LEHIGH ENERGY UPDATE

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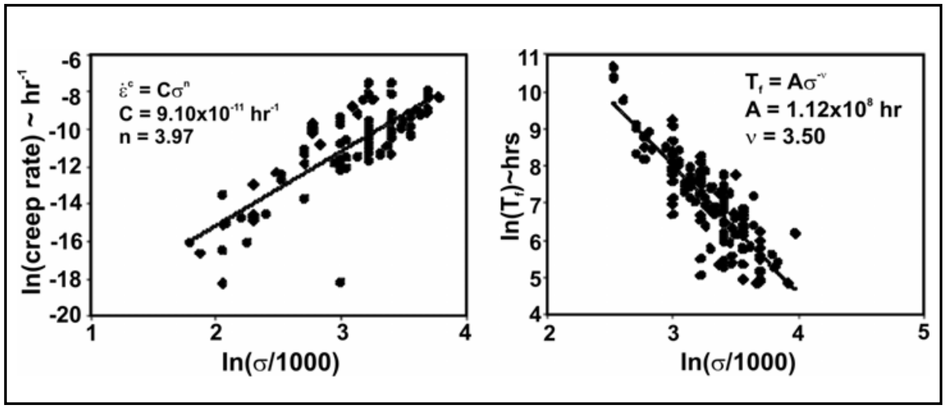
PREDICTING THE REMAINING HIGH OF HIGH TEMPERATURE STEEL PIPING

As the fleet of U.S. coal-fired power plants continues to age, one of the many decisions power generation companies will need to make is when to replace high temperature and pressure steam piping connecting the boiler and turbine. Waiting too long before replacing a creep-damaged steam pipe can lead to catastrophic pipe rupture and replacing a pipe prematurely would be an unnecessary expense. A research team at the Energy Research Center led by Professor Terry Delph has developed an analysis method which provides more realistic estimates of remaining useful life than has been possible up to now.

Delph explains, "Steel components used for high temperature and pressure applications undergo a degradation process referred to as creep damage, which weakens the steel and will eventually lead to mechanical failure by pipe rupture. The years of life which remain in a steam pipe depends on the years of service, operating temperature and stress level, and original creep properties of the material. There are well-defined ASME procedures which can be used for making remaining life predictions, and these require availability of creep and creep rupture test data obtained from material similar to the material used to make the steam pipe. The difficulty with this approach is that there is always relatively large scatter in creep and creep rupture test data, possibly due to differences in properties of steel from one batch to another and to random errors in creep test data. Large uncertainties in the creep and creep-rupture data can result in unacceptably large uncertainties in predictions of remaining life."

To solve the data uncertainty problem, the Lehigh team (Terry Delph, Gary Harlow and Murat Ozturk) turned to Monte Carlo simulations for obtaining predictions of remaining life. The Monte Carlo method is a numerical technique



These two figures show creep data and creep-rupture data for A-335 steel. Plotted on log-log scales, the data exhibit extremely large scatter, which results in unacceptably large uncertainty in calculations for remaining life of high temperature steam pipes.

developed for making probabilistic predictions for a wide range of complex physical phenomena. In this case, the application of Monte Carlo to the steam piping problem gives the probability of failure of a steam pipe at the present time or at a certain number of years in the future.

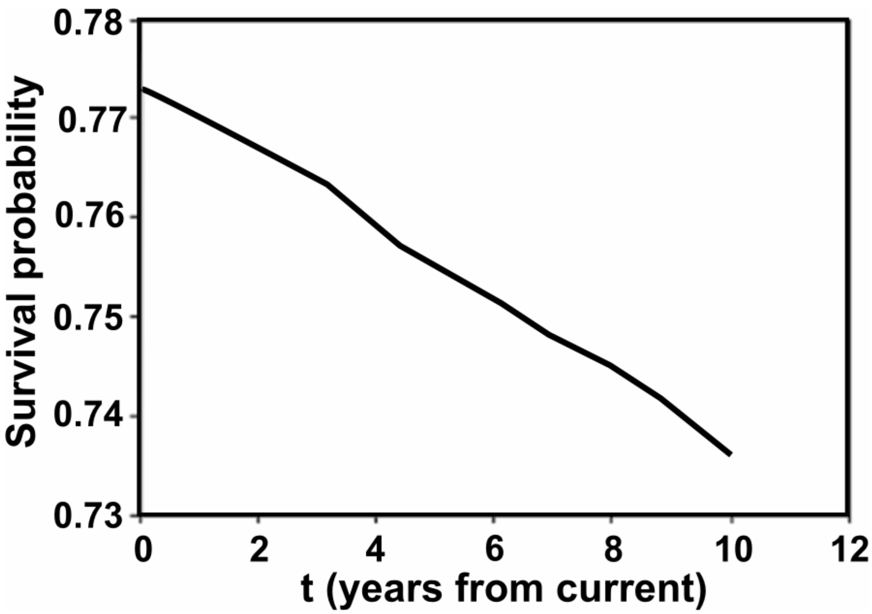
Professor Harlow continues, "We used the Monte Carlo approach to predict the remaining life for three steam pipes in a coal-fired power plant which had close to over 40 years of operation. The predictions for the main steam line, which operates at a steam temperature and pressure of 1000°F and 2400 psia, indicate a failure probability ranging from 13% to 48%, depending on the stress model used to compute the stresses. The hot reheat line, which operates at 1000°F and 600 psia, had a probability of failure of approximately 10%, and a low temperature and pressure steam extraction line (735°F and 200 psia steam) had a negligibly small probability of failure. The results for these three conditions show expected trends with steam temperature and pressure.

The model we've developed can also be used to estimate how the probability of failure changes with time. In one calculation, we saw the probability of failure increase from a value today of 23% to 26% ten years into the future."

Delph adds, "The decision as to what represents an unacceptably high failure probability is, of course, a management decision. However, we believe that the methodology we've developed provides a more rational basis for run/replace decisions than the commonly used deterministic lifetime assessment approach, which is unable to cope with the very large scatter in material creep and creep-failure data."

The Lehigh team is now planning to expand the capabilities of the analysis. There will be some situations in which creep and fatigue damage will combine to increase the probability of failure, and modifications to the analysis methodology are needed to make it possible to determine the magnitude of combined creep and fatigue effects. In addition, girth welds are often made in many locations of the plant. Since the creep resistance of the weld heat affected zone is typically inferior to that of the base metal, this is an important topic that requires more attention. Research is needed to determine the range of data currently available for welds and then

("Creep" Continued from P. 1)
apply the Monte Carlo technique to the weld data. It is also likely that creep data for welds may also need to be developed, since data for welds are typically not readily available for many new and existing steels. ■



As the power plant continues to operate, the survival probability of the main steam line decreases.

RESEARCHERS' PROFILES

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- ***Zheng Yao*** is a Research Scientist at the Energy Research Center and he has a MS degree from Lehigh University in Mechanical Engineering.
- ***Ricardo Moreno*** is studying for an MS degree in Mechanical Engineering at Lehigh University.
- ***D. Gary Harlow*** is Professor of Mechanical Engineering and Mechanics (MEM) and Chair of the MEM Department. His research interests encompass stochastic modeling and fracture mechanics, addressing topics such as the modeling of failure processes in aluminum alloys, steels, and composites, and mechanical and system reliability.
- ***Terry Delph*** is Professor of Mechanical Engineering and Mechanics. He is a specialist in high temperature creep phenomena in structural steels.
- ***Murat Ozturk*** is a Research Engineer in Mechanical Engineering and Mechanics with a Ph.D. in Mechanical Engineering. His research interests are in computational mechanics involving elastic and plastic deformations and stresses.