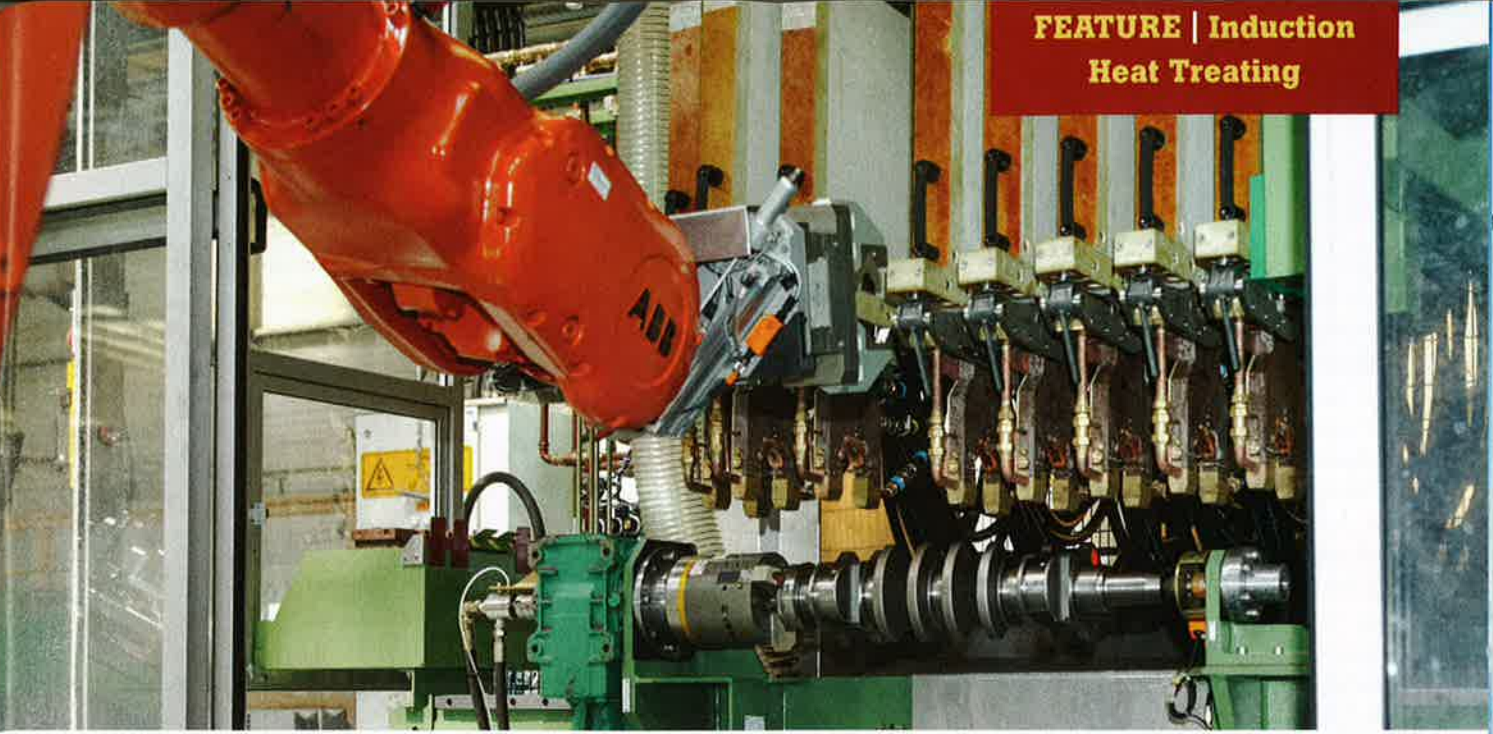

Crankshaft Fillet Hardening: Challenges and Prospects

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Those of us who work in automotive-related industries must sometimes feel we are faced with mission impossible. On one side there is the relentless pressure to squeeze costs, timelines and so on. On the other there is the growing demand for smaller, lighter and more-efficient components and assemblies. And nowhere are these contradictions more evident than with crankshafts.

As the critical component that translates reciprocating into rotational motion, the crankshaft is subjected to significant stresses and loads. Hence the need for surface hardening – a process that reduces wear on the bearing journals and extends the life of the crankshaft.

Fillet Hardening

What is becoming more and more apparent, however, is that traditional induction hardening of the journals is insufficient to meet the automotive industry's shift to lighter engines. This is because conventional induction hardening does not include fillet hardening (Fig. 1). But what is so special about induction fillet hardening, and why should the automotive industry be interested in it? Put simply, fillet hardening is important because it leads to "a significant increase in fatigue strength."[1]

To fully appreciate the implications of greatly enhanced fatigue strength in fillet radii (the radii connecting bearing raceways or bands to the webs), one must first understand the critical role played by these areas. The case is well put by Qurashi and Harne. "Geometry section changes in the crankshaft cause stress concentration at fillet areas where bearings are connected to the crank webs. In addition, this component [the crankshaft] undergoes both torsional and bending loads during its service life. Therefore, fillet areas are locations that are subject to the most critical stresses during the service life of the crankshaft. As a result, these locations are a common fatigue failure site of crankshafts."[2]

Apart from extending a crankshaft's working life (itself a major benefit), fillet hardening helps automakers produce smaller,

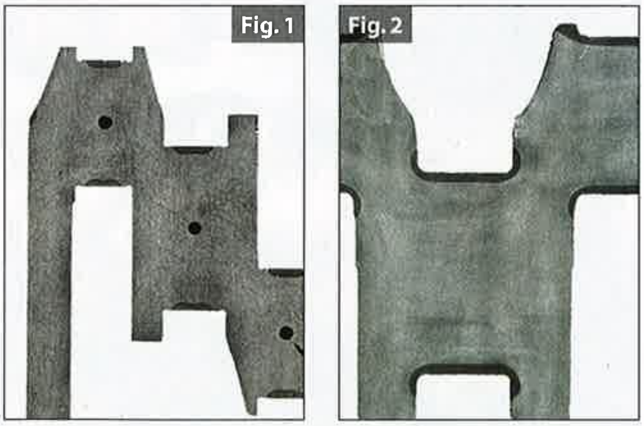
Fig. 1

Fig. 2

Sections showing the difference between conventional and filet hardening. Figure 1 shows conventional hardening similar to that achieved by non-rotational methods. Figure 2 clearly shows that the critical filet areas have been hardened.

lighter engines without compromising power and safety objectives. In other words, crankshafts with hardened fillets mean car manufacturers can "avoid the need for more expensive alloy steels or can enable the engine power output to be increased without a crankshaft design change."[3]

Tests carried out in France illustrate the scale of the benefits achievable with fillet hardening (Fig. 2). Using a Baldwin testing machine, it was found that induction fillet hardening of automobile crankshafts in 35MV7-grade steel resulted in a cracking limit of 1,800-1,900 Nm, which is 80% higher than the cracking limit achieved with roller burnishing. The limit reached before breakage was not as spectacular, but at 2,340 Nm it was still considerable – 10% higher than that reached by the roller-burnished fillets. The residual stresses achieved in a pin and main journal are shown in Fig. 3.

	Pin	Main
Surface stress	360 MPa	430 MPa
Minimum stress	310 Mpa	430 MPa
Maximum stress	520 MPa	670 MPa

Fig. 3. Residual stresses on a pin and main journal of a 35MV7 automobile crankshaft following induction fillet hardening.

Fillet Hardening Challenges

There are of course major challenges to be overcome when attempting fillet hardening with induction heating. As pointed out by Pfaffmann, the complex mass geometries adjacent to the fillets have a substantial impact on "reliably producing the required selective fillet/journal hardened pattern." But there is another even greater challenge: ensuring consistent and minimal dimensional distortion. Failure to do this not only reduces the fatigue strength of the fillets, it means subsequent – and costly – grinding.[4]

Problem Solving

One innovative approach to minimize dimensional distortion (more commonly referred to as TIR, an abbreviation for total indicated runout) involves simultaneous hardening and straightening. Developed by EFD Induction in partnership with a major French automaker, this approach involves sequential heating combined with "dynamic" input power coupling between crank and induction coil. "Dynamic" coupling means the induction system can monitor and automatically adjust the power fed into the crank in accordance with the part's angle of rotation during the heating process. The process for a four-cylinder automobile engine has two main steps:

1. The four pins are simultaneously heated, with power variation ensuring homogenous penetration depths.
2. The five main journals are then treated with localized excessive power that corrects the vertical distortion introduced by step one.

This solution obviously demands advanced induction heating equipment (Fig. 4) and expertise. Sophisticated control software is also needed, as are innovative coils. In fact, EFD Induction has developed its own patented coil design as part of its minimal TIR breakthrough (Fig. 5). This new generation of induction coils ensures optimal contact pressure of the coil guides on the rotating crank. The pressure is such that it does not inflict significant marring or distortion on the crank, but it is still sufficient to ensure accurate and dynamic coupling between the bearing and the coil assembly. The achieved results are impressive, with a TIR of only ≤0.15 mm for car crankshafts (commonly defined as 300-600 mm in length) and only ≤0.6 mm for larger truck/off-road crankshafts (500-1,400 mm long).

The coils were also made lighter, and

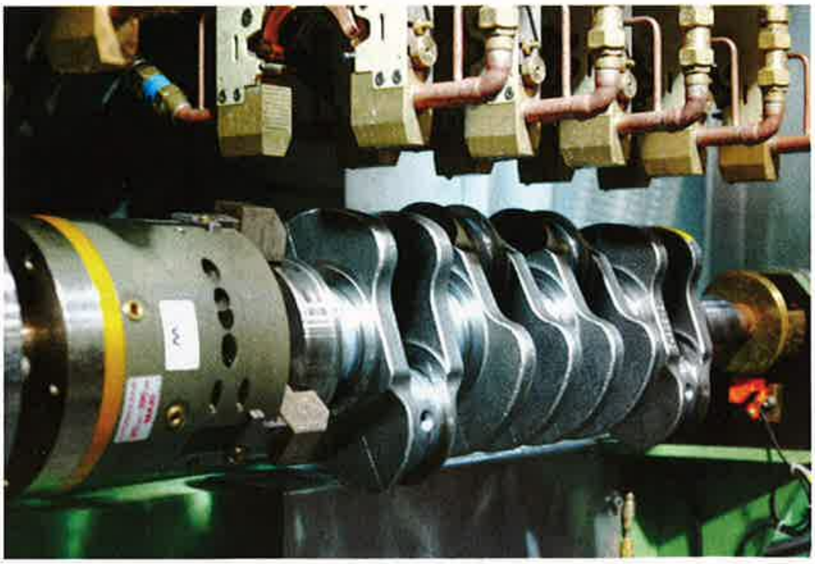

Fig. 4. An EFD Induction robot-type crankshaft hardening system with the U-shaped coil assemblies poised above the shaft ready to descend and heat precisely defined areas as the shaft rotates.

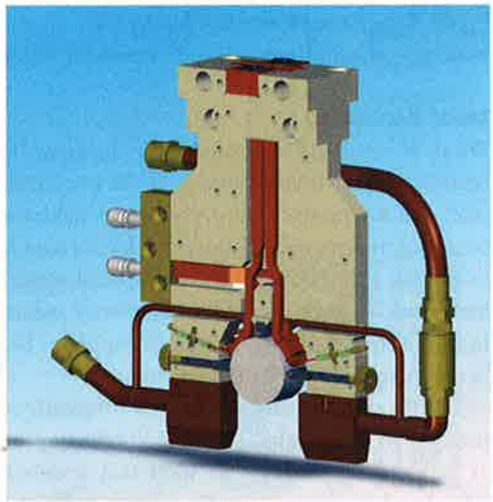

Fig. 5. A detailed drawing of one of EFD Induction's new-generation lightweight coils for crankshaft hardening. The housing surrounding the coil does not need to be cooled by water, thereby significantly reducing its overall weight.