The Value of an Induction Vacuum Chamber/Furnace (IVC/IVF)

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Companies are increasingly struggling to eliminate the batch manufacturing process in lieu of continuous flow or lean manufacturing. The reasons for the change are obvious: shorten lead times, decrease WIP, decrease inventory and scrap, increase flexibility and increase productivity.

One process that has historically been locked into batch mode is the vacuum furnace (i.e. vacuum brazing, hardening, etc.). Until recently there hasn’t been an alternative to traditional batch vacuum furnace processing. Historically, all vacuum processing has been conducted in relatively large vessels which require long pump down and heat cycle times thereby necessitating the inevitability of batch processing. Due to the heat source (typically radiation/convection) traditionally available in vacuum processing, the heat cycle times have been the limiting factor in process cycle time. Therefore, the answer was going to larger vessel sizes increasing throughput with larger quantities of parts while still maintaining similar heat cycle times.

The solution to eliminating batch vacuum processing is in reducing the heat cycle time needed. By choosing an alternative heat source, the cycle time can be dramatically reduced. Through the use of induction, the necessary heat is produced quickly and efficiently directly into the affected area of the part itself (IVC) or into a small graphite susceptor (IVF), radiating the heat uniformly into the part.

Induction heating produces heat in metals and other conductive materials (graphite), through the application of an electromagnetic field. The imposed electromagnetic field produces a current flow in the part (IVC) or susceptor (IVF). The current flows against the resistivity of the part material or the graphite in the susceptor and produces heat. With induction heating, it is possible to specifically design the current flow which is induced into the part or susceptor (hot zone), thereby precisely controlling the heat pattern and therefore the amount and area of heat.

Through the use of induction and small vacuum chambers, cycle times are greatly reduced and parts may be processed individually or in small quantities as needed very quickly.

Vacuum and/or atmospheric processing is required for high temperature nickel brazing of aerospace and other super alloys, copper brazing of steel parts, and processes requiring clean finished parts (medical device hardening, for example). Generally these processes are conducted in vacuum furnaces that can be from 12 inches to 12 feet in diameter. Selection of the vacuum furnace is dependent upon the part geometry, vacuum/atmosphere needed, and batch size desired for processing.

Current practices are better suited to run similar high volume parts. Repair and reworked parts (orphans) are typically uneconomical to run in a large high volume vacuum furnace.

The most desirable parts for vacuum processing are those which can be self fixtured. It is undesirable to have parts which require fixturing because the fixturing as well as the part must be heated during the heat cycle. Typically these parts are tack welded or press fit for traditional vacuum processing.

There are several limitations to conventional batch vacuum furnace processing:

1. Increases part cycle time - Batches of parts are taken out of the manufacturing cell and sent to the furnace for heating. Moving from a continuous flow system to a batch process slows production and causes significant inefficiencies in the manufacturing process (additional inventory, packaging, transportation costs, tracking, shrinkage and scrap). This is exponentially true when the parts are sent off site for processing.

2. Limits quality control - There is no control over individual parts and no way to verify that an individual part reached the desired processing temperature.

3. Produces high reject rates – When braze material melts, it flows to the hottest areas of the part which may not be the joint. This can result in poor cosmetics, poor joints and poor quality. Many firms rely on braze stop off materials which generally require manual application. If a process problem occurs, the entire batch is suspect and could be scrapped.

4. Limited temperature range flexibility - Typical vacuum furnaces utilize tungsten filaments for low temperature applications. High temperature applications require an expensive hardware change to a molybdenum filament.
5. High Fixturing Costs - Brazing operations which require parts to be held (angle parts which are not press-fit) require special fixturing which may not be cost-effective to develop and manufacture. In precision heating applications, close tolerances must be kept on the fixture to allow for thermal expansion. In these applications, fixturing cost will be significant. Since the fixturing is heated along with the parts in a batch system, the life of the fixturing is limited, and the fixturing cost is higher due to the type of materials which must be used.

6. Non-Selective Heating - In a batch vacuum furnace and continuous atmospheric furnace the entire part is heated, not just the joint area. In many applications (i.e. microwave components, electronics, semiconductors, etc.), it is not desirable to heat the entire part.

7. High Energy Costs - To maintain production rates, furnaces and ovens are generally kept at processing temperature between batches, or even left on continuously. This results in significant energy cost and waste.

8. Process Development - Generally an entire batch must be run to effectively model the effect of process parameters. Therefore process development becomes costly due to the high volume of parts which may ultimately need to be scrapped, and the inherent cycle time needed to process the batch.

**Solution**

By integrating induction heating with a small vacuum chamber, virtual continuous flow manufacturing can be realized. The use of induction heating eliminates the long heat cycle time requirements in a conventional vacuum furnace. The use of several, smaller vacuum chambers maintains through put by reducing pump down cycle times. One operator can load and unload a series of chambers thereby keeping the principles of continuous flow manufacturing in practice.

While there are numerous suppliers of both induction heating equipment and vacuum/inert gas systems, there are several critical factors which will determine success of the system. In vacuum, voltage break downs occur at a lower threshold than in air resulting in arcing within the vacuum chamber. Therefore, when choosing an induction heating system, one of the characteristics which need to be considered is the voltage on the coil without sacrificing operating efficiencies. The GH Induction Atmospheres Induction Vacuum Chamber (IVC) and Induction Vacuum Furnace (IVF) systems employ the use of a low voltage work coil with a small chamber to provide flexible platform for various types of atmospheric and vacuum processing including brazing and hardening.

**Advantages of IVC/IVF Processing**

1. **Wide Temperature Range** - The GHIA IVC/IVF systems provide complete system flexibility to handle a wide range of parts and temperatures from 1450°F (788°C) for silver brazing, to 2200°F (1205°C) for nickel brazing and 2200°C (3992°F) for special material processing.

2. **Cellular Manufacturing** - The IVC/IVF systems have been designed to fit in a manufacturing cell; small, compact footprint and built to withstand the riggers of 24/7 operation. As throughput requirements increase, additional vacuum chambers can be integrated; power and controlled separately or by a single power supply.

3. **Improved Quality Control** - The IVC/IVF systems quickly and accurately heat one part at a time, or small quantities of parts. Because the IVC/IVF systems heat one joint (part) or small quantities of parts at a time and the part temperature is controlled, a quality part is assured each time. Real time monitoring and SPC (Statistical Process Control) are available through the PLC, HMI and digital chart recorder; data may be stored and transferred.
directly to a computer. This is critical in any aerospace and medical applications. For precise temperature control, each IVF system includes Type-S thermocouples for control and over temperature and five Type-K workload thermocouples. A two color optical pyrometer is recommended for the IVC system.

4. **Ease of Fixturing** - Even in precision heating applications, fixture design is simplified because only small quantities of parts are heated at a time with the IVF. Fixture life is substantially increased because the fixture is not subjected to heat during the direct heating part process of the IVC.

5. **Selective Direct Joint Heating (IVC)** - Because induction heating affects only the joint area, other components are not exposed to heat. This results in faster cooling times and the ability to easily braze joints which previously have not been practical. Because only the joint area is heated, the braze stays in the joint area. This vacuum chamber system improves cosmetics, reduces the amount of braze material needed, and produces better quality joints. Additionally, firms which previously had to rely on braze stop off, have been able to eliminate it, reducing the manual labor involved in both applying and removing the stop off.

6. **Indirect Part Heating (IVF)** - The Induction Vacuum Furnace is designed to heat parts of virtually any shape in a high temperature, high vacuum environment. With a “Hot Zone” of 12” diameter by 12” high, the quick, clean induction heating system can achieve 1900°F in less than eight minutes.

7. **Lower Energy Costs** - Because the IVC/IVF systems use induction as the heating method, energy usage is significantly lower than a typical vacuum furnace. The energy used with induction is over 80% efficient – as a result over 80% of the energy used goes into heating the part/braze joint.

8. **Ease of Process Development** - Due to the fact that a limited number of parts are processed at one time, process parameters can be easily determined, adjusted and finalized.

**Specific Examples**
The majority of industries that currently use a vacuum furnace for brazing or heat treating, including aerospace, medical, HVAC, industrial components, are looking for continuous flow solutions in all of their manufacturing operations. GH Induction Atmospheres has designed and supplied IVC and IVF systems which satisfy the continuous flow criteria for nickel brazing of superalloys, copper brazing of steel, silver brazing of copper and brass assemblies, material processing and hardening of precision medical devices.

**Conclusion**
Through the use of induction as the heat generator, a small chamber size and integrated controls, effective vacuum chamber and furnace processing is achievable in a continuous flow environment. The flexibility of the GH Induction Atmospheres IVC, Induction Vacuum Chamber and IVF, Induction Vacuum Furnace, can be easily integrated to process various parts in one turnkey system.

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