New developments for continuous heat treatment of floatingly and touchless guided metal strips of copper alloys

Kramer, C. (1), Kramer, T. (2)

Recent developments which improve the technology of strip floatation furnaces for copper alloy strip are described. The new nozzle system allows higher floatation force, higher heat transfer, and improved strip stabilisation. New designs make a considerable increase of the maximum operation temperature possible. The reported results are especially important for furnace exchange and plant upgrading projects.

The continuous heat treatment of high quality copper alloy strips is executed in plants with high protective gas circulation and touchless guided strip. The core piece of such plants is the nozzle system which provides the floatingly suspension and the stabilisation of the strip and, in addition, cares for the convective heat transfer. The demand for higher annealing capacity, a wider range of strip thickness, and an increase of the maximum possible material temperature are a particular challenge for the thermoprocessing engineer.

Especially for the replacement of an old worn out furnace in a still mechanically sufficiently working strip line, the customer usually requires an increased throughput together with a higher maximum operation temperature and a higher upper limit of strip thickness. Furthermore the downtime due to furnace problems should be reduced and the maintenance simplified.

This article reports about some important developments and innovations of WSP GmbH which increase the performance and the efficiency of such plants considerably.

The new WSP-floatation nozzle system

Conventional floatation nozzle systems consist of nozzle arms or ribs with constant width across the strip width, Figure 1 left. The nozzle rib itself has slot nozzles or rows of closely spaced nozzle holes which, together with nozzle opening in the nozzle rib bottom between the slot jets care for building up a pressure cushion between strip and nozzle bottom. This pressure cushion gives the floatation force.

The WSP-floatation nozzles [1], Figure 1 right, have nozzle bottoms like a longitudinal cross section of a barrel with a width decreasing from the centre to both edges. This new nozzle bottom shape has essential advantages:

1. The slot jets enclosing the nozzle bottom at its longitudinal sides are inclined against each other in the plane view. Due to this inclination and the decreasing distance between the slot jets the gas flow at the edges out of the pressure cushion is hindered what increases the floatation force and improves the lateral strip stabilisation.
2. Because of the larger width in the centre the nozzle bottom area is increased which again improves the floatation force.
3. Due to the larger nozzle bottom area in comparison to conventional rectangular nozzle ribs, more round jets can be placed between the slot jets thus increasing the heat transfer for at least 15 % at the same volume flow.

Figure 2 shows the comparison between the floatation pressure coefficient plotted vs. the floatation height for a conventional and for the new WSP-floatation nozzle system. The open area for the compared nozzles is the same. Not only the level but also the progression of the force is increased. This allows the floatation of heavier strip and improves the strip stabilisation. Therefore scratches on the strip surface due to contact with the nozzles are avoided, even for

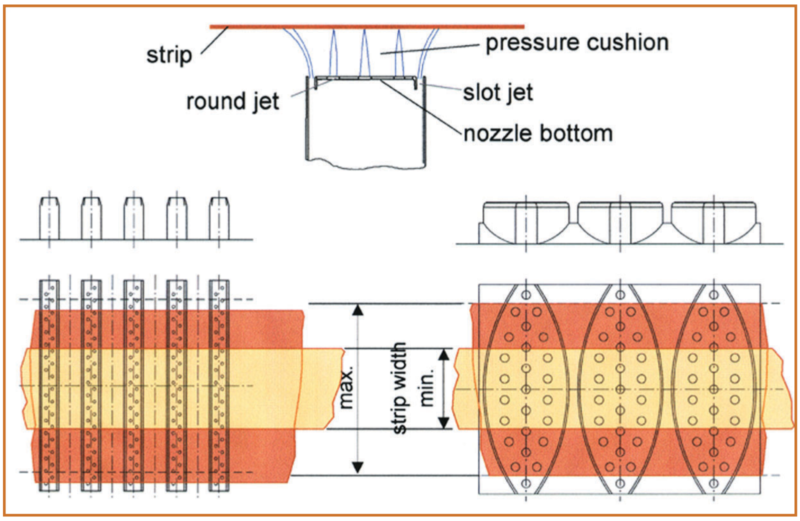

Fig. 1:

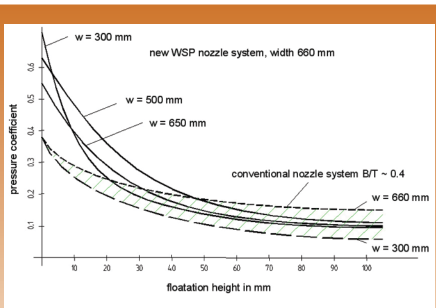

Fig. 2:

badly rolled strips. The new nozzle system shows furthermore a smaller decrease of the floatation force with decreasing strip width than conventional nozzle systems.
Because of the essentially increased floatation force which allows the floatation of copper and brass strips up to 3 mm thickness with protective gas (about 96 % N2, rest H2) of temperatures of 750 °C to 800 °C, it is possible to decrease the convective heat transfer of the nozzle system to the strip without decreasing the distance between strip and lower nozzles essentially. This is especially of advantage if in an existing plant the production speed can be increased due to the new furnace technology. So, with the existing strip accumulators higher productions are possible because the time necessary for the coil change can be increased by reducing the strip speed during this procedure. The final material temperature and the material properties remain unchanged by this novel dynamic operation of the floatation furnace. For a new plant with this technique even the exit strip accumulator can be omitted which reduces the number of rolls touching the readily annealed and clean strip which improves the surface quality. The reliable reduction of the convective heat transfer with still sufficient floatation force is possible by a new developed control concept for the strip heating [2]. This new technology is furthermore of advantage when the strip cross section, together with the strip surface, is changing from coil to coil. The new technology allows a much faster achieving of the steady state condition and thus reduces the transient length of strip which usually has to be scrapped.

Novel furnace design

Modern floatation furnaces for copper alloy strips shall be designed for continuous operation temperatures of 850 °C and more. Therefore, a design for the metallic internal furnace parts is required which is resistant against creep deformation. Furthermore different thermal elongation of different components should not lead to deformations of the internal casing. The new design is [3] shown in Figure 3. The upper nozzles and the lower nozzles of the floatation nozzle system are supplied by separate fans. This allows an easy adaptation of the floatation force by a change of the fan speed. The fans can be positioned in the roof, Figure 3a), or in one side wall, Figure 3b). The later design is of advantage if the furnace is positioned on the shop floor or should replace an old furnace with the positioning of the fans in one side wall, too. In both cases the flow duct has the shape of a horizontally positioned U. For the

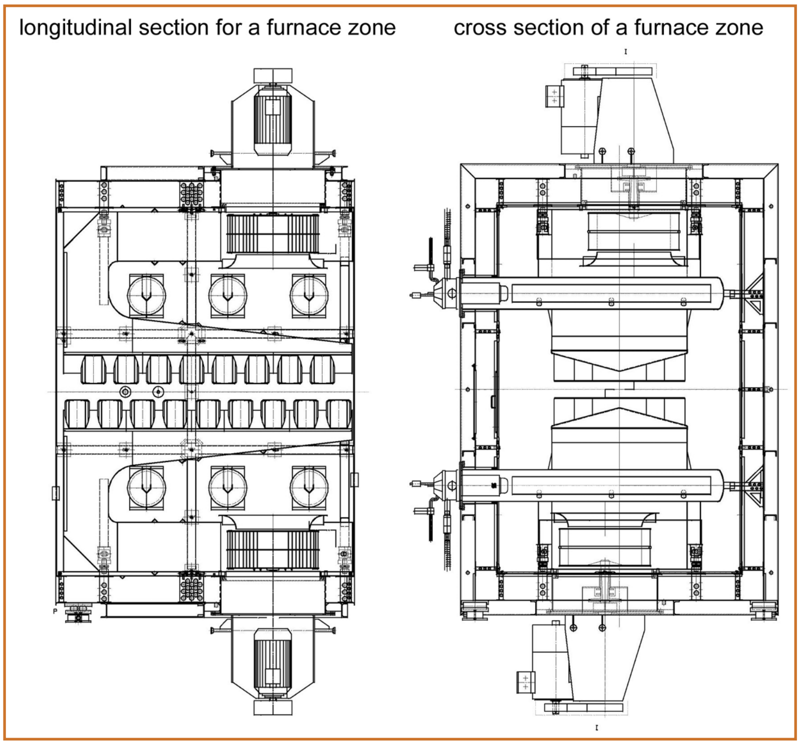

Fig.3a:

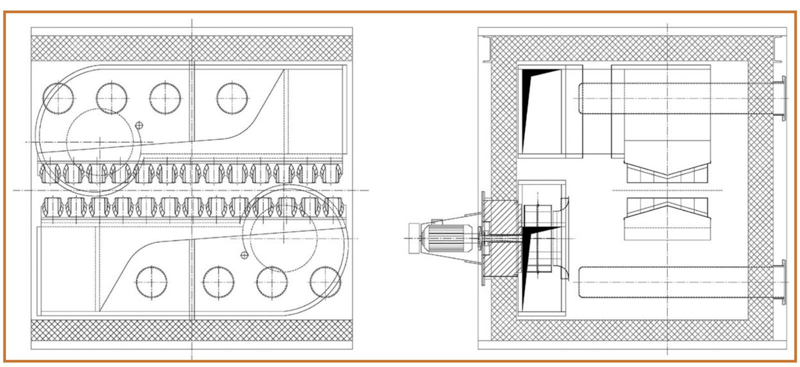

Fig. 3b:

Fig. 4:

design according to Figure 3a) the entire flow circuit is a stiff welded construction of high temperature alloy. In case of the design Figure 3b) a specially designed connection piece allows different elongation of the fan box and the nozzle plenum duct. Due to the design of the connection piece no bending moments and no longitudinal forces can act on the fan box or on the nozzle plenum box. Therefore no deformation due to different thermal elongation can occur. The gaps between the different flow duct components are small and designed for minimised gas flow leakage.

Especially in the first heating zones of a floatation furnace, where a high heat input into the strip is required, the temperature distribution on the flow duct walls is very non-uniform. An investigation based on a numerical modelling [4] shows temperature differences between the hot areas close to the radiant tubes and the nozzle system up to 300 K. The nozzle ribs are the coldest part because the back flow of gas from the strip where by heating the strip the gas temperature is reduced, will "cool" the nozzle rib surface. The difference in thermal elongation due to this huge temperature differences is enormous. Therefore, in the new furnace design, the radiant tubes do not penetrate the flow ducts, but are positioned on the suction side of the fan. Thus the problems of sealing the flow duct in spite of thermal elongation - the radiant tubes are fixed and the flow duct moves - cannot occur. Furthermore straight radiant tubes are used which can be sealed 100 % gas tight in a simple manner with conventional flanges at the outer furnace shell. So the exchange is easier and a leakage through which oxygen could enter the furnace is absolutely excluded. A further advantage against conventional P-shaped or U-shaped radiant tubes is that at a straight single radiant tube no elongation differences which create thermal stresses can occur.

Inside the flow ducts of WSP furnaces the convective heat transfer from the flow duct wall to the gas is increased by special means. By this design the temperature of the sheet metal areas facing the hotter radiant tubes is reduced. Furthermore the materials are selected according to the expected maximum material temperatures. When selecting the material it must be considered that a furnace with a nominal maximum "operation temperature" of 850 °C, which corresponds to the gas temperature at the nozzle exit, can easily have parts in the flow duct which obtain temperatures of 1000 °C and more.

Special care is taken on the design of the fans, Figure 4. The fans developed and manufactured by WSP have round plugs and are sealed against the external housing by round flanges with double seals. The shaft is sealed by a gas chamber seal which is pressurised by protective atmosphere and the pressure in this chamber is monitored. The fan motor together with the fan shaft bearing are fixed to the plug. So different displacements between the fans, standing on a platform or fixed to the shop floor, and the furnace casing cannot occur. WSP hot fans can be equipped with an oscillation monitoring system and with a special lifetime survey software which calculates the still remaining lifetime depending on the gas temperature and the fan speed. So a fan exchange, which may be necessary if the fan operating under extreme conditions, reaches the allowed limit of creep deformation, can be planned in advance and a non-expected breakdown of the plant due to a fan problem is completely excluded.

New strip turn with integrated cooling

Especially for an exchange of a heat treatment plant in an existing line, in combination with an increase of production an augmentation of the cooling capacity is of importance. Therefore, a strip turn was developed [5] at the exit of the plant which does not only care for the strip centring control but is also equipped with a highly efficient cooling, Figure 5. The new strip turn consists of a multitude of rollers of small diameter which are arranged in the shape similar to a quarter of a circle. The rollers are covered by sleeves of special blend Aramid fibres of increased temperature resistance. Because of the effective cooling by cooling gas nozzles arranged between the rollers, the cooling effect is increased and the rollers cooled by the gas act additionally as "cooling rollers". So in spite of an increase of strip speed and throughput the temperature for the immersion of the strip into the water closure at the end of the line can be kept constant or even be reduced.

Continuous strip furnaces for extreme temperatures and 100% hydrogen as protective atmosphere

For extreme material temperatures up to 1000 °C a continuous strip furnace was developed with high convective heat transfer by gas circulation and up to 100 % hydrogen as protective atmosphere [6]. The strip can be guided in a catenarian curve or vertically with a 180° free strip turn at the lower end. In this turn the strip is touchless stabilised by floatation systems. These floatation systems also care by perfect lateral strip stabilisation for the strip centring without any additional means. The advantage of this design in comparison to vertical furnace according to the state of the art, is that the strip, in case of a sudden strip stop, may freely shrink without building up excessive tensions which are the usual reason of a strip rupture at such occasions. The strip tension is constant "by design" and may not exceed values of about 1 N/mm strip cross section.

Literature

[1] C. Kramer and E. Fiedler (Inventors): Bed of air cushion nozzles to guide webs in a floating manner, EP 0 864 518 B, granted 31.10.2001

[2] C. Kramer (inventor): Verfahren zum Betrieb einer Durchlauf-Wärmebehandlungsanlage mit über-wiegend konvektiver Wärmeübertragung, German patent application, 103 37 502.3, 14.08.2003

[3] C. Kramer and E. Fiedler (Inventors): Apparatus to guide webs in a floating manner, EP 0 864 518 B, granted 25.06.2003

[4] K. Hornig, R. Bölling, H.-J. Odenthal, H. Pfeifer, K. Berns, K. Schmitz, Strömungssimulation eines Schwebebandofens für NE-Metallbänder, GASWÄRME International (52) Nr. 5/2003, S. 256 - 262

[5] C. Kramer (Inventor): Umlenkvorrichtung für bewegte Bänder, German patent application 103 26 071.4, 10.06.2003

[6] C. Kramer: A new Technology for the Heat Treatment of Floatingly Guided Metal Strips of Copper and Aluminium Alloy - Heating, Soaking, Fast Cooling; 1st International Conference on Plant and Process Technologies for Non Ferrous Metals, Conference papers published by Messe Düsseldorf GmbH

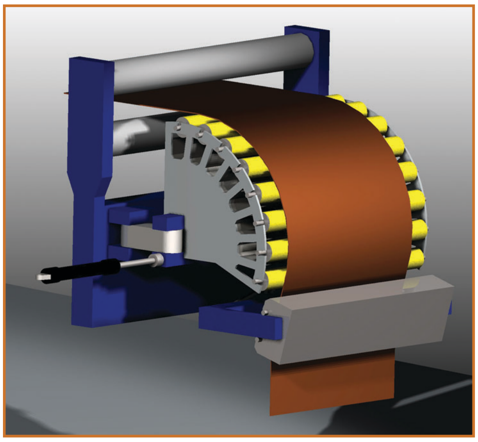

Fig. 5:

(1) Prof. Dr.-Ing. Carl Kramer, consulting engineer, chairman of the scientific board of WSP GmbH

(2) Dr.-Ing. Thomas Kramer, general manager of WSP GmbH