Western Technologies, Inc.

EXTENDING THE OPERATING LIFE OF THE GALVANIZING KETTLE

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Abstract

The paper gives a report on a new firing method for high velocity furnaces aimed at increasing the working life of a galvanizing kettle.

Introduction

It is easier to explain the techniques we use to extend kettle life if we first understand the principles of a high velocity furnace.

The end firing high velocity galvanizing furnace has an excellent record spanning more than 25 years. Best estimates give the number of high velocity galvanizing furnaces in operation at over 250. All but a hand-full are end firing only.

The writer has been directly involved or responsible for designing 101 high velocity end fired furnaces over a period of 23 years. Of those 101 furnaces, 39 were over 23 ft. (7m) long, 20 were over 34 ft. long (10 m). The longest furnace was 60 ft. long (18.3m), the deepest 12'-3" deep (3.73 m), and the largest contained 860 MT of zinc. The subject of end fired high velocity furnaces has been researched extensively and data obtained from furnaces in operation for over 18 years.

There are several advantages to end firing including uniform kettle wear, fuel efficiency, low maintenance, etc. However, the most significant advantage is in the event of a burner failure. With a correctly designed furnace, if a burner tube fails, the flame is directed along the gallery and not into the kettle. Failure of flat flame burners and side wall mounted high velocity burners, with a cranked firing tube, can burn out the kettle in less than 48 hours, if the firing tubes fail or the flame pitched forward.

Design Criteria

In the system designed by Western Technologies, high velocity gas or oil-fueled burners are mounted into one or two diagonally opposite corners of a continuous gallery running 360° around the kettle. The output momentum of the burners, firing at up to 500 ft./sec, causes a rapid recirculation of hot gases around the kettle, producing high rates of heat transfer for all available points on the kettle.

At the same time, this bulk flow of recirculating gases absorbs the intense local burner heat, redistributing it evenly around the periphery of the kettle. The result is high operating efficiency and uniform heat transfer; both around the kettle and over its depth, leading to low, uniform kettle wear.

With regard to heat distribution around the kettle let us take a typical design with a total gross heat input of 9,000,000 Btu/hr heating a kettle 50'-0" long x 6'-0" wide x 8'-'0" deep with a throughput of 36,000 lbs. per hour. Here, the burner output temperature is around 1,500°F higher than the flue temperature yet measurements confirm that the gas temperature actually 'seen' by the kettle – that of the recirculating flow – is maintained within a 230°F range.

As we have observed, the principle is simple. However, the actual design of an individual furnace is complex, taking into account such variables as gallery width, burner size, precise burner location and optimum gas velocity for safe heat transfer levels with an avoidance of damage to insulating materials. These and many other factors must be considered in the design process, which is guided both by practical experience and by applied theory.

At this point, it is perhaps worth elaborating on one of the more basic theoretical aspects of galvanizing furnace design, since it is often a source of confusion. This aspect is the derivation of system efficiency based on a calculated flue temperature.

When a gaseous fuel is mixed with air within its limits of flammability, the mixture can be burned to release heat. The efficiency of this combustion should always be referred back to the total potential heat production of the gas: its gross calorific value – for natural gas approximately 955 Btu/ft. Only 90% of this heat is usefully available under normal circumstances; the other 10% is lost in the production of steam in the products of combustion.

Of the useful heat remaining, a proportion is lost through the furnace insulation, a proportion heats the kettle and a further proportion leaves the furnace as flue losses – actually a valuable source of energy which can be used, for example, in a drier or process pre-treatment tank heating.

Because insulation losses are very small, we define the system efficiency as the percentage of gross heat input, which is transferred from the combustion products as they pass through the furnace.

Thus, the system efficiency can be simply derived as a function of the volume of excess air used in combustion and of the temperature of the flue gases upon exiting the furnace. Complete combustion of the fuel cannot be achieved with less than 0% excess air – this is one theoretical limit of efficiency. The other limit imposed is the zinc temperature; clearly, if zinc temperature is 840°F, the flue gases cannot exit at less than 840°F. From these parameters, we can calculate the maximum theoretical system efficiency for a furnace operating on natural gas to be 74%.

The flue gas temperature in the Pulse-Fired High Velocity Furnace depends on the kettle size and required production, but rarely ever exceeds the zinc temperature by more than 350°F. In addition, excess air levels (required in practice to ensure complete combustion and minimize CO emission) are precisely monitored. For individual furnaces this figure can often approach 70% (Remember the absolute maximum efficiency is 74%. An improvement on this would, therefore, be almost impossible without adding waste heat recovery equipment.

In heating galvanizing baths, temperature uniformity is of prime importance, as this evens out the wear rates at different parts of the kettle and gives longer life.

Such uniformity is best achieved by the convective heat transfer, which results from circulating hot gases around the bath at a high speed. As the gas speed increases so the temperature of the gas required for heat transfer falls. Lower as temperatures give less storage of residual heat, better control and lower case losses as well as enabling more cost-effective use of materials.

In the case of firing a galvanizing furnace with high velocity burners, it can be shown that the proportion of convective to radiant heat transfer increases as the burner output increases.

It is therefore advantageous to fire the burners at the highest output that can be achieved without giving rise to local high heat transfer effects in the immediate vicinity of the burners – an area where very careful furnace design is required.

Firing at high output also gives more efficient mixing in the burner and virtually eradicates the production of poisonous carbon monoxide, which is caused by incomplete combustion. It also means that the burner can be accurately set at one firing rate to use the minimum amount of excess air. This can be compared with burners operating over a wide range of outputs which often require higher excess air levels to ensure stability, thus reducing furnace efficiency and sometimes generating aldehyde pollution resulting from too-low flame temperatures.

The question which follows is how to achieve a seamless variation in furnace heat input while firing the burners only at their highest output or on their standby output, and here we must consider the method of control.

A conventional high/low temperature control system is inadequate.

The conventional high/low system operates as follows: the temperature of the zinc is sensed by a thermocouple and an electrical signal is sent to an ON/OFF temperature controller. When the temperature rises above a preset high limit, the burner output will be automatically reduced to its minimum setting. When the zinc temperature drops below a preset low limit, the burner output is increased to its maximum setting. But owing to the effect of the time delay from the switching, this system actually caused the zinc bath temperature to follow a sinusoidal (or sine wave) pattern – continually rising and falling and even with close switching limits the temperature overshoot and undershoot is unavoidable, making it difficult for the galvanizer to achieve a consistent product.

In fact, from a control point of view, in order to maintain very close tolerances on the zinc temperature, the mean rate of heat input to the high velocity furnace must be adjustable in small steps between maximum and minimum output. Yet, any modulation of the burner input is immediately at odds with the furnace requirement for high/low input only.

We have resolved this contradiction by utilizing a control system where the adjustable variable in the mean heat input equation is not burner input . . . but time. With this system, known as the 'pulse-firing' system, the burner input follows a square waveform of a constant period with regular step changes between the low fire and high fire states. In this waveform, the high fire peaks are known as 'pulse'. The mean heat input to the furnace is adjusted by varying the duration of the high fire pulses. Since the wave period remains constant, the effect of lengthening or shortening the pulses is, respectively, to provide a greater or lesser mean rate of heat input, corresponding to the changes in galvanizing production rate.

It is important to realize that the step-changes in the burner output do not result in sharp changes in temperature at the steel/alloy or alloy/zinc interface. Providing that the pulsing frequency is high enough and that a standard bath thickness is used, then the kettle acts to smooth out temperature changes and the alloy "sees" only a very gentle modulation in heat input, which is of great benefit when endeavoring to minimize kettle wear.

We referred earlier to the limits on burner output imposed by the need to avoid local high heat transfer in the vicinity of the burners, and here we must recognize that there is always a balance to be struck between furnace production and long-term kettle wear.

It is perhaps stating the obvious to say that kettle wear is a function not only of kettle temperature but also of time. However understanding the pay-off between these two variables enables us to provide greater operational flexibility to galvanizers without compromising kettle life.

Temperature Control System for Peak Demand

To this end we have developed a system where burner output can intermittently be increased above the maximum output used for pulse firing, and we term this 'Turbo Mode'. If we were to design a furnace which operated continuously in Turbo mode this would undoubtedly give a significant reduction in kettle life. But if applied only to isolated production peaks then the total time on Turbo would be a very small proportion of the working hours and the kettle lifetime would not be greatly affected.

We will now consider how the Turbo effect should be applied in practice.

The number of dips per hour through a galvanizing bath depends upon the type of work and the handling system but 4 to 6 dips per hour is the norm for a manually operated plant.

When work is immersed in molten zinc the zinc temperature will drop. The drop in temperature is dependant upon the heat stored, i.e. the heat content of the zinc and kettle, and has little to do with the heat input from the burners. However the response time, or time for the zinc to regain its set temperature is dependent upon the furnace heat input.

As mentioned earlier kettle wear is a function not only of the temperature to which the kettle is over-heated but the time for which that over-heating occurs.. If we look again at a typical design:

Kettle Dimension		50' – 0" x 6' – 0" x 8' – 0" deep
Maximum Throughput Per Hour	=	36,000 lbs./hr.
Annual Throughput	=	40,000 Tons/yr.
Hours Worked Per Year	=	4000
Average Throughput	=	20,000 lb./hr.
Zinc Temperature	=	840ºF

Using a number of burners at 100% output the maximum throughput would be 36,000 lbs./hr. Using the same burners on 80% output maximum throughput of 26,400 lbs./hr. would be possible.

The erosion rate of the kettle is dependent upon the temperature of the alloy layer and the time at that temperature. When firing at 100% output the alloy temperature of the kettle wall may reach 873ºF. When firing at 80% output, the maximum alloy temperature would be only 867ºF. If we can reduce the alloy layer temperature and the time at this temperature we can increase the kettle life. To maintain the throughput we must allow the burners to operate at 100% output but only when absolutely necessary and for the shortest time possible.

The drop in zinc temperature for a 5,280 lb. load, which equates to a throughput of 26,400 lbs./hr. at 5 dips per hour, (i.e. burner firing continuously at 80%) is 5ºF. Therefore, if the temperature drops 5ºF below the setpoint we can see it exceeds the average hourly rate of 26,400 lbs. and would require an input in excess of 80%.

Armed with this information we can now program our microprocessor temperature controller to operate with our Turbo function.

In the example given, the furnace would operate from 0 to 80% burner output up to an average throughput corresponding to 20,400 lbs./hr. If any dip exceeded the predetermined average resulting in a higher zinc temperature loss the Turbo system would respond immediately increasing the burner output to 100%.

Iron Loss from the Kettle

The loss of iron at 100% burner capacity, giving a mean heat transfer rate of 8,361 Btu/ft² equates to 5.87 x 10?? inches per hour, and with a throughput of 40,000 tons/year would result in an annual maximum iron loss of 0.166". The loss of iron from the kettle at 80% burner capacity firing at 100% for short periods only but with same annual throughput and a mean heat transfer rate of 6,765 Btu/ft², would be 3.62 x 10?? inches per hour resulting in an annual maximum iron loss of 0.143". Assuming the kettle is removed after 1" iron loss and not repaired, we can see with conventional pulse firing, the minimum kettle life is 5 years but with Turbo firing is 6 years.

Conclusion

This firing system can be customized to suit any general jobbing furnace, and can increase useful kettle life in almost all cases, by 20% or more.

References:

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