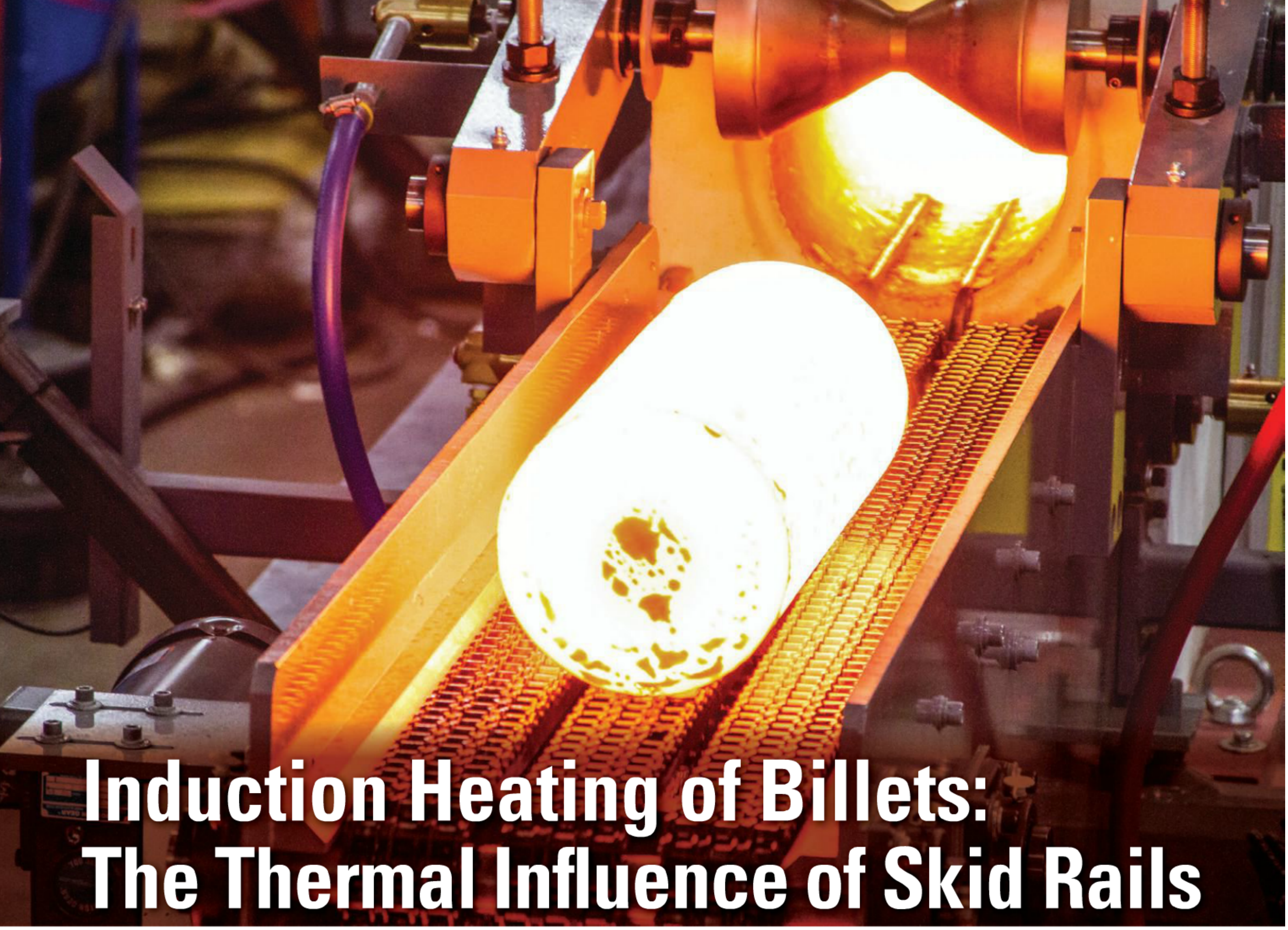

Induction Heating of Billets: The Thermal Influence of Skid Rails

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A hot billet exits an induction heating system. Skid rails are seen above and slightly right of the billet.

The design of skid rails used in continuous induction billet heating systems is more complex than one might think. Due to the appreciable influence that skid rails exert on billet temperature uniformity, the ability to predict their thermal implications is valuable in efforts to improve induction billet heating quality and the final reliability of forged products.

Skid rails are a common, yet somewhat underappreciated, feature of continuous induction billet heaters. Rails span the interior length of each coil assembly, providing rigid contact surfaces for billets to slide along as they are fed through the coil line. Discussions about skid rails typically revolve around their longevity and cost-effectiveness. However, their influence on billet temperature uniformity – a critical metric of induction heating quality – certainly merits some discussion as well.

Basic Design Criteria

Skid-rail design is driven largely by the need to endure the harsh operating conditions that exist inside the coil opening of continuous induction billet heaters. Some of the most critical design requirements associated with these operating conditions are:

- **Electromagnetic "transparency"** to minimize induced heat generation in the rails and maximize electromagnetic efficiency
- **Stiffness and strength** to support the weight of a full coil length of billets without substantial deflection or deformation (in many cases this collective weight is on the order of thousands of pounds)
- **Wear-resistance** to withstand perpetual frictional forces resulting from the continuous sliding of billets

Most skid rails are fabricated from relatively small-diameter (e.g., 3/8 inch) austenitic stainless steel tube. The size of the tube and its electromagnetic material properties render the rails electromagnetically transparent at common billet heating frequencies. Provided that the rails are adequately cooled and mechanically supported, this material also offers sufficient stiffness and strength to the weight of typical billets.

While common austenitic stainless steels (e.g., alloy 304) are

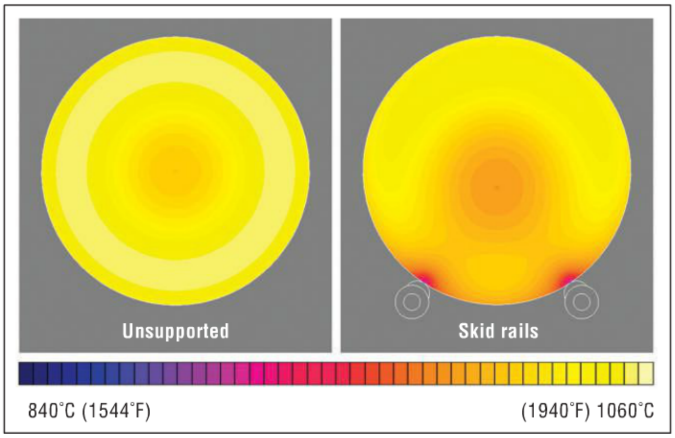


Figure 1. The influence of water-cooled skid rails on temperature distribution in a 3.0-inch Inconel 718 billet immediately after heating (1000-1050°C target forging temperature).

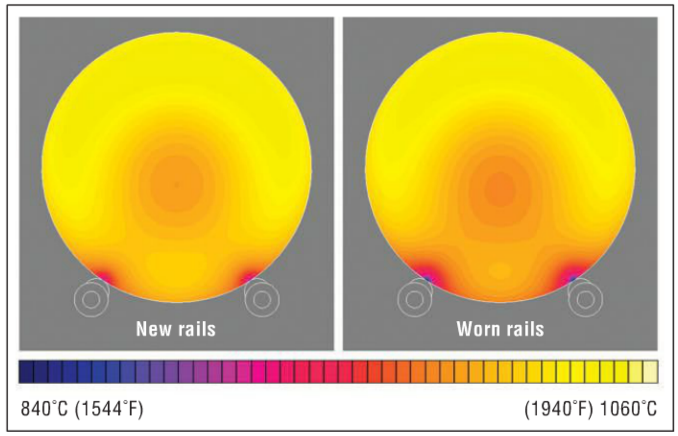


Figure 2. The thermal effects of skid-rail wear (same heating process as shown in Fig. 1).

not highly wear-resistant (due primarily to their low carbon content), they can be hard-faced and coated reasonably easily, providing dramatically improved wear properties. Stainless steels are also intrinsically corrosion-resistant, mitigating the risk of internal water-cooling paths deteriorating due to rust.

Thermal Implications

From a heat-transfer perspective, skid rails act as localized heat sinks, drawing thermal energy out of the billets through the contact surfaces. In addition to reducing the thermal efficiency of the induction heating system, this effect can substantially reduce the resultant temperature uniformity in the heated billets (Fig. 1). The rate of thermal-energy transfer out of the hot billets is directly related to the magnitude of the temperature gradient existing between the billet surface and the water-cooled interior surface of the rails and the total surface area of the billet-rail interface. The thermal conductivity of the billet material, rail material(s) and thermal contact conductance coefficient (or effective thermal conductivity) associated with the contact surface also affects the rate of thermal-energy transfer.

A number of practical conclusions can be drawn from these relatively simple mathematical and physical relationships – some quite obvious and others more subtle.

- Because the rate of thermal-energy transfer is higher when the billet surface temperature is higher, skid-rail life is usually shortest in the coil(s) at the "hot end" of the system (wear resistance of these materials decreases at higher temperatures).
- Hardfacing and coating can provide temperature-uniformity improvement in addition to increasing wear resistance. These surface treatments decrease the magnitude of the temperature gradient by increasing the distance between the billet surface and the water-cooled interior surface of the rails and also reduce the rails' effective thermal conductivity.
- As skid rails wear, the contact surface area increases and the distance between the billet surface and the water-cooled interior surface of the rail decreases, resulting in a higher rate of thermal-energy transfer and more pronounced temperature non-uniformity on the billet surface (Fig. 2).
- When a billet exits the coil line (when contact with the rails is ceased), the internal temperature gradient drives thermal energy toward the rail contact areas and reduces the temperature non-uniformity at the billet surface (Fig. 3).
- Substantial surface temperature-uniformity improvements can be attained by using solid (non-water-cooled) skid rails (or skid plates) near the end of the coil line. The probable reduction in skid-rail life can be justifiable in certain forging applications in which billet surface temperature uniformity is absolutely critical (e.g., backward extrusion).

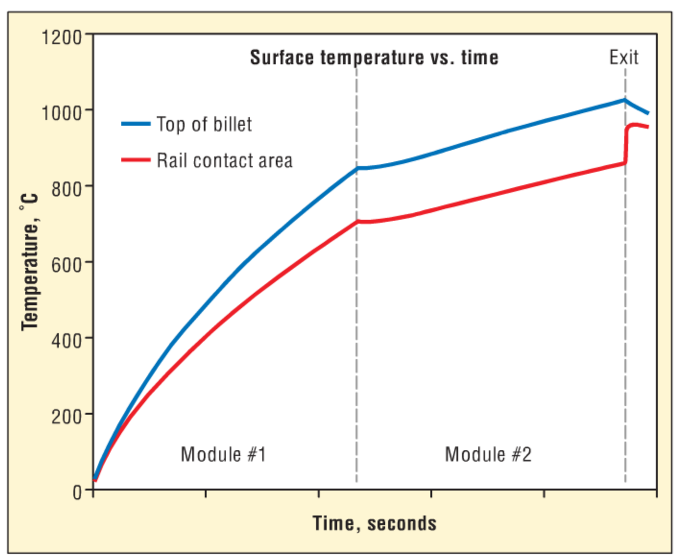
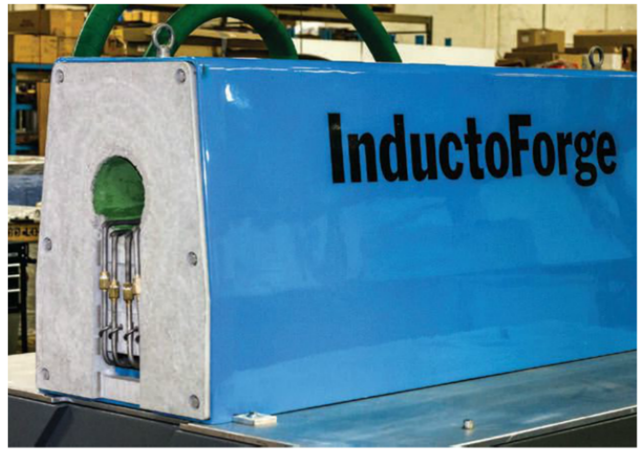


Figure 3. Surface temperature non-uniformity decreases relatively quickly after billets have exited the coil line (same heating process as shown in Fig. 1).



InductoForge induction heating system

Conclusion

Despite their simple appearance and seemingly basic function, designing skid rails and quantifying their effects on billet temperature uniformity are considerably more involved than one might expect. The physical consideration of skid rails introduces additional variables to an already complex electromagnetic and thermal system, further increasing the value and importance of modern computer simulation software. Due to the appreciable influence that skid rails exert on billet temperature uniformity, the ability to accurately and precisely predict their thermal implications is quite valuable in efforts to improve induction billet heating quality and, ultimately, to advance the performance and reliability of forged products.

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