs.

4. Summary / Conclusion

- Being Process repeatability & reliability of large gears a major concern, we need to supervise each variables affecting the end results and to achieve this, we need data transmitting field devices and powerful analyzing tools to take care any abrupt situation even before it actually happens. In this context atmosphere furnaces like sealed quench, box and vacuum furnaces are much reliable than pit furnaces, when it comes to maintaining temperature uniformity or carbon/nitrogen potential or even possibility of install such device/facility.
- Material handling throughout the installation (sealed quench, box and vacuum furnaces) is much easier due to horizontal transportation of charge by automatic external power traversed wagon, which ensures absolute process consistency and optimized throughput times. This level of automation is not possible with a pit furnace plant.
- Operating conditions like Temperature, working pressure and hydro-carbon / flammable atmosphere invariably makes these furnaces explosive in nature. That's why, it is very important to consider precautionary safety measurement at very initial stage of design itself. On this ground, pit furnace operations are bit risky due to its open quench oil bath, which is obviously not the scenario in case of sealed quench, box and vacuum furnaces etc.

So, we can say, these furnace designs (sealed quench, box and vacuum furnaces) represent considerable improvements over existing furnace technology (pit furnaces) in terms of quality, safety, level of automation and also economy. And Ipsen-India is now ready & well-equipped to cater these diverse range of requirements – "Powering Innovation Worldwide".