1991103

Volume 4
Issue 4

THE SHOT PEENER

Winter 1991 INTERNATIONAL NEWSLETTER FOR SHOT PEENING-SURFACE FINISHING INDUSTRY

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TESTING SHOT PEENING STRESSES IN THE FIELD

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The benefits of shot peening are work hardening of the surface and subsequent generation of beneficial compressive stresses at and below the surface. The conventional way of measuring these stresses is x-ray diffraction, which is a well-established method and provides accurate stress values. The beneficial compressive stresses are subsurface; consequently, to quantify shot peening quality, evaluation below the surface is necessary. The penetration depth of x-rays in many cases is limited to several microns. To measure the subsurface stress with x-ray diffraction requires successive removal of material and repeated x-ray measurements. Such a procedure is acceptable for laboratory evaluations on selected samples but is impossible for 100% nondestructive evaluations in shot peened components in the field. Difficult-to-reach areas such as holes, fillets or roots of gears cannot be directly tested with this method. Additional techniques which overcome these problems and have sufficient accuracy are desirable.

Barkhausen method (B-method) is presently used in several industries including automotive and aerospace to nondestructively inspect surface integrity of camshafts, piston pins, bearings, gears, etc. to insure optimum fatigue performance (1). The B-method is well suited for both static and dynamic inspection of the surface. The measurement depth is mainly dependent on the permeability of the material and is typically several 0.001 inch for surface hardened components. Since this depth is 10 to 100 times that obtained by x-ray diffraction, B-method has the capability of quantifying subsurface stress by inspecting at the surface. This fact has offered the possibility of detecting subsurface tensile stress in aerospace bearings; the technique is presently applied to test 100% of the production of certain bearing grades (2). In addition, changing instrumentation parameters adds some flexibility in controlling the depth of analysis in the B-method.

The B-method for testing stress is based on the dependence between the material's magnetic properties and elastic strains/stresses. Figure 1 shows an example of measured Barkhausen noise level as a function of stress (calibration curve). The Barkhausen noise level systematically increases with decreasing compressive stress and increasing tensile stress, provided that the stress is within the elasticity limits of the material. If the material is deformed so that it work hardens (e.g. shot peening), its elastic limits are changed and a different Barkhausen noise response to stress is obtained.

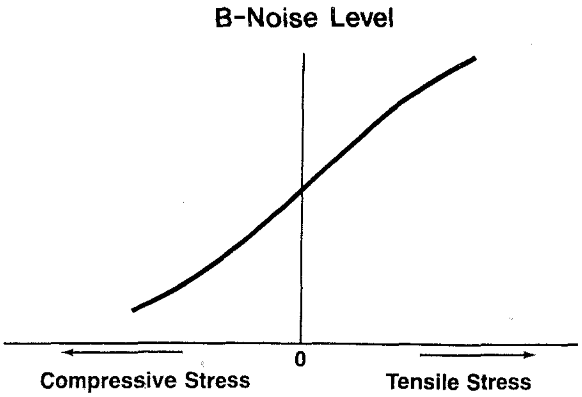

FIGURE 1 *Barkhausen noise level as a function of stress in the elastic region.*

Barkhausen noise can be calibrated against the shot peening process or x-ray diffraction, or it can be used qualitatively. An alternative is to calibrate the Barkhausen noise level of differently shot peened samples directly to fatigue life.

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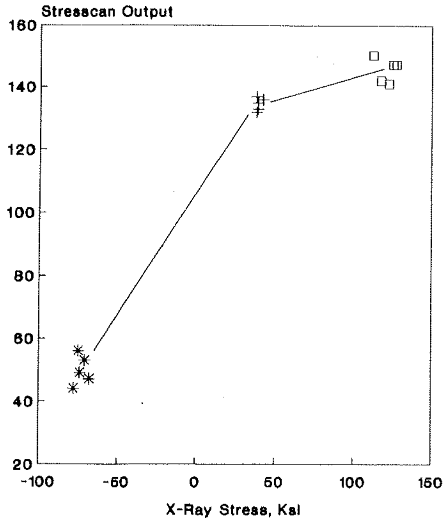
SURFACE STRESS

Figure 2 is a presentation of stress in the surface of valve springs as measured by both Barkhausen noise level (STRESSCAN output) and x-ray diffraction. The springs were in three different conditions: as coiled, stress relieved and shot peened.



Barkhausen noise level (STRESSCAN output) plotted against stress measured by x-ray diffraction (AST Model 2000) on valve springs in three different conditions.

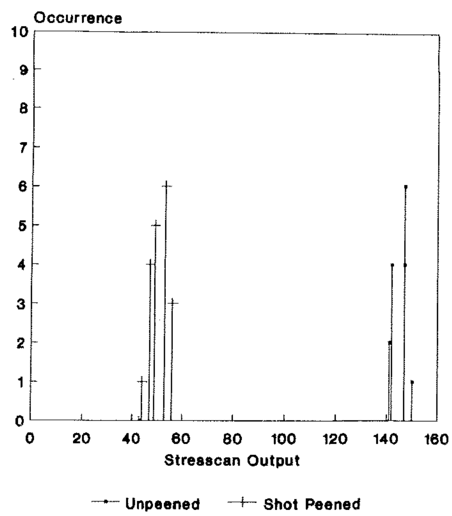
□ coiled
\+ stress relieved
✳ shot peened

FIGURE 2

Coiling of valve springs leaves the inside surfaces of the coiled wire under high tensile stress, as measured by x-ray diffraction and indicated by a high B-noise level. Furnace stress relief treatment decreased the level of tensile stress. However, it was the shot peening process that was able to remove the surface tensile stress and generate high compressive stresses. Figure 2 indicates that a good correlation is obtained between level and x-ray stress: high STRESSCAN output was obtained for high tensile stress and low STRESSCAN output was associated with high compressive stress.

Figure 3 presents results for testing 17 unpeened spring samples and 19 peened samples. It is obvious that there is a bimodal distribution of STRESSCAN output separating the unpeened and peened springs from each other.

Figures 2 and 3 indicate that the B-method can be used to confirm that components are shot peened and the level of surface compressive stress is at the required level.



STRESSCAN evaluations on unpeened and shot peened valve spring samples.

FIGURE 3

SUBSURFACE STRESS

Figure 4 is a presentation of five hypothetical stress profiles for unpeened and peened samples. Due to limited penetration, x-ray diffraction would measure +110 ksi for curve 1 and -70 ksi for curves 2, 3, 4 and 5 on the surface. However, the subsurface stresses in curves 2, 3, 4 and 5 differ from each other and would cause components with corresponding stress profiles to have considerably different fatigue lives.

Taking the damping of B-noise into account and the material's calibration curve, it is possible to calculate the level of B-noise that is measurable from the surface. This was done for the five stress profiles of Figure 4. The calculated B-noise levels ranged from 100 for curve 1 down to 19 for curve 5. Although the surface residual stress is the same, distinctively different B-noise levels were obtained for curves 2 to 5 due to the different levels of subsurface stress.

Five different stress profiles for unpeened and shot peened samples. The corresponding calculated B-noise levels are:

Curve	B-noise level (relative units)
1	100
2	41
3	32
4	23
5	19

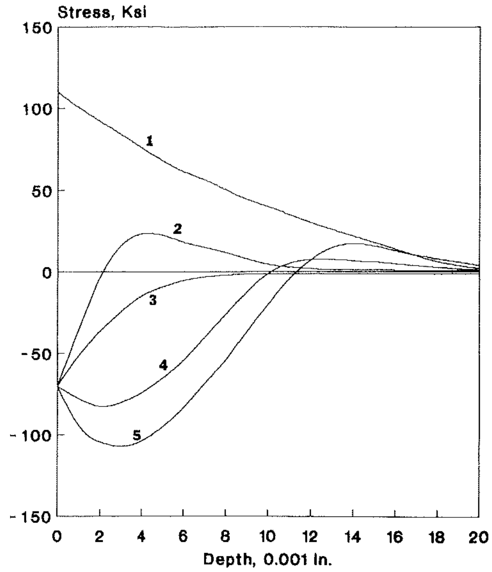


FIGURE 4

APPLICATION OF B-METHOD FOR SHOT PEENING

The examples given above demonstrate that surface evaluations with B-method yield the following benefits:

1) Separates unpeened parts from shot peened parts.
2) Quantifies shot peening quality and provides non-destructive process control for shot peening.

The B-method is well suited for production or quality control environment. The testing is nondestructive and can be either static or dynamic depending on the requirement. Various kinds of scanning heads are presently available so that difficult to reach areas (like holes, fillets and gear roots) can be inspected. B-method is a production tool that complements the laboratory evaluations of stress by x-ray diffraction.

REFERENCES

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2) *C. A. Griffiths, Closing the Loop on Product Integrity on Bearings with Engineered Source Approval, Split Ballbearing Features, Company Newsletter, July 1989.*