by Glyn Richards | Proto Manufacturing

Residual Stress Measurement in Process Control

FROM THE INTRODUCTION of John Almen's shot peening process control tool in the 1930s to the present day, Industry has been faced with a difficult question: How can we know that today's peened product is truly the same as the first production part and the last part to enter service? The answer we accept is to rely on process control. Almen's method is used to set up and regularly verify the intensity of the stream of peening media, and a set of parameters (peening time, nozzle and part movements) is independently selected to achieve predetermined coverage on the parts.

The residual stress profiles generated by shot peening are a fundamental characteristic of the part. The profiles can be used as a baseline to evaluate future changes in the manufacturing process, repair schemes for parts in service, the effects of excursions from normal operating conditions, and in a 'retirement-for-cause' environment, to help to assess suitability for future service at overhaul inspections.

In an example from an aircraft engine manufacturer, an established family of engines was to be expanded to include a larger and more powerful model. The supplier of a forged, machined and shot-peened Titanium alloy part for the earlier model was selected to produce similar parts for the new model. The new components were larger, but of the same general shape, and the peening intensity required in one area was increased from 6A to 11A. The supplier had developed his business during the years of production of the original components, and had recently installed a shot peening line. He had successfully added his own shot peening to the original process, and included it in the proposed process for the new parts. When the pre-production parts were submitted for evaluation, the peened surfaces in the 11A areas were visibly rougher than the equivalent areas peened to 6A on the original parts.

Fortunately, the test plan had correctly included residual stress measurements. Proto Manufacturing used their X-ray diffraction method with electro-polishing to generate residual stress profiles through the shot peened surface and into the underlying material. The profiles were significantly different from others in the experience of the engine manufacturer, having unusually large compressive stresses near the surface, and shallower residual stress fields than others of the same Almen intensity. The X-ray diffraction peaks from the regions of high compressive stress were also broader than typically seen in the Titanium alloy, suggesting severe mechanical distortion of the material.

Scanning electron microscopy and metallographic sections later revealed extensive rolled edges and peened surface extrusion folds. These features can provide origin sites for future fatigue cracks, and are extremely undesirable in peened surfaces. Conversations with the supplier revealed that this was the highest intensity of shot peening he had attempted to date. He had experimented with increased shot velocity and exposure time, and could achieve the required intensity on Almen strips without increasing shot size. The Titanium alloy of the parts did not interact with the high intensity, small diameter shot in the same way as the steel of the Almen strips, generating a rougher surface texture, the heavily worked sub-surface layer and a resultant unusual residual stress profile.

The Proto LXRD Residual Stress Measurement System

There are lessons and benefits for both the customer and the supplier in this. Some customer and Industry specifications mandate the shot sizes to be used for given peening intensities, rather than leaving the choice to the supplier. Similarly, the lack of a specified coverage probably led the supplier to use the same extended peening time he used for the Almen strips. The importance of correct interpretation of saturation curves was highlighted for both supplier and customer. The supplier gained a valuable insight into the details of his own process, and incorporated those insights into a much improved and satisfactory process.