DISCUSSION

W. G. Gibbons[1] (*written discussion*)—Subsurface failure initiation sites have frequently been noted in the fatigue of specimens which have experienced a surface residual stress treatment such as shot peening. The authors have not indicated observation of this phenomenon. However, initial results of a rotating beam fatigue study on a steel of comparable hardness do indicate subsurface failure origins for specimens containing surface residual stress. Thus, further discussion of this topic is merited.

The material employed in the aforementioned study was H-11 steel (0.35 C, 5.00 Cr, 0.4 V, 1.5Mo) in a 55 to 56 HRc condition. Discussion of some shot-peening results will indicate similarities and differences with respect to the authors' work. For the H-11 specimens the peak residual stress of -110 ksi, determined by X-ray techniques, occurred at the surface. Since the shot-peening intensity employed was 0.024-in. Almen A-2, comparison with the information of Fig. 8 shows a higher surface residual stress for the H-11. This difference might be partially accounted for in the polishing of the hourglass gage section of the 0.250-in. minimum diameter specimens subsequent to shot peening. Although the nonpeened H-11 specimens indicated a fatigue limit of 111 ksi at 10^7 cycles (higher than the authors' results of Fig. 13), the peened fatigue limit was 118 ksi, which is essentially identical with the peened results.

Subsurface failure origins were observed to occur in the shot-peened specimens near the location of the maximum net tensile stress. The variation in the results was due to the differences between the specimens of the residual stress gradient and the fatigue strength gradient. The net stress had been considered for only the tension-loading portion of the fatigue cycle. To obtain this for some of the authors' results, the tensile portion of the applied alternating stress would have to be added to the net mean stress curve of Fig. 16. In performing that operation, it appeared that the peak tensile stress would occur at the surface. Thus, failure would initiate at the specimen surface and no subsurface failure origins should be identified.

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D. V. Nelson (author's closure)—Mr. Gibbons's interesting results further point out the necessity for analyzing the residual and applied stresses for each particular fatigue problem. A residual stress-inducing process can have widely differing effects in fatigue, depending on the applied stresses. More work is needed to determine how far below the surface the balancing tensile stress has to be before it no longer has a measurable detrimental effect in fatigue. Stress gradients would have an important effect in such an investigation.

The fatigue limit of the H-11 steel in the nonpeened condition ($\sim$111 ksi) is higher than that of our unpeened curve in Fig. 13, because the tougher H-11 steel presumably has more resistance to the tension-governed fatigue failure mode. However, by optimizing hardenability, heat treatment, and section size to obtain high compressive residual stress (in an economical steel) we could obtain a fatigue limit of approximately $\pm$170 ksi at the 55 to 56 HRc level compared to the $\pm$118 ksi for the peened H-11 steel. Our highest fatigue limit of $\pm$215 ksi occurred in SAE 1045 steel at high hardness with a residual compressive stress of 250 ksi. This very high fatigue limit was a direct result of the very high compressive residual stress in the unpeened SAE 1045 steel.