CFC Fixtures Increase Productivity in Carburizing, Nitriding and FNC

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Furnaces for heat treating require capital expenditures, they take up valuable plant floor space and they can be a bottleneck to productivity in a manufacturing cell. For smaller and critical component part sizes, like gears, properly fixturing the parts is a necessity. Fixturing needs to be designed for best heat transfer, for proper surface engineering and for maintaining critical dimensions. Cast and wrought alloys are most widely used as furnace fixtures, but they consume a large amount of the available load weight, which limits furnace throughput. As well, they lose shape over time and with rapid cooling can lose shape quickly.

Recently, CFC tooling (commonly called Carbon Fiber Composite) has been employed allowing significant benefits in heat treating, of which weight reduction is a major benefit. However— depending upon the heat treatment or surface engineering process—there are additional benefits to CFC tooling, as well.

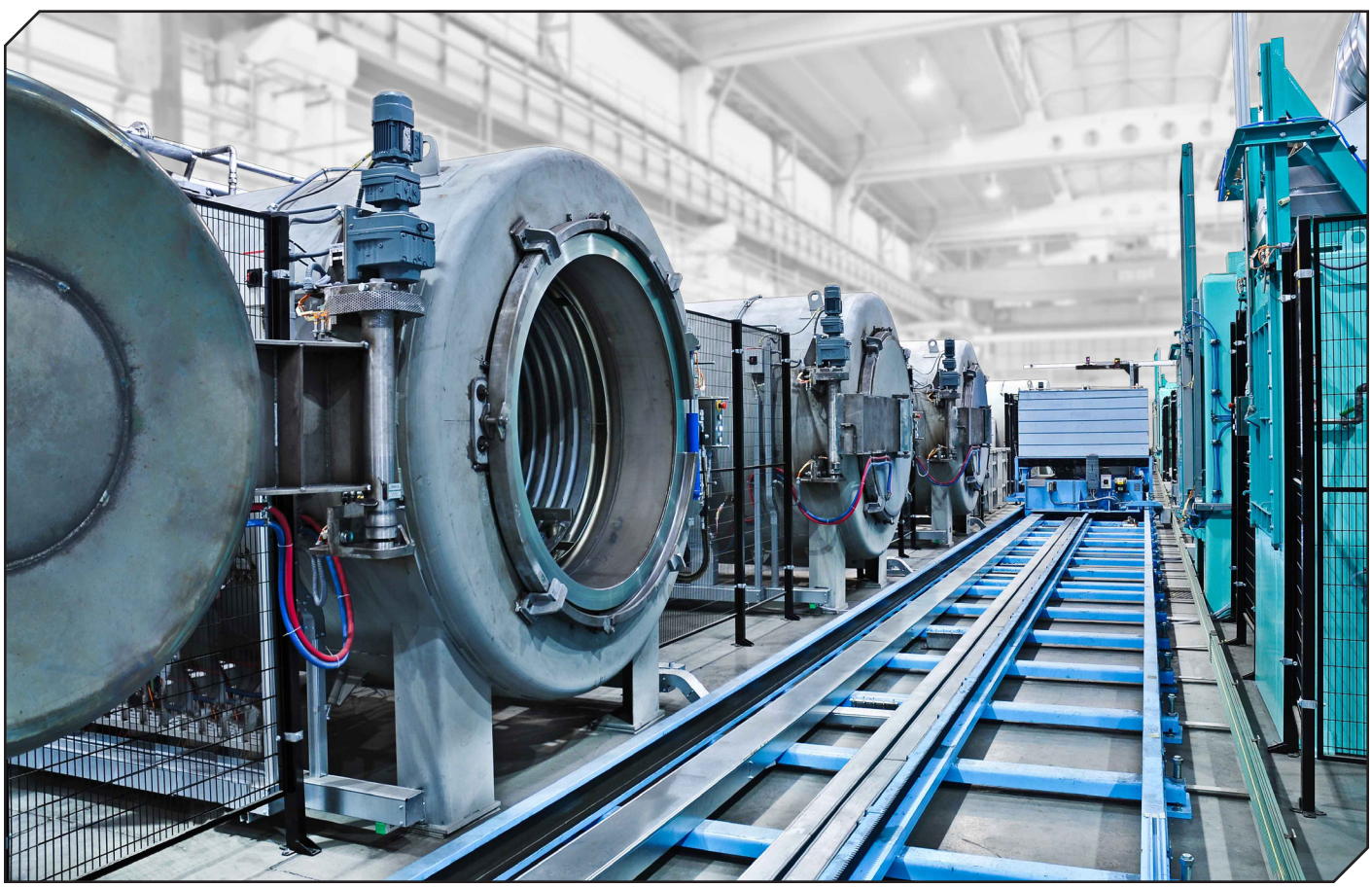
In recent years CFC material has become more affordable and designs have become much better proven. Manufacturing methods for CFC have matured to the point where we now can expect long fixture tooling life, which decreases ownership costs, even compared to alloys.

However, component manufacturers and furnace manufacturers have been slow to specify these fixtures, mainly due to high initial tooling costs and perceived lack of robustness of the tooling during material handling. Applications for CFC in heat treatment are not just for vacuum furnaces for aerospace applications anymore. Applications today range from ferritic nitrocarburizing and nitriding to gas carburizing, oil quenching and even air tempering. Figure 1 shows tooling for a gear application for nitriding and atmosphere stress relieving. CFC tooling is emerging as an alternative and as a workhorse in standard, high volume manufacturing plants. As more CFC tooling has been hitting the market, papers and testimonials are proliferating.

Why CFC Furnace Tooling?

In recent months there has been quite a bit of information published by manufacturers of CFC fixtures used in heat treating (Refs. 1–3). Referenced here are some of these articles and they are excellent resources. To recap, the most important features of CFC versus alloy are:

- CFC fixtures are much stronger at high temperature (Ref. 2).
- CFC fixtures retain their precision shape during heating,



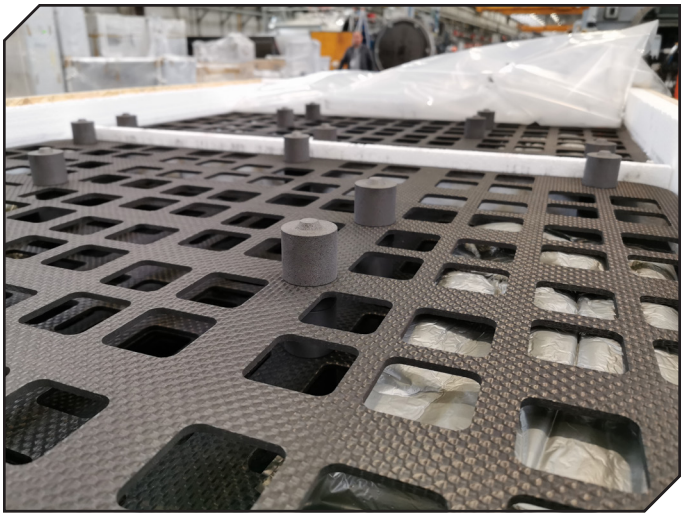


Figure 1 CFC fixture designed for holding gears, for maximum gases flow, and for supporting the layer above (courtesy of Nippon Kornmeyer).

quenching, and over time (no alloy creep).
- CFC fixtures can be coated to prevent oxidation and oil degradation.
- CFC fixtures are around 10–20% of the weight of alloy (Refs. 1,2).

Concerns with CFC fixtures include:
- CFC fixtures, at elevated temperatures (typically over 2,000F), may need to employ special holders for contact points with metal parts due to eutectic welding and some further reaction issues with the carbon (Ref. 3).
- CFC Fixtures are not very impact resistant and must be handled differently than alloys.

In standard integral oil quench carburizing furnaces, for example, it may be more advantageous to use alloy base plates (Ref. 3). However, this again adds weight and potential for base plate distortions. New furnace designs exist in the integral quench market which can easily use CFC base plates (Ref. 4). In this newer and modern furnace design, loading and internal movement from heating chamber to oil quench is more advantageous to CFC fixtures where a fork-style loader is used internally (Figures 3 and 4) to carry the load, rather than pushing or pulling the load. As a further example of productivity gains, in carburizing, with a load capacity of 1500 kg, an all-alloy fixture can be around 300–700 kg just for the fixtures. This can mean up to 50% of the load is fixture weight when using alloy fixtures. Even at 20% of the alloy weight, CFC fixtures would only consume 140kg, or less than 10% of the load weight. This translates into much more net production and fewer furnaces needed when using CFC for the same annual production.

As well, CFC fixtures can be coated to prevent oil and oxygen degradation. In the application shown in Figure 1, using a nitriding furnace like is shown in Figure 2 can require a pre-oxidation step during ferritic nitrocarburizing (FNC) at around 350°C. This step helps activate the surface of the metal part and CFC fixtures are not affected. In harden and quench applications, if quenched parts would be air tempered (following any carburizing/hardening), then a coating—known as chemical vapor infiltration (CVI)—would be recommended which allows air tempering with oxidation resistance up to 820°C

Figure 2 Furnace for nitriding and ferritic nitrocarburizing (photo courtesy of Seco/Vacuum Technologies).

Figure 3 Precision internal furnace fork loading for oil quenching compatible with CFC trays.

Figure 4 Clean integral quench carburizing furnace with no toxic gases and precision, high-volume carburizing for gears, shafts, and various other components.

(1500°F) for the carbon fixtures.

As well, with oil quenching applications, the load and fixtures must be washed of oils. The coating helps to stop oil infiltration into the carbon fiber voids by instead adding carbon infiltration via the CVI process. CVI is a type of CVD (chemical vapor deposition) in which the gases infiltrate the pores and cause a densification of the structure of the material (***source: Nippon Kornmeyer data sheet [NK-PyC]***). This resists absorption of oils (and water) into the fiber matrix pores and allows washing of the fixtures. Any remaining oils and moisture after washing would come out during the tempering process.

CFC Fixtures are Becoming Common

The loading density possible by using CFC fixtures allows for much more compact and precision loading of parts, which can translate into fewer furnaces. Figure 5 shows how tightly packed parts can be positioned and still allow for adequate gases flows and precise part support. In one heat treating department, we found that CFC fixtures allowed for very dense loading of light gears and allowed the reduction of required furnaces from close to 4 units to only two units. This saved significant floor space in the cell (floor space is extremely tight in any manufacturing plant). CFC fixtures allow for more compact and precision loading of the parts, which translates into more parts per load and the costs of the fixtures was more than offset by fewer furnaces.

As an example in Figure 5, with a large enough batch furnace, 1,000 gears are possible per load. The weight of the tooling on a large size load would be only about 10% of the load. The layering of parts on a very flat surface is also critical for minimizing distortion. This type of load creation is just not possible with alloy mesh separation sheets, cast alloy or fabricated alloy. The upfront cost differential of CFC tooling is totally offset by longer tooling life and by higher furnace productivity. It should be noted that the installation shown in Figure 2 processes over 1 million gears per year for FNC.

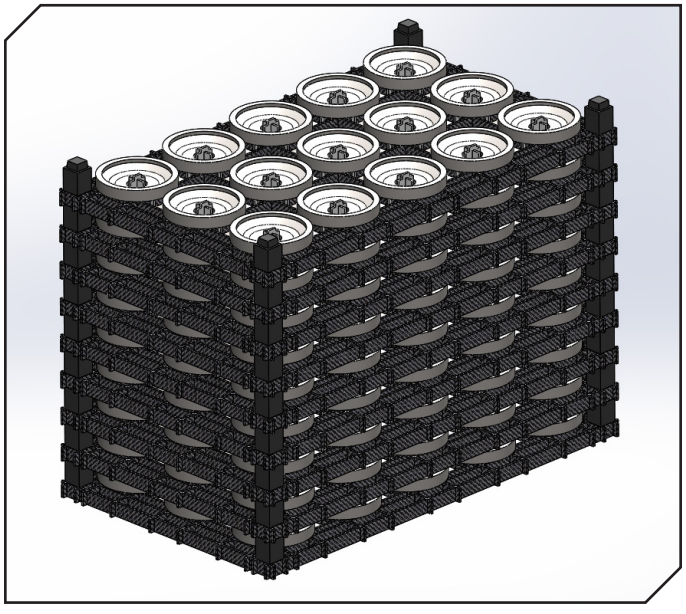


Figure 5 Typical CFC tooling with gears closely spaced to maximize volume (courtesy of Nippon Kornmeyer).

Advanced Fixtures, Advanced Clean Furnaces

Figure 2 shows gas nitriding furnaces with vacuum purging, and also, the option for ferritic nitrocarburizing with pre and post oxidation. CFC fixtures work with all these options. In addition to advanced fixturing, furnaces today need to run cool, run quiet and run without excessive toxic gases. Often, they are located near CNC machining centers and in climate-controlled buildings. This means vacuum tight construction allows these advanced furnace designs to co-exist in a cleaner room environment. Both the gas nitriding furnaces shown and the gas carburizing furnace shown in Figure 4 can operate and co-exist with CNC type equipment. The furnaces operate cool and without ammonia odors or toxic carbon monoxide. They run with minimal noises, no hot walls or doors, no billowing smoke, or flames. It is now much easier to "in-source" heat treating, as these machines can be turned on and off with no issues and no idling required between shifts or on weekends. The days of hot, smokey, smelly and dingey heat treating are gone. As well, being co-located with manufacturing, this all saves work-in-process time compared to outsourcing heat treating. Freight costs and handling damages are virtually eliminated.

Figure 6 For vertical applications and oil quenching, precision positioning of parts like shafts is critical.

Long Parts and CFC Tooling

In heat treating vertical parts, keeping very hot parts straight when they are dunked into oil and rapidly quenched is very difficult. By the nature of lowering a load into oil, or even gas quenching with variable gas flows, non-uniform cooling is guaranteed in all instances. Controlling these massive thermal forces and distortions is critical and any changing uniformity leads to excessive part distortions. For lowering long parts into oils, straightness of entry as the part enters the oil is mandatory. However, it is difficult to assure straight entry in a high production environment. CFC tooling allows for precision fixturing designs. When one combines this with precision internal movement, repeatable results are assured. Alloy fixtures distort and creep over time, so precision fixturing is never guaranteed.

CFC stays straight and precise, even after being subjected to quench oils over and over. Alloy fixtures distort much like the parts they are holding. Figure 6 shows how a precision fixture, made of CFC, looks for long parts.

Conclusion

Heat treating is changing, and it is changing rapidly. Advances in furnace designs and fixturing are opening up new ways of thinking. Precision fixtures like CFC allow weight reduction, long life, and precision load building. Furnaces take up valuable plant floor space, so methods need employed that maximize their use. Critical parts, like gears, demand precision tooling which only CFC can offer. CFC is lighter, stronger at temperature and keeps its shape even after the abuses it sees with years of use in a furnace environment. Combining all these benefits of CFC tooling, the savings may far exceed the initial capital cost premium and should be considered, especially with today's modern furnaces.

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Challenges and New Market Opportunities in Heat Treating

Gear Technology recently caught up with Mark Hemsath, Seco/Warwick, for a brief discussion on the heat treat industry in 2021:

GT: What's the current state of the heat treat market in 2021?

MH: Had I answered this a year ago, it would have been "It's great!" So now, there are definite challenges, thanks to a year of COVID. However, all things considered, there is strength in a lot of areas with really aerospace being the main problem area. MTI, which supports commercial heat treaters, is showing growth in most months since last summer, but we are far away from maximum capacity. Recent data shows that the U.S. economy had the best showing last year of all the major developed countries, except for China. So, we are coming out of COVID damaged, but not destroyed and heat treating is the same. There have been major structural changes everywhere, but in general, it could have been a lot worse.

GT: What market trends will be noteworthy in the coming years for heat treating gears and other power transmission components?

MH: I have heard a lot of chatter about electric vehicles due to the differences in power transmission and how that affects the heat treat market. Will the next few years bring a bigger push in EV? I think that is probably a given. EV means different heat treat needs and different materials. Autos, in general, are still going to have to get better mileage if they use gasoline and that means lighter transmissions and more speeds and probably some more hybrid options. As far as auto demand, we had a huge trend to Uber before COVID and now with the emptying of big cities, will more people want or need cars? We have emptied retail stores, and everyone is used to fast home delivery. How does that effect demand for heat treated parts?

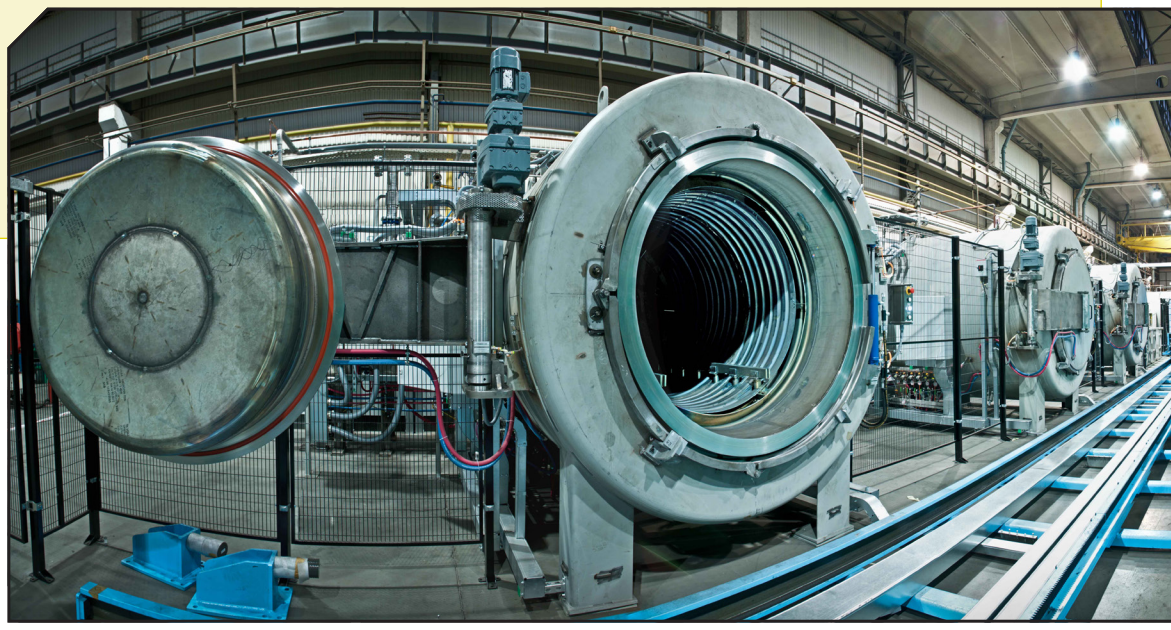
GT: How is the demand for heat treating changing in areas like automotive, aerospace, and the steel and metal processing industries?

MH: I read an article that said manufacturing in the United States is looking up for a number of structural reasons. The manufacturing Purchase Managers' Index is strong, as well. Both sources suggest we will see strength this year in manufacturing. At the same time, I do not think we have ever seen such major structural changes in such a short time. COVID stunned commercial aerospace. We are still 18 months away from it getting back to some normalcy. Throw in the Boeing issues before COVID (737 MAX and 777x) and it may be longer. Military and Space are, however, strong. Leisure and sporting are at a frenetic pace. Guns, Marine, RV's, ATV's are all selling like crazy. Automotive will continue to move away from heavier steels, but demand seems to be holding for cars, trucks, etc. Steel prices are very high right now due to demand being higher than supply.

GT: What new and improved technologies are playing a key role in the heat treatment of gears today?

MH: Is it finally time to really go to low pressure carburizing as a substitute for standard atmosphere carburizing? We, as a company, think so, so we have invested big in the most revolutionary heat treating product in decades, our Super IQ furnace. Super IQ offers LPC qualities with capital investment and operating costs comparable to standard atmosphere carburizing. We think Super IQ is revolutionary and will allow heat treating to move away from a dark and dirty plant environment to an Industry 4.0 environment that any manufacturer can be proud of.

GT: What are the greatest challenges for your heat treat customers in gear manufacturing in 2021?



MH: Can gear manufacturers take the time, with confidence, to step back and look at their business, the changes that are occurring and invest in new equipment and advance their art? Or..., is it survival and business as usual?

GT: How important is it for your gear customers to have a working knowledge of part materials and the chemistries involved in manufacturing?

MH: This is a major challenge. How do we get materials engineers, heat treat engineers and power transmission engineers to really look at how steel grades, heat treating (carburizing, ferritic nitrocarburizing, or nitriding) and market demands and trends work hand in hand? I think many more advances are possible, but getting these experts to work together to make changes is always challenging.

GT: Do you offer training or educational opportunities to keep customers up to date on new heat treat technologies and processes?

MH: I try to present one or two webinars a year. I try to write a few articles each year. I will happily visit anyone and discuss all these issues. It is my passion. Before COVID we were planning a "Road Show" to go to larger companies and have many of these discussions. I am still ready to help and to travel.

GT: How will the heat treat market evolve in the coming years? How can gear manufacturers better prepare for this evolution?

MH: Gears cover a broad range of power transmission needs from autos to aerospace to heavy industrial. Heavy industrial seems to be an area of largest growth possibility as we move to more infrastructure work and more manufacturing. Combined with recreational needs, this means more gears in smaller volume runs, for demanding applications that need high quality.