GILLESPIE & POWERS OVERVIEW

AI IN FURNACES

CASE STUDY

Furnaces INTERNATIONAL

FURNACE TECHNOLOGY FOR THERMAL PROCESSING OF METALS, GLASS & MATERIALS

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SEPTEMBER 2025

It isn't irrational to worry about the increased use of AI and the impact it could have on jobs.
We've all heard or seen the memes describing how AI will leave a trail of unemployment in its wake.
As a journalist, I am deemed most at risk, with a large language model able to write more quickly and accurately than any fallible human.
But trying to stifle innovation can hamper progress.
For how many years were human lift operators required in US cities even after automatic elevators became mainstream?
I was reminded of this at a recent manufacturing conference in India where a presenter said that AI will not replace jobs but will make jobs more interesting.
As well as making industrial processes more efficient and safer, it will enable humans to embrace varied roles rather than repetitive ones.
An article in this issue by Watlow highlights how AI can be used in electric furnaces. It describes how a plant-wide data backbone - complete with humans in the loop - can improve decision making.
Automation may be disruptive but it is a pathway to higher productivity for facilities and humans alike.

And by the way, just in case you were wondering, this was written by me and not an AI bot!

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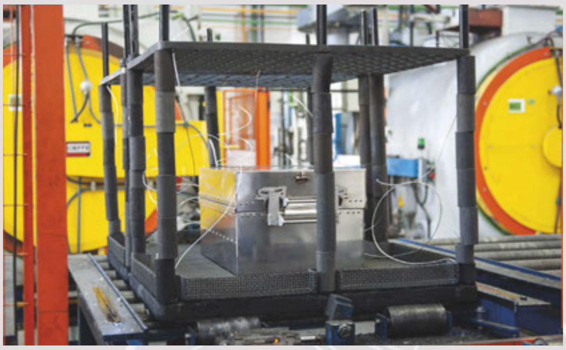

Thru-process TUS

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- Oil, salt and water quench thermal barrier options

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- Thermocouple type and plug connection options for quick installation
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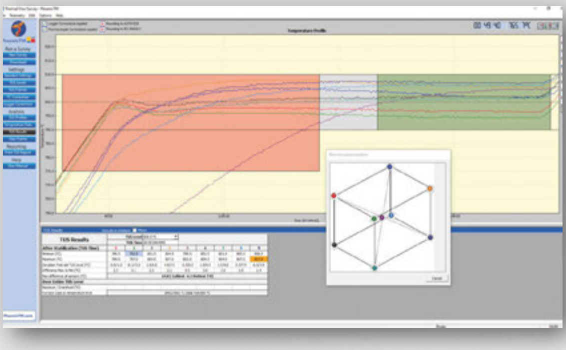

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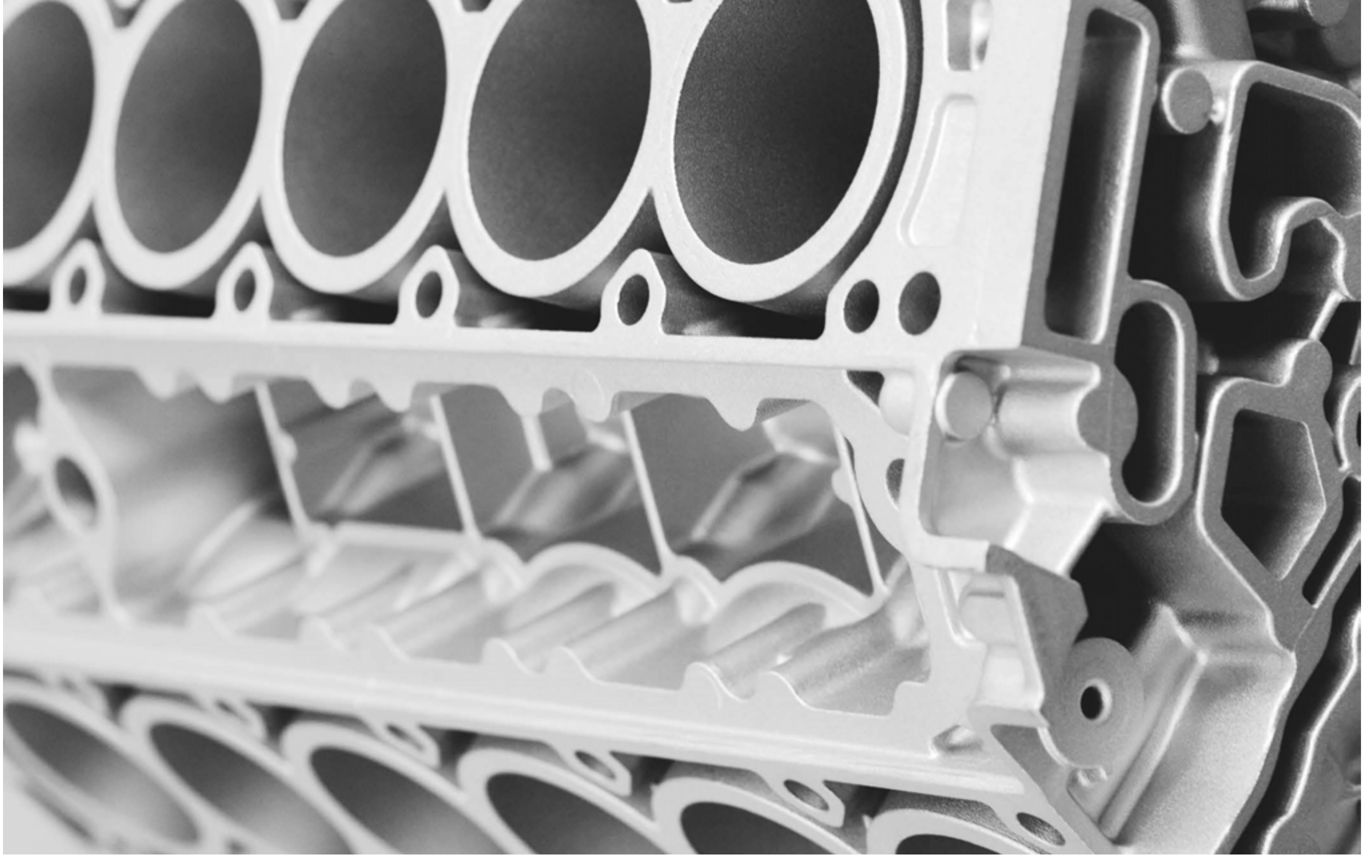

‘Thru-Process’ temperature profiling

Dr Steve Offley, ‘Dr O’*, discusses a monitoring solution for T6 heat treat quality which can provide protection at 550°C for up to 20 hours.

In today’s automotive and general manufacturing market aluminium is the material of choice being lighter, safer, and more sustainable.

Manufacturers looking to replace existing materials with aluminum require new methodology to prove that thermal processing of aluminium parts and products is done to specification, efficiently and economically.

To add strength to pure aluminum, alloys are developed by the addition of elements dissolved into solid solutions employing the T6 heat treatment process (**Figure 1**).

The alloy atoms create obstacles to dislocation movement of aluminium atoms through the aluminum matrix. This gives more structural integrity and strength.

Process temperature control and uniformity is critical to the success of the T6 process to maximise the solubility of hardening solutes such as copper, magnesium, silicon and zinc without exceeding the eutectic melting temperature.

With a temperature difference of typically (5°C to 8°C) knowing the accurate temperature of the product is essential. Control of the later quench process (Figure 1 Phase 3) is also critical not only to facilitate the alloy element precipitation phase but also prevent unwanted part distortion/warping and risk of quench cracking.

T6 Process Monitoring Challenge

The solution reheat process (T6) comes with many technical challenges where temperature profiling is concerned. The need to monitor all three of the equally important phases, solution treatment, quench and then the age hardening process makes trailing thermocouple methodology impossible.

Even when considering applying thru-process temperature profiling technology, sending the data logger through the process, protected in a thermal barrier (**Figure 2**), the T6 process comes with challenges. A system will not only need to protect against heat (up to 550°C) over a long process duration, but also withstand the rigours of being plunged into a water quench.

Rapid temperature transitions create elevated risk of distortion and warping which need to be addressed to give a reliable robust monitoring solution.

PhoenixTM has developed a monitoring system to suit the T6 process (**Figure 3**). The thru-process monitoring system can provide protection at 550°C for up to 20 hours.

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All images provided by author except where noted.

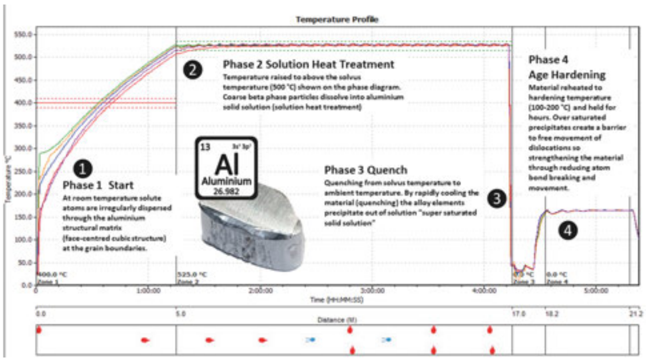

Figure 1. Critical temperature phase transitions of the T6 aluminum heat treatment process.

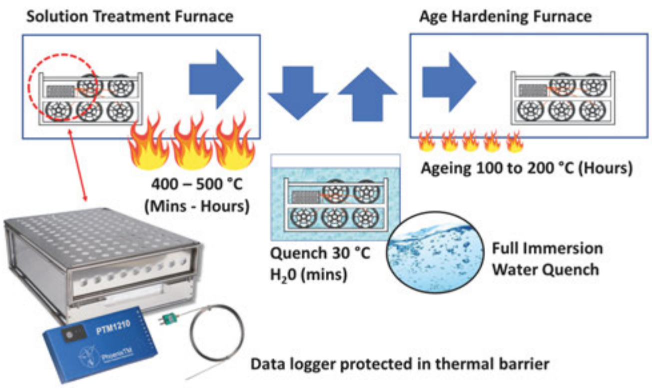

Figure 2: Thru-process temperature monitoring of the three T6 heat treatment phases

Thermal protection technology

To meet the challenges of the T6 process the conventional thermal barrier design employing microporous insulation is replaced with a water tank design, with thermal protection using an evaporative phase change temperature control principle.

Evaporative technology uses boiling water to keep the high temperature data logger (max operating temperature 110°C) at a stable operating temperature of 100°C as the water changes 'phase' from liquid to steam. The advantage of 'evaporative' technology is that a physically smaller barrier is often possible.

It is estimated that with a like for like size (volume) and weight an evaporative barrier will provide in the region of twice the thermal protection of a standard thermal barrier with microporous insulation and heat sink. The level of thermal protection can be adjusted by changing the capacity of the water tank and the volume of water. Increasing the volume of water increases the duration at the T6 temperature the barrier will maintain the data logger temperature of 110°C before it is depleted by evaporation losses.

The TS06 thermal barrier design (Figure 4) incorporates a further level of protection with an outer layer of insulation blanket contained within a structural outer metal cage. The key role of this material is to act as an insulative layer around the water tank to reduce the risk of structural distortion from rapid

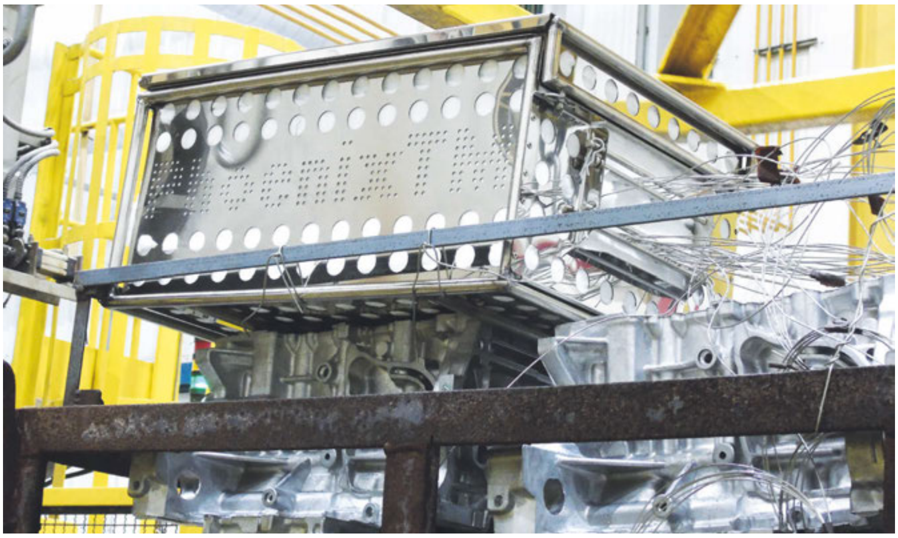

Figure 3: PhoenixTM's 'thru-process' temperature profiling system installed in the product cage monitoring the T6 heat treatment (solutionizing, quench and age hardening) of aluminum engine blocks.

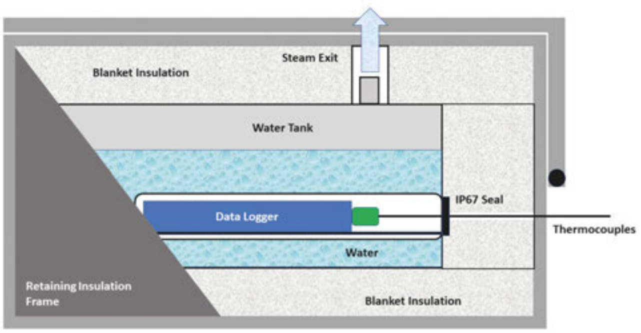

Figure 4: TS06 Thermal barrier design showing water tank, housing the data logger at its core, installed within structural frame containing the insulation blanket surface layer. Water tank shown with traditional compression fitting face plate seal.

Figure 5: TS06 Thermal barrier innovative IP67 bi-directional rubber gasket seal. Quick easy installation of Mineral Insulated (MI) thermocouples and RF antenna aerial.

Figure 6. Temperature Uniformity Survey of the T6 process – Phase 1 Solution Re-heat

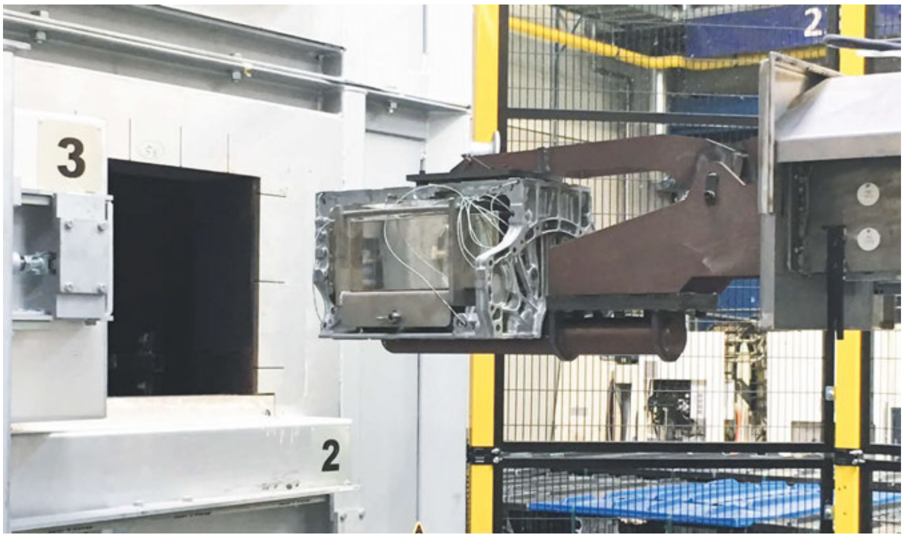

Figure 7. Component and PhoenixTM system being loaded into rotary furnace by gripper. Photo courtesy of: BSN Thermprozesstechnik GmbH based in Simmerath Germany.

temperature changes both positive and negative in the T6 process.

IP67 Sealing Design

Passing through the water quench the data logger needs to be protected from water damage. This is achieved in the system design by combining a fully IP67 sealed data logger case and water tank front face plate through which the thermocouples exit. Traditionally in heat treatment applications mineral insulated thermocouple are sealed using robust metal compression fittings. Although reliable the compression seals are difficult to use requiring long set-up times. The whole uncoiled straight cable length has to be passed through the tight fitting which for 10 x 4 m thermocouples takes some patience. Thermocouples can be used, as installed for multiple runs if undamaged. Unfortunately, as the ferrule in the compression fitting bites into the MI cable, removal of the cable requires the thermocouple to be cut, preventing reuse.

To overcome the frustrations of compression, fitting an alternative thermocouple sealing mechanism has been designed by PhoenixTM for use on the T6 thermal barrier (**Figure 5**).

Thermocouples can be slotted easily and quickly, tool free, into a precision cut rubber gasket without any need to uncoil the thermocouple completely. The rubber gasket has a unique bi-directional seal allowing both sealing of each thermocouple but also sealing of the clamp face plate to the data logger tray, which is then secured to the water tank with a further silicone gasket seal.

The new seal design not only offers quick easy set-up but allows thermocouples to be uninstalled and reused, substantially reducing operating costs.

Accurate process data considerations

The T6 applications comes with a series of monitoring challenges which need to be considered carefully to guarantee the quality of data obtained. Although the complete process time of the three phases can reach up to 10 hours, it is necessary to use a rapid sample interval (seconds) to provide a sufficient resolution. The PhoenixTM data logger is designed to facilitate this with a minimum sample interval of 0.2s over 20 channels and memory size of 3.8 million data points allowing complete monitoring of the entire process. A sample interval of 0.2s provides sufficient data points on the rapid quench cooling curve. The high resolution allows full analysis and optimisation of the quench rate to achieve required metallurgical transitions yet avoid distortion or quench cracking risks.

Addressing temperature monitoring challenges

For a process time as long as the T6, real time monitoring capability is a benefit. The two-way RF telemetry system used on the PhoenixTM system helps address the technical challenges of the three separate stages of the process.

The RF signal can be transmitted from the data logger through a series of routers linked back to the main coordinator connected to the monitoring PC. The routers being wirelessly connected are located at convenient points in the process (solutionising furnace, quench tank, ageing furnace) to capture all live data without any inconvenience of routing communication cables.

A major challenge in the T6 process

is the quench step from a RF telemetry perspective. A RF signal cannot escape from water in the quench tank. To overcome this limitation a 'catch up' feature is implemented.

Once the system exits the quench and RF signal is re-established any previously missing data is retransmitted guaranteeing full process coverage.

Process Quality Assurance

In the automotive industry many operations will be working to the CQI-9 special process heat treat system assessment accreditation. As defined by the pyrometry standard operators need to validate the accuracy and uniformity of the furnace work zone by employing a temperature uniformity survey (TUS).

The thru-process monitoring principle allows efficient method by which the TUS can be performed employing a TUS frame to position a defined number of thermocouples over the specific working zone of the furnace (product basket). As defined in the standard with particular reference to application assessment process table C (aluminium heat treating) the uniformity for both the solutionising and ageing furnace needs to be proven to satisfy ±5°C of the threshold temperature during the soak time.

Small is Beautiful

With a strong drive in industry to fully automated processing, multi-level rotary hearth furnaces are growing with popularity. The single product is loaded into the custom heat treat chamber, by a robot/gripper, and the product passes through the furnace in a circular path (heat treat carousel) isolated from other products.

The difficulty arises in the monitoring system design from the conflict between limited space and demanding heat protection performance. It must also be ensured that the thermal barrier is adapted to the component in such a way that the robot can still grasp it automatically. To address such issues engine blocks are milled out so that the thermal barrier fitted inside the product being monitored.

The system with the data logger in the barrier does not protrude beyond the external dimensions of the component. The gripper takes the prepared block (the thermocouples were placed in advance in the relevant places) and puts it, without interrupting production in the furnace chamber (see figure 7). The furnace profile run with temperatures around 550° C / 1022°F and a process time of several hours is recorded, the block is removed and left in the quench bath. In the water, the barrier water tank fills up again preparing it for the next hot aging furnace. Thus, longer process times are no problem and the automatic assembly makes it easy for the user to measure regularly and reproducibly according to quality specifications and standards.

Summary

To fully understand, control and optimise the T6 heat treat process it is essential that the entire process is monitored. Thru-process monitoring solutions, designed specifically, allow not only product temperature profiling of all the solutionising, water quench and age hardening phases, but also comprehensive temperature uniformity surveying to comply with CQI-9. ■