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Quench Tank Agitation Design Using Flow Modeling

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Abstract

The last but often critical step in many heat treat cycles is the quench process. Many schemes are deployed to ensure quench effectiveness: speed of drop, quenchant temperature, quench concentration and water soluble additives. However quench tank agitation has not been studied in the field as thoroughly as the other phases. The main obstacle has been our inability to see the flows and how they are related to the loads we insert into the tanks. Many quench tanks are installed with designs that move volumes of quenchant with limited consideration to flow pattern and additions of work fixtures. Work fixtures or baskets can disrupt a seemingly well thought out agitation scheme in ways that completely defeat the designed agitation. The purpose of this paper is to show how a seemingly "well" agitated quench tank (the surface is moving) can be studied and the process improved by using finite element analysis.

QUENCH TANK AND AGITATION SYSTEMS have been studied and analyzed in several publications. This paper will outline guidelines that were used in modeling and measuring an existing quench tank with a conventional pumping agitation system.

The tank held 15,000 gallons of solution and the pumping scheme ensure six turnovers per hours of the tanks. This particular tank was used for variable concentration of PAG quench and also cold water and/or hot water quenches. A wide variety of parts were processed in the furnace/quench-sheet metal forging/castings and bar stock. During runs of heavy stock, 4.6 cm to 7.6 cm (2 inches to 3 inches) cross sections, it was noticed that parts placed at different locations in the load would show variable hardness readings after aging. Suspicion was placed on the agitation, since temperatures and oven uniformity were checked and found to be within specifications. Quench speed was timed by the programmable logic controller, and was found to be consistently within +0.5 seconds. Since an existing tank was used, we did not model propeller agitation due to space restraints in the tank

A plan to survey and document the agitation was then developed.

STEP ONE – **Equipment Inspection**.

Pumps, vales strainers and piping were inspected. This ensured that the system worked as it was designed and that no mechanical problems were disturbing the flow.

STEP TWO – **Mechanical Survey**.

A mechanical survey was performed with the tank filled with water at 10 degrees c (50 degrees F). A closed flow meterflow meter was used to make measurements at different points throughout the tank.

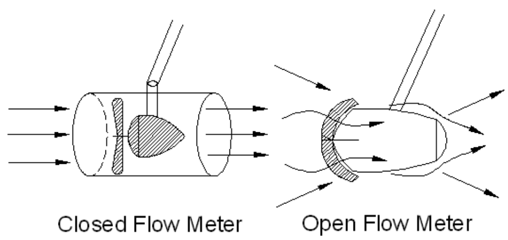

Figure 1 Picture of standard flow meter and open propeller flow meter.

Open propeller flow meters are more accurate for turbulent flow measurement. In order to properly evaluate flow characteristics and to respond with effective agitation design, these more accurate instruments are required.

The work basket/rack was then lowered into the tank and a new series of measurements were taken.

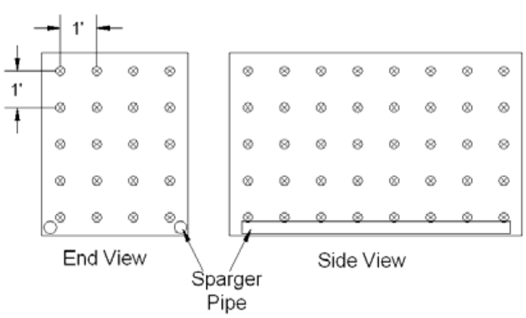

Figure 2 illustrates the pattern of measurements taken in the quenchant.

Several areas of low or no flow were noticed, especially on the floor of the rack, which consisted of a fairly heavy grid that supported the parts during heat treat process. Note that most mechanical flow meters are very sensitive to flow direction.

STEP THREE – Element Analysis.

After discovering that the tank had areas with limited or no flow, a finite element analysis was used to model the flow with the existing agitation scheme. The flow patter, shown in Figure 4, corresponds closely to the initial measurements. However, the model showed flow speed of two to three times higher than measured flows. With this basic data, it was then decided to study flow pattern improvements that could improve quench of the 4.6 cm to 7.6 cm (2 inches to 3 inches) thick parts.

After studying cooling curves related to flow, we decided that a 24.3 cm/second (0.8 feet/second to 1.5 feet/second) was the target we would aim for in the area where the parts would most likely be located when quenched in water. (Note that the literature is very vague on definitions of flows. Most have something like slow, moderate, and adequate. Adequate agitation has been defined as looking at a babbling brook.)

Since most of the parts that were heat treated had pockets and irregular shapes, a scheme that created turbulent flow was preferred. In the modeling, this was taken into account with limited success.

Below is described, in simplified form, some of the options that were modeled. Modeling made possible to visually see the flow pattern and strength in different areas of the tank when the pumping and piping scheme were changed.
For modeling purposes, the tank was only modeled in the one quarter as the tank was perceived to be symmetric (See Figure 3.)

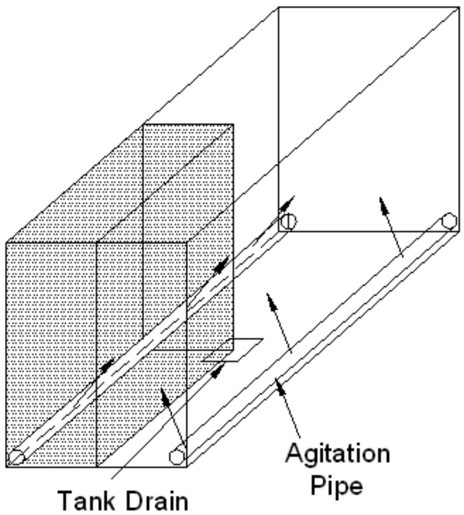

Figure 3 illustrates the modeled area.

Results of this modeling showed the following:

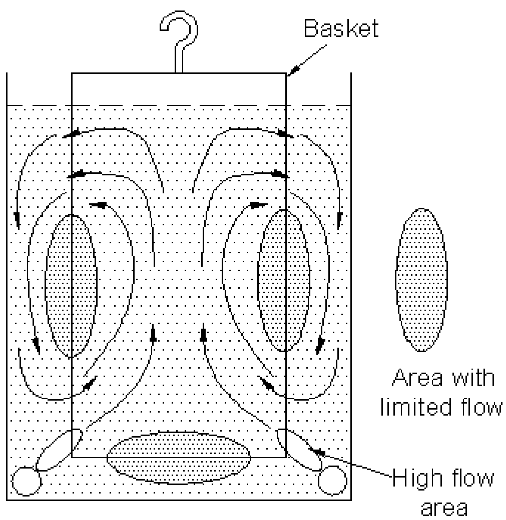

Figure 4 illustrates design 1.

Existing flow, which was, confirmed with flow measurements with a standard flow meter. The outlet located in the middle of the tank, affected the flow in that area considerably. A vortex was calculated to be up to 91.4 cm to 121.9 cm (3feet to 4 feet high) above the drain.

The next model moved all the flow directly under the work load.

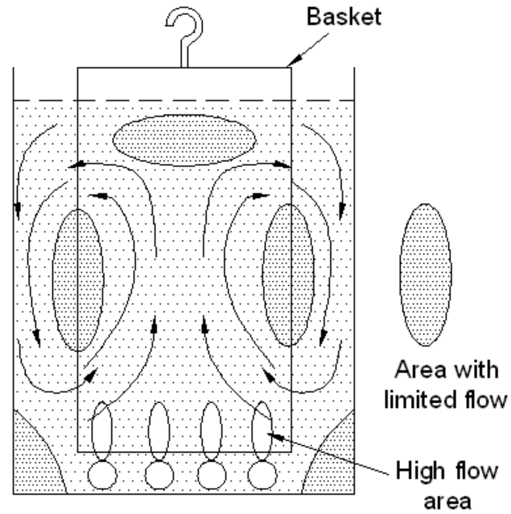

Figure 5 illustrates design 2.

A concern with this design is the very high speed in certain areas that can cause spot cooling on large parts.

The design used pipes approximately 22 cm to 25 cm (8 inches to 10 inches) apart, which was 1.5 cm (0.625 inch) holes on 15.2 cm (6 inch) centers. The speed of the water leaving the holes was calculated to be up to 10.3 m/second (34 feet/second).

Increasing the flow to 106.83 LPM (2,350 GPM) and adding more pipe created the following scenario.

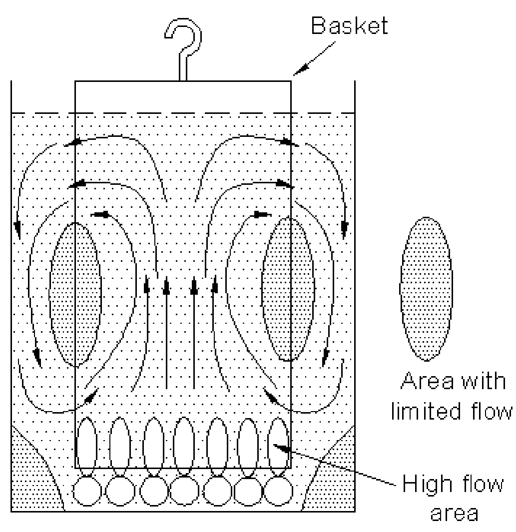

Figure 6 illustrates design 3.

The overall flow on the center of the workload went up, but the area at the edge of the basket still had “dead” zones. The possibly of cold spots was still a concern, however less than the previous design. Increasing volume of flow makes the non-flow areas more defined.

Eductor Design

The use of eductors can increase the volume of flow by four times and decrease the speed of the flow by four times. This could, in theory, get our flow to the4 desired levels of 24.38cm to 45.7cm (0.8 feet/second to 1.5 feet/second) on the workload. To give a more even flow we modeled then with a baffle under the load.

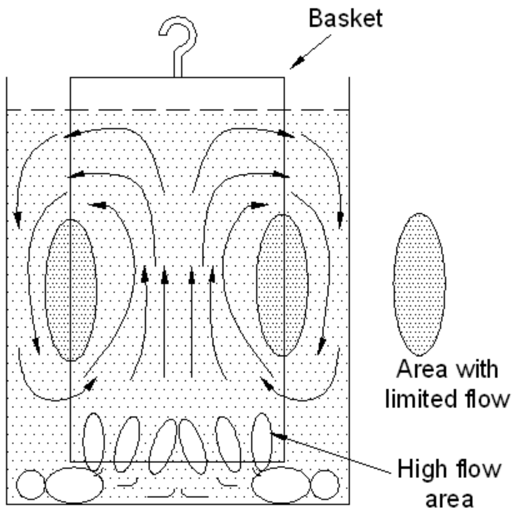

Figure 7 illustrates the eductor design.

Conclusion

By using finite element analysis and field measurements, it was possible to predict flows and test different ideas without touching the hardware.

The flow in existing quench tanks is, in most cases based on design criteria that specifies pulping volumes and not flow pattern in the quench area.

Quenching the load is a vital part of the heat treat process to ensure properties in the finished product. If the flow patterns and velocities are unknown factors, it is very difficult to ensure consistent results.

The process compatibility to use PAG at different concentrations, even for heavy material 1.2 cm to 7.6 cm (1/2 inch to 3 inches), requires uniform velocities and more predictable flows in the quench tanks. However, since water is the most commonly used quenchant for these materials, the flow is of greater importance.

An additional benefit from this study was the heightened awareness among heat treatment personnel regarding the importance of racking methods and consistency over time for different parts.

Setup cards and methods were developed and documented which considerably improved the process.

References

G. E. Totten. C. E. Bates and N. A. Clinton, “handbook of Quenchants and Quenching Technology”, pgs 354- 378 AMS International, Materials Park, OH (1993).