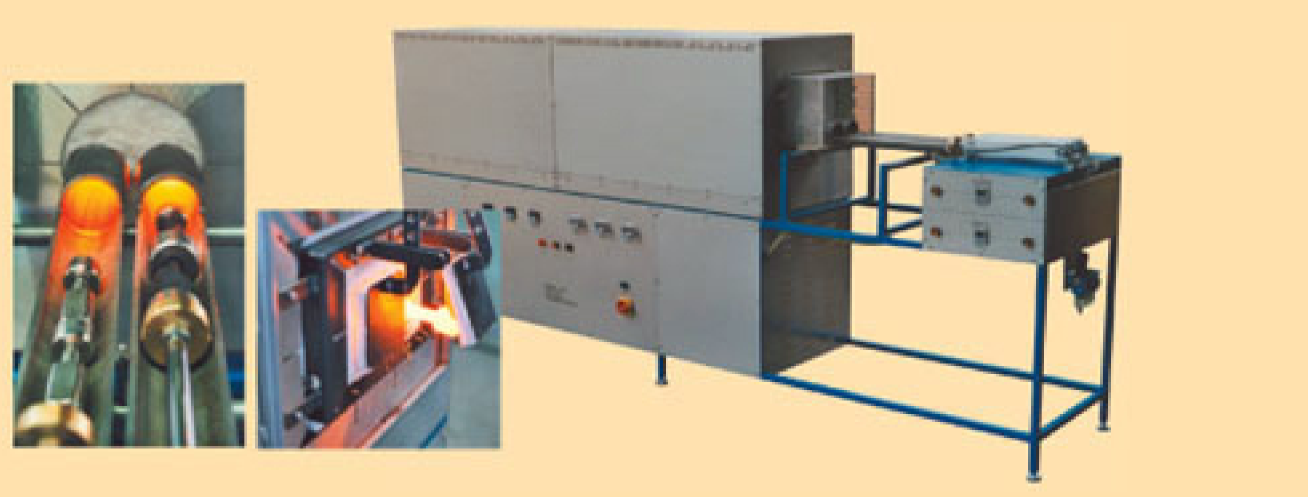


Tubular furnace for pre-heating of valve forged parts

Heat treatment concepts for the product-related technique

The continuous optimisation and development of production technologies, especially in the remodelling technique, led at Linn High Therm to the development and production of units made to customer specification. In the following is a selection of new furnace concepts presented.

Since Deprez in France built the first resistance heated furnace with heaters made of sugar coal in 1849, in many cases the modern units have reached the limits of available materials due to the various possibilities of use and application of electric furnaces. A lot of modern high-tech materials are used for the furnace construction and new revolutionary furnace concepts are possible due to newly developed materials.

The know-how which has been achieved at Linn over the last 30 years in the industry, laboratory and microwave furnace, high frequency-generators and special unit construction, brought the best material knowledge and experience in all production technologies, temperature and frequency ranges. This experience potential, combined with a flexible advanced training of all employees and a continuous experience interchange with customers from industry, universities, research centers and suppliers, also leads, even at high risks in the construction of units made to customer specification and devices for research, to constant success.

Tubular furnaces at metal forming

The application field of modern tubular furnaces is spread widely. It ranges from heating, absorbing, drying, relaxing, drawing, tempering, refining, calcining, pull-, tilt- and break experiments, thermocouple calibration furnaces, pulling of precision glass capillaries up to sintering of iron and non-iron materials as well as on thermal-chemical processes like nitration, recarburizing, hardening, final and bright annealing, just to mention the most important process technologies. The different furnace types are:

– *Standard tubular furnaces* up to a maximum operation temperature of 1300°C with in fiber insulation embedded Fibrothal heating modules, 1 and 3 zones for horizontal and vertical operation, if desired divisible, up to 1150°C.
– *Standard tubular furnaces* up to a maximum operation temperature of 1500°C with SiC tubular heating modules.
– *Custom tubular furnaces* up to a maximum operation temperature of 1800°C with molybdenum-disilicide heating elements.
– *Custom tubular furnaces* with molybdenum-, tungsten- or graphite heating and insulation, respectively cold-wall build-up, multi-zone unit for horizontal or vertical operation up to over 2000°C possible.

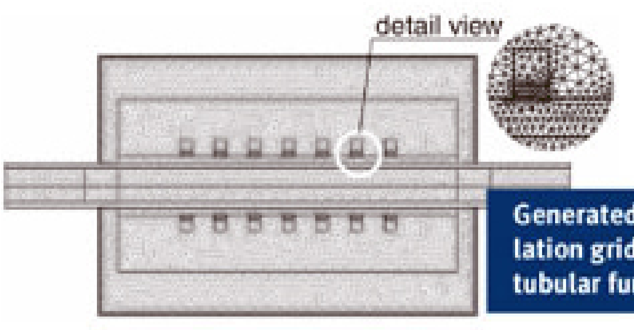
A large number of options enables various applications and variation possibilities.

Constructed with modern materials

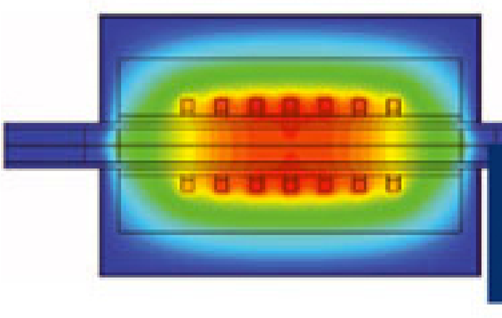
The tubular furnaces can be equipped with various insert tubes. Usable materials are quartz glass (T_{max} = 1100°C), ceramic (T_{max} = 1750°C) and heat resistant steel (T_{max} = 1300°C). By means of gas and vacuum tight end caps, processes can be carried out under controlled protective gas atmosphere and under vacuum up to 10^{-5}mbar. Furnaces with sapphire insert tubes (maximum diameter 40mm) are gas- and vacuumtight up to 1850°C. With appropriate gas feeding device, safety package and burning-off device, an operation with hydrogen is possible. The furnace is controlled, in accordance with the customer, by devices ranging from a simple ramp controller to temperature program controllers with integrated SPS and extensive visualization and documentation software.

The author Dipl.-Ing. Jürgen Dix has been employed since 1996 by Linn High Therm GmbH, Eschenfelden/Germany, as development engineer. He is responsible for project execution and is in charge of units made to customer specification.

Caused by using ceramic fiber insulation materials a revolution in the field of furnace construction took place in the past years and decades. Today, the modern fiber insulation, respectively a combination of light building bricks and fiber, has gained more and more acceptance. In regard to fiber insulated furnaces, the chamber weight of the insulation is reduced by up to 80% compared to the conventional method of construction. This means a reduction of the stored heat of 80%. In addition, the fiber insulation contains app. 80% air. For this reason, the inactive air is an ideal insulator. This leads to an extremely low heat radiation at high temperature stability. Due to the use of vacuum formed standard modules it is possible to compensate the high costs for material by considerable savings for the installation.



Generated calculation grid for a tubular furnace



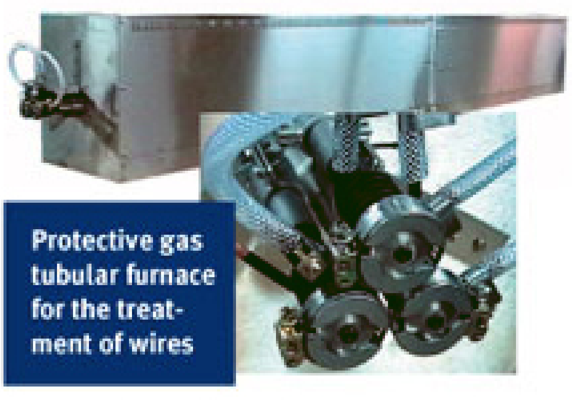
Calculated temperature distribution in a tubular furnace

The exchange of insulation and heat conductor is considerably easier, hence making the furnace service friendlier and the maintenance time shorter. Scarce resources mean increasing costs for energy. Increasing costs for energy mean increasing overhead expenses/running costs. Increasing overhead costs force effective constructions. The most modern fiber materials are usually the best solution. Modern fiber insulated furnaces make the economical optimal use of the applied primary energy. Along with the higher material costs for fiber material it should not be withheld that also the application of fiber materials has limits. Due to the high air content the mechanical stability is limited. By using ceramic bottom plates, the use of fiber material is, however, most of the time possible. Fiber insulations are sensitive to some aggressive materials, since they are affected more easily than refractory bricks due to their very large specific surface. For this reason, two-layer insulation systems are used in such cases in order to combine the advantages of the fiber insulation with the advantage of refractory bricks.

Tubular furnaces in application

With a especially developed modern high temperature protective gas tubular furnace, wires under various protective gases can be treated continuously up to 1300°C at the same time in 3 integrated heat resistant tubes. The protective gas supply is placed in the middle so that a regular protective gas atmosphere is realized. This furnace is used for surface treatment of titanium wires of Ø 0,2 – 2mm. There are cooling-zones attached to the outlet.

A special tubular furnace with 2 insert tubes made of high heat resistant alloys was designed for pre-heating of various forged pieces, so that continuous temperatures up to 1300°C can be used without having to drop the mechanic stability and thermoshock resistance of a metallic alloy. The heated length of 2000mm is regulated by a 3-zone controller. The two pneumatic feed units are operable separately. If required they can be extended with a charging magazine so that a fully automatic system solution is possible.



Protective gas tubular furnace for the treatment of wires

This furnace is used for a very wide production range with various shapes and weight of the parts. The variation variety could be achieved by the optimisation of the fixing elements. In order to reduce the heat losses at the outlet an insulated tilting mechanism was installed so that the forged pieces are ejected at almost maximum temperature.

Simulation calculation of heat treatment units

The traditional way of developing new furnaces for the most empirically comes across economic limits and risks due to the variety and processes becoming more and more complex. The costs for experimental surveys and parameter studies increase considerably along with the increasing dimension of devices and increasing complexity of the processes. This program offers an efficient way to improve the furnaces already in the offer and construction phase.

Calculation example for the heat treatment of forging parts

Basic data are: the forging parts are 160mm long and have a weight of 1,3 kg, each incl. fixing element. The through-heating duration is min. 18min, the heating-up temperature of 1250°C must be reached. The power of throughput results by the following formula:

$$\text{parts/tube} = \frac{\text{heated length}}{\text{length of part}} = \frac{2000\,\text{mm}}{162\,\text{mm}} = 12\ \text{parts/tube}$$

$$\text{fillings per hour} = \frac{60\text{min}}{\text{throughwarming duration}} = \frac{60\text{min}}{18\text{min}} = 3{,}5\ \text{tube fillings/h}$$

$$\text{throughput/tube} = \frac{\text{tube fillings/h}}{\text{parts/tube}} = \frac{3{,}5\ \text{tube fillings/h}}{12\ \text{parts/tube}} = 42\ \text{parts/h}$$

$$\text{mass throughput in the furnace} = \frac{\text{throughput / tube x 2}}{\text{weight / parts}} = \frac{42\ \text{parts/h x 2}}{1{,}3\ \text{kg/part}} = 109\ \text{kg/h}$$

$$\text{total energy requirement} = \dot{Q} = c \times m \times \ddot{A}t$$

$$\text{total energy requirement} = \dot{Q} = 0{,}5\,\frac{\text{kJ}}{\text{kg}} \times 109\,\frac{\text{kg}}{\text{h}} \times 1230\,\text{K} = \underline{\underline{18{,}6\,\text{kW}}}$$

Modern furnaces have to comply with the various requirements in regards to geometry, maximum temperature, temperature homogeneity, heating up and cooling down process. In order to be able to solve this problem as user-friendly as possible, a corresponding simulation program was developed in co-operation with the University of Erlangen. The CAD-drawing which was made with an external system is brought in and if necessary processed for the automatic grid-generation. After that, the grid structure has to be refined manually on special spots in order to achieve the most realistic result as possible.

After that, the material data for heating elements, insulation and furnace atmosphere are assigned by a material data base. Here, anisotropic and temperature dependent material characteristics can be taken into consideration. For the modern furnace construction, mostly materials are used which have anisotropic material characteristics, e.g. carbon (CFC) reinforced with carbon fiber for insulation and as heating material or pyrolytic boron nitride as material for crucibles. The heat conduction abilities of such materials differ from each other in radial and axial direction by considerable scale (in the case of boron nitride for example by a factor of 60). Moreover, it is possible to solve inverse problems like figuring out the heat conductor dimension and the temporal and local course of the heating power of a desired temporal and local temperature dispersion. This does not only contain the temperature calculation itself but the physical phenomena like the formation of solid/fluid phases. Appropriate approximations based on the differential equation at discretion ensure a high calculation velocity, so that the solving of such matrixes is possible within only a few hours on a fast PC. The result can be shown with a wrong-colour-visualization with a legend or, alternatively, temperature cut sequences can be shown.

Chamber furnaces at metal forming

Besides the wide range of standard chamber furnaces with a volume of 1,5 – 2750l and maximum furnace temperatures up to 1800°C under air, protective gas and vacuum, special custom made furnaces are increasingly in demand. Due to innovative development and research projects, everything from the modification of a standard furnace to a complete new development specially designed for a customer's specific operation, is possible.

This high temperature rotary feed table chamber furnace was especially developed for pre-heating of valves of large-size-engines up to 1220°C. Due to the split sliding door a continuous loading and unloading of the two-stage-rotary feed table (made of heat resistant steel) is possible. The encapsulated regulation technique with cooling-aggregate provides an operation under extreme conditions.

Rotary feed table-chamber furnace for pre-heating of forging parts

Concluding should be said that only a combination of modern calculation methods with the use of advanced materials and technologies, paired with optimal control technologies, will lead to a customized solution for the continuously increasing demands of each individual customer. ■