THE LOW GAS CONSUMPTION CONTINUOUS FURNACE: ADVANTAGES OF THIS NEW FURNACE CONCEPT FOR PM APPLICATIONS

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Abstract
When a need was seen for a furnace with an increased cooling rate and reduced gas consumption, a (patent applied) Low Gas Consumption furnace concept was developed. The LGC furnace is a hybrid of mesh belt and pusher furnaces, utilising the best aspects of each to create a new product. The authors report on the goals behind the LGC furnace's development, and what can be achieved using this new furnace concept.

The LGC furnace: Evolution

The motivation behind the development of the LGC Furnace was to increase the flow through the sinter hardening cooling blower in mesh belt sintering furnaces to the cooling rate.
This new design concept also reduces gas consumption substantially and makes it possible to change the way several thermal processes are performed.
Mesh belt furnaces used for processes like debinding, sintering, steam treatment, annealing, normalising and brazing – are, in principle, tunnels, open at both ends and having sufficient headroom to allow a conveyor belt loaded with parts to travel into and out of the furnace (Fig. 1).
Typically, the amount of gas these furnaces consume is in proportion to the cross-sections of the tunnel opening.

Fig. 1 A conveyer belt loaded with parts passes into a mesh belt furnace (Courtesy Fluidtherm)

The quantity of gas required for blanketing or for reaction with the parts' surfaces in a mesh belt furnace is only a small fraction of the amount of gas consumed; most goes towards keeping air out of the furnace tunnel. Other furnaces – such as pushers, walking beams and roller hearths – utilise atmospheric lock doors to keep air out of the furnace, thus substantially reducing gas consumption when compared with an equivalent capacity mesh belt furnace.

To address the considerable difference in gas consumption between these furnace types a decision was made to add atmospheric locks to a mesh belt furnace.

Steel, ceramic or graphite trays are required to carry the parts through the LGC furnace; these trays enter the furnace and exit sideways, passing through atmospheric locks at both the entry and exit points.
(Fig. 2 left and right, respectively).

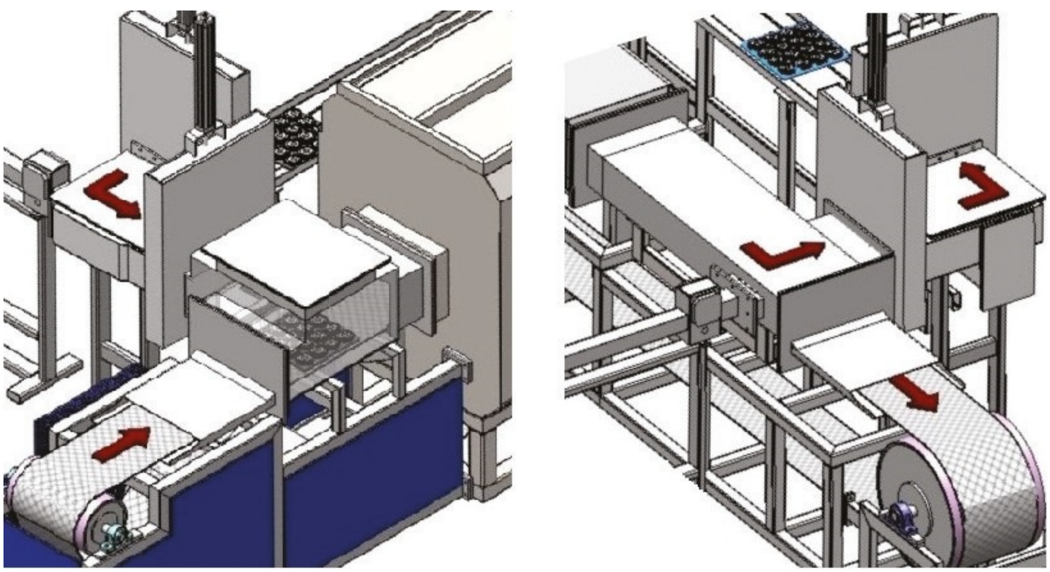

Fig. 2 Part-carrying trays enter and exit the LGC furnace sideways, passing through atmospheric locks at both the entry and exit point

With this side entrance layout, the belt is empty at the place where it enters and exits the furnace tunnel, allowing the front and rear openings to be only a few millimetres taller than the belt itself without the need for head- room (Fig. 3). This reduces the gas consumption to the low levels seen in pusher furnaces.

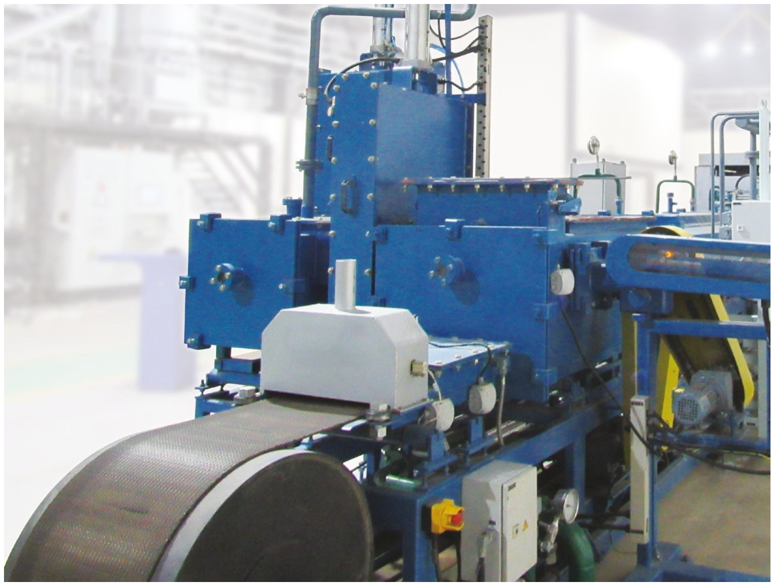

Fig. 3 Because parts enter and exit the furnace via a side entrance on the LGC, the front and rear openings through which the conveyer belt passes do not require the same headroom as in a typical mesh belt furnace

WHY NOT JUST USE A PUSHER FURNACE?

The question that might arise when considering the development of the LGC furnace is what its applications might be. In fact, LGC furnaces which are hybrid mesh belt/pusher furnace combine the advantages of both; over mesh belts in terms of gas saving and over pusher furnaces in terms of a reduction in the deadweight of the trays (typically, LGC trays weigh a third of pusher trays); the elimination of tray pile up; not having to feed empty trays to empty the tunnel of parts; the elimination of problems caused by undulations in the pusher track, in the case of older metal alloy muffle furnaces; and the possibility of using higher-capacity plants, with trays for 600 mm to 900 mm wide belts.

This new Low Gas Consumption design opens up multiple possibilities.

Reduction in Cost of Thermal Processing

Gas consumption is the second highest component of the overall cost of most thermal processes, next only to heating energy cost. Any reduction in the gas cost has a significant impact on the overall processing cost. The energy needed to heat unnecessary gas to the furnace temperature must also be considered.

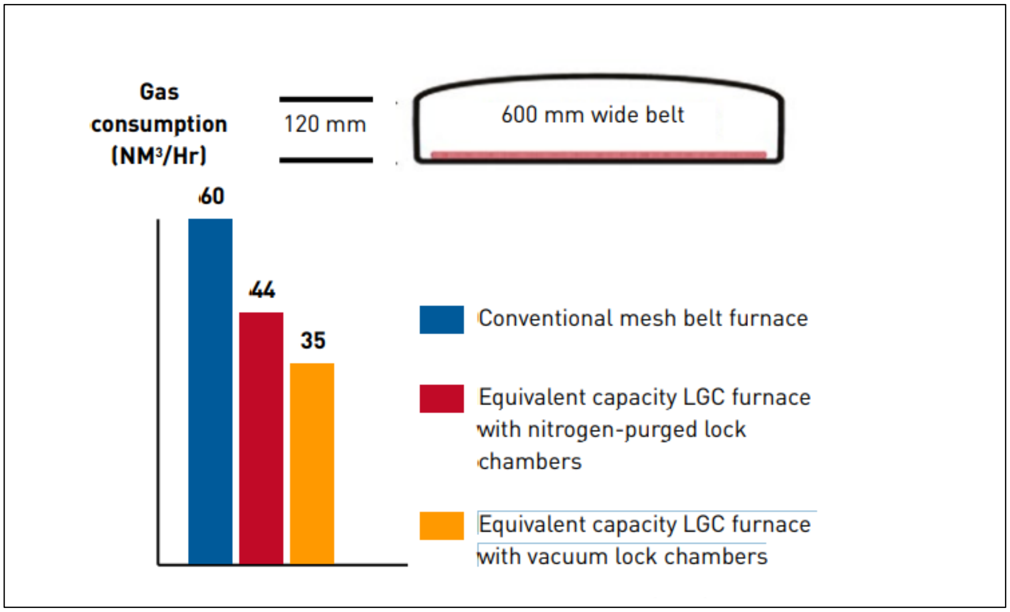

Fig. 4 Gas consumption in a conventional mesh belt furnace (blue), equivalent capacity LGC furnace with nitrogen-purged lock chambers (red) and equivalentcapacity LGC furnace with vacuum lock chambers (orange)

The gas consumption of an LGC furnace equipped with nitrogen- purged atmospheric lock chambers is about 27% lower than a traditional 300 kg/hour net, 600 mm wide belt furnace operating with a mixture of N_2 + 10% H_2. When the LGC furnace is equipped with vacuum atmospheric lock chambers, the gas consumption reduces by 42% (Fig. 4).

Unlike conventional mesh belt furnaces, increasing the LGC furnace size (belt width & tunnel length) does not cause a proportionate increase of gas consumption. Consequently, the cost saving due to reduced gas consumption increases with an increase in furnace capacity. The cost saving increases dramatically when the content of expensive hydrogen in the gas mixture is high for instance, when copper brazing or sintering stainless steel.

SINTER HARDENING IN MESH BELT FURNACES:

Sinter hardening occurs when the furnace gas is recirculated across a cooler and is impinged on the surface of hot sintered parts as they emerge from the sintering furnace. The performance of a sinter hardening module is considered satisfactory if heat is extracted from the parts at a rate of around 3℃/sec.

If the fan speed is increased in an effort to increase the cooling rate, air can often enter into the furnace tunnel, resulting in oxidation of the sintered parts despite blocking systems (Fig. 5).

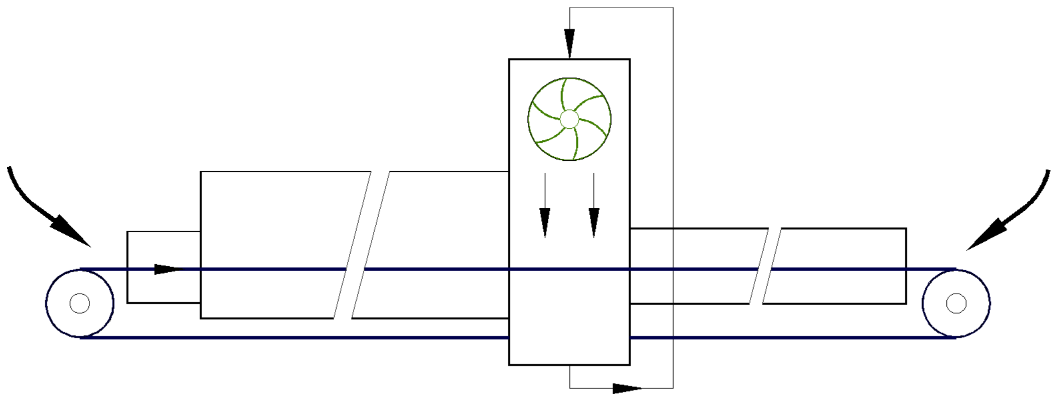

Fig. 5 When fan speed is increased to increase the cooling rate, air can often enter into the furnace tunnel, resulting in oxidation of sintered parts

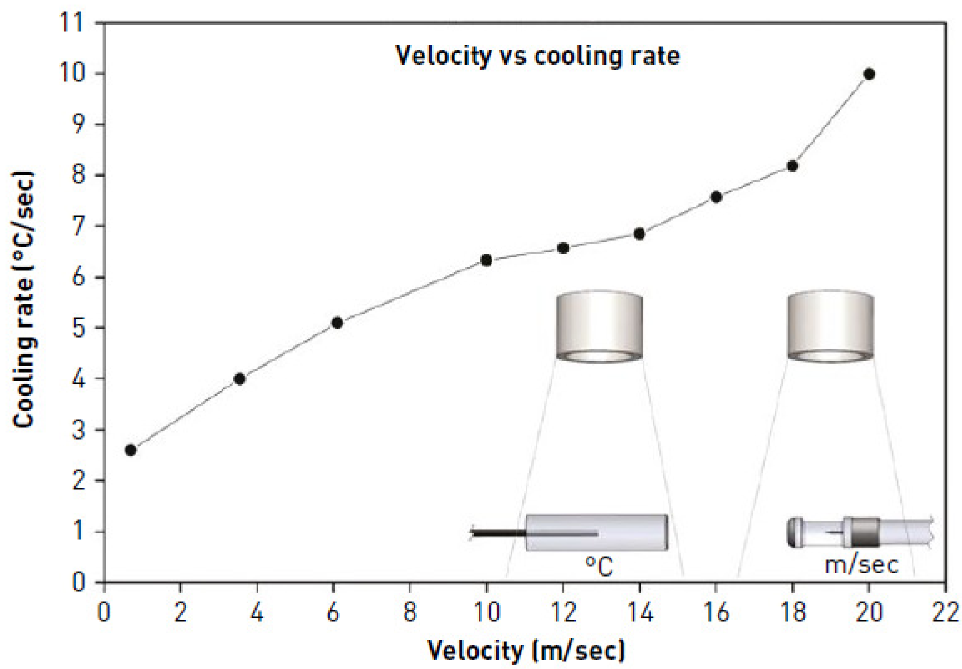

Fig. 6 Velocity vs cooling rate test. A Ø12.5 mm x 50 mm Inconel rod with a Ø2.6 mm N thermocouple inserted to the centre was heated to 1080 °C and subjected to a nitrogen stream from a D50 tube nozzle placed 120 mm above the rod

When the cross section of the entrance and exit is severely reduced, as in the LGC furnace concept, the chance for air to enter the tunnel is correspondingly reduced. The sinter hardening blower is then able to work at a higher speed and the untapped potential of higher velocity gas impingement (Fig. 6), which would result in a higher cooling rate, can be realised. This has the potential to reduce the cost of certain PM parts by reducing the extent of expensive hardenability enhancing elements.

Continuous Carburising Of PM Gears With Low Pressure Gas Quenching:

At the 2016 World PM congress in Hamburg, Germany, the authors presented a paper discussing the viability of carburising PM gears in a continuous mesh belt furnace, similar to a sintering furnace, followed with hardening by gas quenching at atmospheric pressure in a sinter hardening module [1]

Results were reported on the testing of PM gears made from Höganäs' Astalloy 85Mo powder, carburised and hardened at a cooling rate of 8℃/sec in a prototype furnace.

The LGC furnace, with cooling rates higher than those generally achieved in a mesh belt sinter hardening furnace, will make the continuous carburising of PM gears viable at an industrial scale. One such continuous furnace has the capacity to replace the several batch atmosphere and vacuum furnaces currently used in this application and at a lower processing cost. This was, in fact, the primary reason for the development of the LGC furnace concept.

Continuous Furnace Brazing Of Tall Parts: *Several parts that are brazed – such as small gas cylinders and tube manifolds – sit tall on the furnace belt. The consumption of hydrogen- rich gases in a continuous furnace for brazing such parts would be high, if not for the 'humpback' construction of inclined and extended front and rear tunnels, which reduce gas consumption by half. However, there are limits to the angle of inclination to prevent parts sliding down the furnace belt; this increases the plant length (Fig. 7). One of the consequences of this extra length is the added cost of replacement belts, which are sold by the metre. The installation of a long hump back furnace can also become a problem when manufacturing floor space is inadequate.*

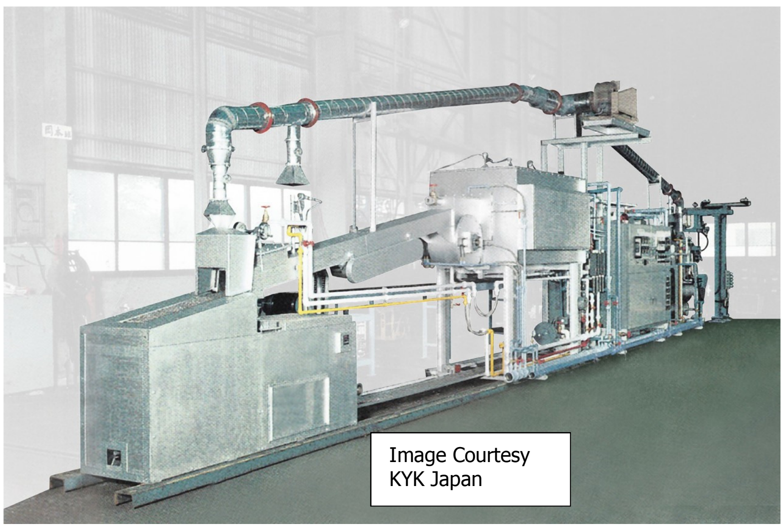

Fig. 7 The 'humpback' construction of inclined and extended front and rear tunnels in continuous brazing furnaces reduces gas consumption by half, but there are limits to the angle of inclination to prevent parts sliding down the furnace belt.

An LGC brazing furnace of the same capacity is shorter, as the inclined entrance and exit tunnels are replaced by the shorter atmospheric lock chambers, which allow increased headroom without a proportionate increase in gas consumption.

Continuous Steam Treatment Without Boilers:

Many companies, which need to maintain boilers for process steam, would be receptive to the idea of a steam treatment furnace that does not require a boiler. On top of the problems related to boiler safety and maintenance, one has to consider the cost of the energy required for the latent heat of trans-formation of water to steam.
In a conventional mesh belt steam treatment furnace with an open entrance and exit, the process steam from a well-maintained boiler is an economical option for the amount of steam the furnace consumes. As is the case with most processes conducted in these conventional furnaces, the amount of steam actually required for the process of oxidising the PM parts is a relatively small fraction of the total quantity of steam used, most of which serves the function of keeping air out of the furnace tunnel.

When the gas consumption is reduced in an LGC furnace with entry and exit atmospheric lock chambers, it becomes cost-efficient to use nitrogen gas saturated with water vapour in a heated bubbler (humidifier) in place of steam.

A purpose-designed humidifier, equipped with special tubular heaters and droplet capture, gives the same result as steam from a boiler for both shock absorber and refrigeration parts. The ability to add a ‘finishing’ step involving the direct injection of an oxygen source makes it especially useful for parts subjected to high hydraulic pressures, as well as parts that require a particularly lustrous blue-black hue.

Sintering of Aluminium Parts:

The purity of the protective nitrogen atmosphere in an aluminium sintering furnace has to be of a higher order than what is required for iron parts, considering the affinity of aluminium for oxygen [2].

In this case, the LGC furnace would have, in addition to the atmosphere lock chambers that reduce air in the tunnel, an all-metal hot zone comprising a metal alloy muffle to prevent reactions with the furnace insulation, recirculation fans for improving temperature uniformity in multi-tier work baskets, in-muffle heaters that are isolated from the parts for convective heat transfer without hot spots, and atmosphere isolation that keeps binder fumes away from the sintering chamber [3].

Soft magnetic alloy processing:

An LGC furnace built with features suitable for aluminium sintering, as well as for steam treatment, also becomes suitable for the stress relaxation of soft magnetic alloy parts where required, with atmosphere isolated sections for binder removal, inert gas and high-dew point (steam) atmosphere (Fig. 8).

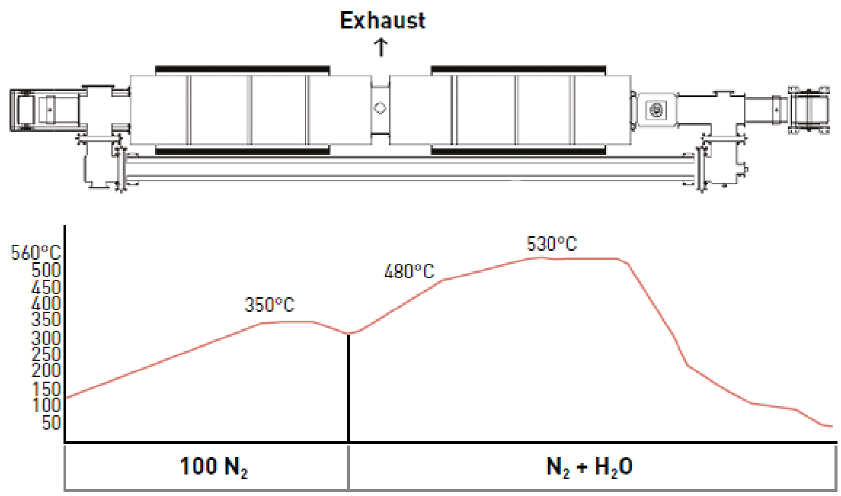

Fig. 8 An LGC furnace with features suitable for aluminium sintering and steam treatment would be suitable for the stress relaxation of soft magnetic alloy parts where required

Conclusion:

With the reduction in gas consumption and the range of applications made possible or made more efficient in Fluidtherm's Low Gas Consumption furnace, it is clear that this new technology could represent a key development for some segments of the metal powder-based manufacturing industry. The more cost efficient and versatile PM production becomes the easier it can compete with conventional manufacturing processes, and provide a wider range of solutions for a changing market.

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