AP Torque™

Implementing Technology Into A Charge Car

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Abstract

With advances in process technology, emphasis on predictive maintenance and the movement toward the Internet of Things, implementing technology into arguably the most integral part of a heat treat line, the humble Charge Car should not be an afterthought.

Systems are now available to transform an ordinary means of transport for workloads into a predictive maintenance machines for an entire heat treat line. Under the fullest utilization, new systems can be used to track the condition of the furnace hearth and alert users when maintenance is required, before larger problems occur. This study explains the tools implemented in the modern charge car and the benefits provided by the tools.

Introduction

The Charge Car in a batch integral quench furnace line historically has been the most overlooked and under-developed item in the line. Automotive, aerospace, and other industry standards focus on material properties and thus, only thermal processing equipment is regulated through these specifications. The Charge Car is not directly associated with the processing; therefore, the attention, development, and advancement does not keep up with other equipment in the line.

Heat treating furnace specifications include safety interlocks, process monitoring, secondary process monitoring, redundant control, and recording of all parameters instrumental in providing precise, repeatable, processed parts. Controls can be remotely accessed and predictive maintenance tools have lengthened uptime and reduced surprise shut-down events.

SCADA systems have been developed to track parts throughout the entire thermal process procedure, recording all parameters and allowing for searchable reports.

Even part washer technology has been advanced with the inclusion of more advance oil removal devices, vacuum degreasers, programmable recipe logic, etc.

Although the Charge Car does not have a direct effect on the thermal processing of a part, a jammed load can cause lost time on a furnace, creating late deliveries and lost production. The development of a better, more reliable Charge Car load handling system was the main goal in improving the Charge Car.

Initially, removing the friction disc and/or ball clutch from the charge car handling drive seemed like a logical place to begin as numerous repeated complaints arose from maintenance surrounding mechanical clutches.

Figure 1: Charge Car loading a Batch Integral Quench Furnace.

A secondary item targeted for improvement was load positioning. From a reliability standpoint, precise load placement was needed. From a flexibility standpoint, ease of setting the load distance into a furnace was desired.

The following details the process and development of the patent-pending AP Torque™ system, which not only eliminated the mechanical clutch from a charge car, but also provides tools for monitoring the condition of furnace hearth conditions and maintenance requirements in a predictive manner.

Design History

A mechanical clutch has been utilized on stiff chain load placement Charge Cars for over 60 years. The clutch is used to protect the handler chain motor in case of jams caused by a multitude of issues including warped furnace alloy, distorted trays, failed brickwork, displaced parts from the workload, etc.

There are two (2) types of clutches generally used on this type of Charge Car. Both utilize springs to produce pressure against the handler drive sprocket so it will move and drive the handler chain, moving the load. If the amount of force increases due to one of the issues mentioned above, the springs compress, allowing the handler motor to spin freely, protecting the motor.

With a friction disc clutch, a flat presses against another plate creating the friction and force required to move the sprocket. The friction disc wears away over time until replacement is required.

With a ball clutch (Fig.1), multiple balls are set in pockets and held in place with an adjustable spring plate. When the clutch is overloaded, the balls are allowed to roll out of the pockets, freeing the motor before damage is done. Once this type of clutch is engaged too many times, a groove begins to wear between the pockets and the clutch requires replacement.

Both types have advantages and disadvantages, but both can wear and become unreliable, especially after several engagements/slips.

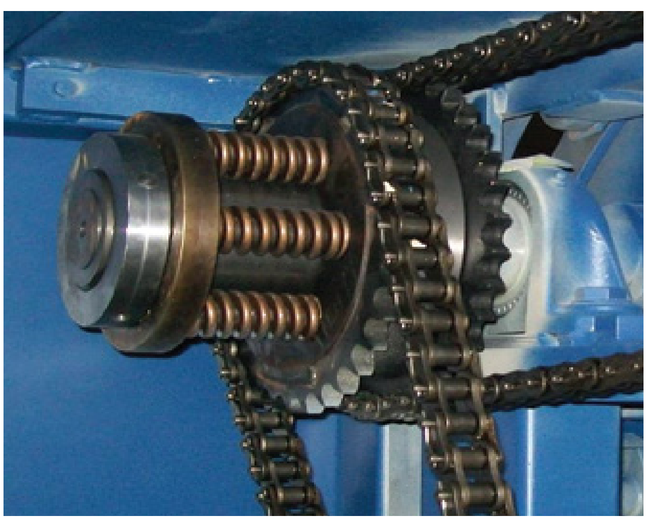

Figure 2: Ball clutch applied to a Handler Drive of a Charge Car.

Every time the clutch slips and wears a little, the clutch/spring setting starts to deviate, causing the Charge Car load rating to lower. Operators may then adjust the spring setting blindly which can be unsafe and unreliable for the design of the equipment. The primary goal of the new design was to replace the mechanical clutch with a more reliable system.

Recent Improvements

The main component of the updated car included a Variable Frequency Drive (VFD) replacing the mechanical clutch. A drive was chosen with an ability to limit torque at any speed (or while not moving at all) and alarm under “clutch slipping” conditions.

Additional components included a Programmable Logic Controller (PLC) used for programming, and alarming, a Human Machine Interface (HMI) for easier set-up and operation, and an absolute encoder to take the place of the rotary limit switch for load placement.

The VFD was set-up to protect the handler motor in a manner similar to a mechanical clutch, in that they each disengage power from a the motor when the drive shaft requires more power than it is designed to handle. Unlike a mechanical clutch that will erode and eventually require replacement, the VFD does not wear.

There are a few parameters of the VFD used in the application of the new car design. The primary setting used in the VFD was the torque limiting feature, which is a configurable parameter limiting the drive to use a percentage of the full load amps of the motor. The mechanical components of the car itself are based upon different sizing calculations, including the strength of the drive chain, the gearbox ratio, the drive shaft diameter, etc. The torque limiting feature of the VFD provides a tool to integrate the mechanical design parameters with the torque provided by the motor.

The torque setting was tested by incrementally loading more weight onto the Charge Car, measuring the power output of the drive and comparing this to the calculated values expected. The car was eventually “overloaded” with weight and the handler drive stalled as the power required exceeded the limits set in the VFD.

A second VFD parameter was also tested and utilized in the Charge Car design, the Shear Pin Setting. This setting worked like a shear pin on a mechanical drive shaft, stopping the motor once the amp draw surpassed the full load amp rating of the motor. This setting was tested by blocking the path of the handler head to assure the maximum motor amp rating would be reached.

Once the VFD parameters were set, the faults generated were communicated to the PLC and alarmed on the HMI.

As part of the Charge Car improvement, a multi-turn encoder was included for tray positioning to replace the mechanical rotary limit switch. Through the PLC programming and with the touch screen interface, the encoder allows for easy set-up of tray positioning without having to open doors to access the inside of the Charge Car. In addition to the two (2) faults set-up in the VFD parameters, the PLC also utilizes the encoder readings to generate a “Jam Fault” if the motor is running and the encoder is not moving for a given period of time. This further alerts the operator about potential problems.

Added Value: Predictive Maintenance

Figure 3: Output Current vs. Handler Position Graph on a Test Stand.

The prototype car was built in 2014. The car was thoroughly tested and setup in the shop with a test table to push and pull the weighted load. After shipping it to the field for installation and commissioning, the car was having difficulty pushing and pulling loads effectively in a few furnaces. It was at this time, the added value of predictive maintenance was discovered. The end user had recently performed a retrofit to an existing batch integral quench furnace, installing new alloy and re-bricking the furnace. A 7,000-pound load (maximum weight) was placed on the car and loaded in and out of the retrofitted furnace several times without faulting either the torque limiting or shear pin parameters.

It was with this discovery, a predictive maintenance component was realized. With the VFD installed, the output current (or the power) could be recorded and graphed against the handler position (provided through information from the handler encoder). The initial recordings illustrated greater current required at both the beginning of a push or at the beginning of a pull cycle. Smaller spikes occurred every 6-inches as the handler chain moved in or out of a sprocket position. Both of these were expected. Additional spikes in current were also found in transition areas between alloy sections of the handler chain guide.

Prior to shipment, each car is tested to ensure that the output amps from the motor are consistent with previous versions. Looking closer at the data above:

- The dashed lines show the output current from the handler moving with no load.
- The solid lines show the output current when the handler is pushing/pulling a load.
- The red lines indicate when the handler is “pulling” from the “vestibule” to the home position.
- The green lines indicate when the handler is “pushing” from the home position to the “vestibule”.

Once the equipment is shipped, the data can either be compared to the shop-test data or if new equipment or re-built equipment is available, a baseline of operation can be recorded. As the equipment is put into operation, regularly scheduled recordings could be compared to aid in predictive maintenance procedures for both the Charge Car and to furnace line equipment.

For the Charge Car, a comparison in the 6-inch spikes should be monitored. As the handler chain stretches over time, the spikes will grow and provide indication the handler chain should be replaced. A stretched chain can lead to misalignment within the car, resulting in jams between the chain and sprocket or other locations.

For the furnace line equipment, each piece of equipment should be tested and recorded. The current measurements can be compared with newer equipment vs. older equipment to determine if maintenance is required. The current or torque measurements of the same piece of equipment can also be compared over time to determine if torque requirements have been creeping higher and higher, indicating maintenance could be due.

Figure 4: Variable Frequency Drive installed in a Charge Car Control Cabinet.

Maintenance items such as chain guide and roller rail replacement or alignment can be monitored with the AP Torque Charge Car. Misalignment can be spotted by an increase in power required to pass through a transition point.

Alternatively, multiple trays can be tested through a furnace to determine if one tray may require more power than another, suggesting new hardware may be required.

Even if the current or power levels are not charted and recorded, a repeated car alarm occurring consistently in certain areas would indicate likely issues with misaligned chain guides, roller rail warpage, etc.

It is important to note again the VFD is controlling based on the motor function only. As noted previously, the motor works through a gearbox which is connected by sprockets and the drive chain to the handler driveshaft. Each of these components have been sized to move the rated load of the Charge Car. If the settings of the VFD are modified or if the motor size is increased, the other components are at risk of failure.

Conclusions

Since the first installation in 2014, twelve (12) additional AP Torque Charge Car Systems have been ordered. The feature is available in System #1™ and Extended Reach Charge Car designs, and in multiple size cars. The addition of the PLC, HMI, encoder and VFD may require a troubleshooting technician with a different skill set than a mechanic replacing a clutch. However, considering the technology required in other heat treat equipment, this skill set is probably already available.

The predictive maintenance aspect the AP Torque system brings to the Charge Car should help prevent unscheduled jams and crashes in furnaces, increasing production and decreasing scrapped loads.

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