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Discussion

Measurement of Residual Stresses in a Circular Ring Using the Successive Cracking Method[1]

W. Cheng[2] and I. Finnie.[2] In a recent paper by Kang and Seol (1996) the residual hoop stress in a thick-walled ring was measured by introducing a cut of progressively increasing depth, which in concept is the same as our crack compliance method. Their success in residual stress measurement provides one more example of value of the approach. However, some of their comments on our work are misleading and need to be clarified.

1. They noted that the use of Legendre polynomials to describe the unknown stress field satisfies the equilibrium conditions but incorrectly stated that the corresponding estimation was often unrealistic. In fact, the limitation on using Legendre polynomials or any other continuous functions applies only to the measurement of near surface residual stresses for which higher order estimations may become unstable. However, for measurement of residual stresses through the thickness which is the case in question, the estimation is much more stable than for near surface measurement and, when combined with a least squares fit, the order of the approximation can be as high as 10, which should be sufficient for most applications.
2. They appear to be unaware that the crack compliance method also applies to thick-walled cylinders (Cheng and Finnie, 1994). To demonstrate this capability, we used the strains measured by Kang and Seol to estimate the distribution of the residual stress in the same thick-walled ring. The estimation converged when the highest order of Legendre polynomials was equal to and larger than three. Kang and Seol, in their Fig. 10, used results obtained by sectioning to validate their approach. However, as shown in Fig. 1(a), the results obtained using the crack compliance method are in much better agreement with the sectioning measurements than Kang and Seol's approach and satisfy equilibrium conditions exactly. Since our approach allows the use of a least squares fit, the influence of random error on estimated residual stress is minimized and the result is considerably more stable than that obtained by Kang and Seol.
3. Regarding the location of strain gages, Kang and Seol failed to distinguish the difference between near surface measurement and through the thickness measurement. In the crack compliance method strain gages are always placed near the cut for near surface measurement. For through thickness measurement of normal residual stresses the optimum location is on the back face opposite the cut, which allows the prediction to cover from about 4 to 96 percent of the thickness. For the thick-walled ring considered by Kang and Seol, this location can be shown to lead to a larger strain response than that at the 90 deg location.
4. Finally, the dimension of the ring specified in their paper appears to be a diameter not a radius.

References

Kang, K. J., and Seol, S. Y., 1996, "Measurement of Residual Stresses in a Circular Ring Using the Successive Cracking Method," ASME JOURNAL OF ENGINEERING MATERIALS AND TECHNOLOGY, Vol. 118, pp. 217–223.

Cheng, W., and Finnie, I., 1994, "An Overview of the Crack Compliance Method for Residual Stress Measurement," *Proceedings of Fourth Int. Conf. on Residual Stresses*, Soc. for Exp. Mech., Bethel, CT, pp. 449–458.

Authors' Closure

We thank Professor Finnie and Dr. Cheng for their interesting and important comments on our study (Kang and Seol, 1996) and also we like to pay our respect to them for their many contributions on residual stress measurement. Our answers are as follows.

1. If the residual stress distribution of a body whose history in manufacturing process or service is unknown is to be measured, it is difficult to know whether the distribution is smooth enough to be fitted in a Legendre polynomial. Often the residual stresses are not distributed in smooth function such as the Legendre polynomial. Vaidyanathan and Finnie (1971) showed that residual stress near the welded region may change abruptly, not in the typical distribution generally known. In fact the non-smooth distributions are often found near the region with micro-structural change or near the interface of dissimilar materials joint (Kang, 1996).

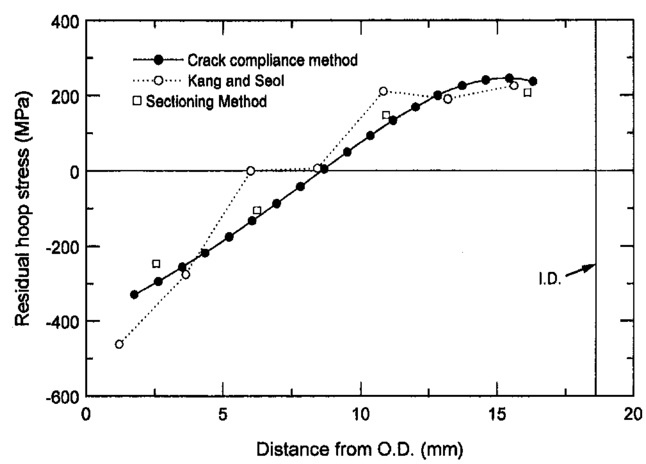

Fig. 1(a) Residual stresses predicted by Kang and Seol and their validation using sectioning procedures compared with the prediction of our crack compliance method using their strain measurements

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[1] By K. J. Kang and S. Y. Seol, published in the April 1996 issue of the ASME JOURNAL OF ENGINEERING MATERIALS AND TECHNOLOGY, Vol. 118, pp. 217–223.

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2. We used the result by sectioning only for comparison, not as the exact value. In fact, the results by sectioning may be crude or inaccurate because the method give only the average stress over a region under the assumption of uniform stress distribution. Also, the strain values from which the residual stresses are evaluated are quite sensitive to cutting procedure, i.e., heat generation and plastic deformation because the sectioning should be done as close as possible to the strain gage. We think both the sectioning method and crack compliance method have the same weakness from the point of view that both of them are based on an assumption of the stress distribution. It is true that our results of the residual stress measured by the successive cracking method don't look so impressive, but the accuracy of the method itself should be evaluated on the basis of its theoretical exactness. Its accuracy could be much improved by using more precious equipments such as the sharper saw or an electric discharge wire machine and with the smaller cut increment.

3. We agree that the back face opposite the cut would be the better location for a larger strain response than the outer surface. But in many cases of the axisymmetric members such as a thick walled circular ring of our specimen or a pipe, it is difficult or impossible to bond the strain gage on the inner surface or to make a cut from the surface. That is the reason why we chose that location.

References

Kang, K. J., 1996, "Measurement of Residual Stresses in a Dissimilar Material Bond Using Successive Cracking Method," in Preparation.

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Vaidyanathan, S., and Finnie, I., 1971, "Determination of Residual Stresses From Stress Intensity Factor Measurements," ASME JOURNAL OF ENGINEERING MATERIALS AND TECHNOLOGY, Vol. 118, pp. 217–223.