Evaluation of Induction Hardening of 4140 Steel Ring Dies

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Abstract
California Pellet Mill (CPM) manufactures steel ring dies for food pellet production and is considering induction hardening the interior of the passages. The feasibility of this method of surface hardening was evaluated by experiment and a simple model, which estimates transient temperatures in the die. Experimental results showed sufficient surface hardening, but the model suggested that the process is feasible only in dies in the larger end of sizes considered. The major constraint at smaller sizes is the cooling of the induction coil.

Project Background
A proof of concept for a process improvement of steel ring dies from vacuum hardening to induction hardening was considered. The goal was to reduce cost by switching to 4140 steel, while maintaining a surface hardness of ~52 HRC for wear resistance and minimizing distortion.

Results / Discussion
Sample Characterization
Optical microscopy confirmed that the required case depth was hardened to martensite, while verifying that quenching was needed to attain that martensitic transformation.

Experiments
The purpose of the experiments was to determine the viability of induction hardening a small hole with a hairpin coil. Pre-hardened 4140 steel samples were induction hardened with a 7.6 mm diameter hairpin coil, at different times and power levels at 180 kHz frequency.

Modeling
A model was developed to determine the feasibility of heating a ring die hole above austenitization temperature and quenching to martensite for specified conditions. Two coil designs were considered: Figure 6a and 7a show a hairpin coil and Figure 6b and 7b an internal return pigtail coil (IRPC).

Recommendations
It is recommended that CPM still continue to investigate induction heating with the IRPC design in figure 2b, as it would not require spinning and could produce more power. It is also recommended that flame hardening be considered, as it is applies heat locally, but can be used in small passages without the constraint of coil cooling.

Future Work
• Tests should be run to validate the IRPC model
• Fabrication of coil design
• Flame hardening should be investigated as an alternative local hardening method
• Ability to spin the coil should be investigated
• Modeling in 2D to account for the flux intensifiers

Acknowledgements
We would like to thank Tom Kanaby from CPM, Kyle Hummel from Contour Hardening, Prof. Matthew Krane from Purdue University, and David Lynch from Induction Tooling.

References

This work is sponsored by California Pellet Mill, Crawfordsville, IN.