Hazardous situations created by improper piping analyses

Some computer programs do not handle hot condition calculations correctly

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Piping flexibility and stress analysis is required in design of most piping systems before the piping is installed in an industrial plant. It is intended to ensure plant safety and, thus, protect the interests of the owner and the general public. Due to availability of powerful software packages, the analysis has become simple and routine. However, improper piping analysis may actually create a hazardous situation rather than ensure plant safety.

Improper piping analyses stem from many areas. Misunderstanding of the software approach, input errors and wrong boundary conditions from CAD data are some common ones. These common mistakes are easy to detect and check if proper isometrics and input data echoes are provided. However, some areas of improper analysis are not as obvious and may even be misconstrued.

One area of improper analysis, which is openly mishandled by some software packages, warrants special attention. This improper analysis involves the so-called piping resting or single-acting support. The resting support allows the pipe to move up without restriction, but will support the pipe preventing it from moving downward. It is obvious that when the pipe moves up and off the contact point, it is no longer being supported. This very fundamental fact somehow is not recognized by some popular software packages and their users. They treat the pipe as being supported in the hot condition simply because it is supported during the cold condition.

To ensure structural integrity of the pipe, at least two stress categories normally have to be evaluated. One is sustained stress that is controlled by the pressure and weight. The other is expansion or displacement stress that is determined by thermal expansion of the pipe and movement of the connecting equipment. The sustained stress maintains the same magnitude through plant operating life. Its allowable is determined by the pipe's yield, rupture and creep strength at operating temperature.

On the other hand, the displacement stress relaxes once the material yields or the temperature reaches a certain point. Its allowable is determined by the strain range that is conveniently measured by the strength at cold condition, adjusted slightly by the strength at operating temperature. Treating a pipe that lifts off its support as being supported can greatly underestimate the sustained stress. It may not create a noticeable problem in the beginning, but the seemingly satisfactory piping system may actually have a safe operating life of only a small fraction of what is intended. This situation can better be explained by a typical example.

Piping system example. A typical piping system is commonly placed directly on the support structure as shown in Fig. 1. This is the most economical and direct approach of installing a piping system. Depending on operating temperature and pipe size, modifications are often required to ensure piping safety and operating life. In this particular example, because of the 12-in. size and 1,000°F temperature, an experienced engineer will install one or more spring supports to ensure that the sustained stress due to weight and pressure is not excessive at operating temperature.

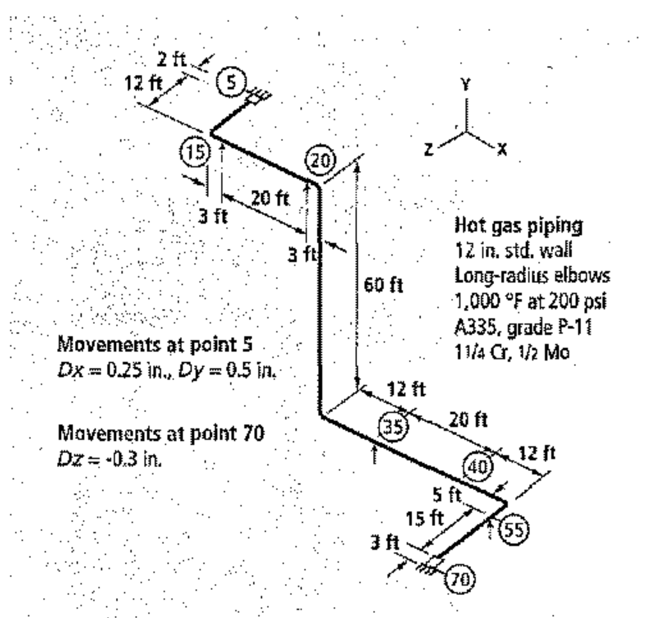

FIG. 1. A typical piping system is commonly placed directly on the support structure.

However, the situation may appear to be different to a computer-oriented engineer, because the system as it is laid out will meet piping code requirements when run through some popular computer programs. According to these computer programs, no spring support is required. This, on paper, saves substantial money for the owner. But in reality, it puts the plant in great danger. To understand this situation, finding out how a computer program handles resting supports is necessary.

Computer programs have become an essential part of piping stress analysis. As the technology progresses, these computer programs also get more powerful and sophisticated. The capability of handling resting supports and other single-acting restraints has been available for over two decades. To analyze the resting support, a good

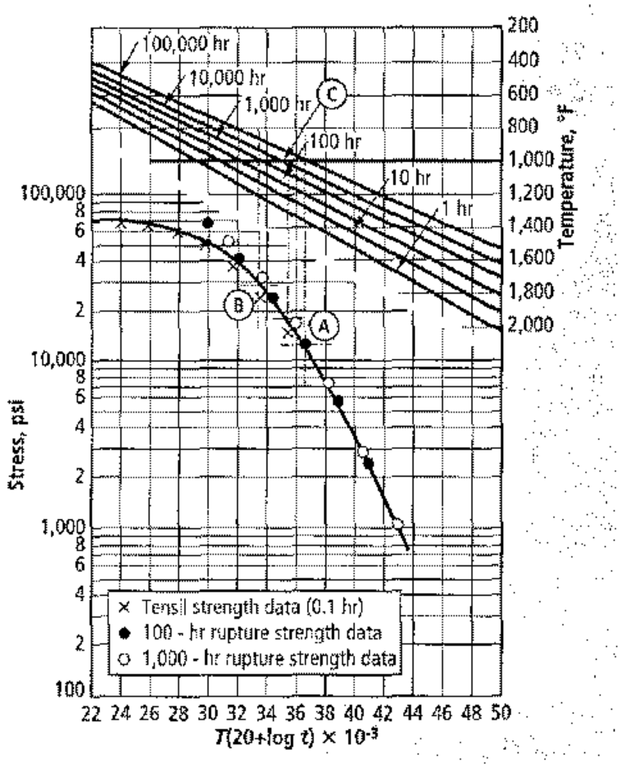

FIG. 2 Larson-Miller graphs can be used to estimate piping life at high temperatures.

computer program will first check the normal operating condition to see if the pipe will lift off a support when operating. If the pipe will lift off from a support, then that particular support will be unable to support weight during operating conditions. That support will be ignored in calculating sustained stress. Therefore, with the Fig. 1 example, the program will show that supports at points 15 and 20 are not active. Without these supports, the piping is greatly over-stressed under weight and pressure. This in turn signals the engineer to add some spring supports.

This kind of simple logic, however, is not adopted by all computer programs. Some popular computer programs instead use a simpler, but tricky, approach by calculating the sustained stress at cold condition assuming all supports are active. They then calculate the thermal expansion stress by allowing the pipe to move up on all resting supports. This erroneous approach completely ignores the sustained stress at operating conditions, when the plant life is counted. The piping may be all right by their account, but this simplified approach of calculating sustained stress has already greatly shortened the piping life.

To estimate piping life at high temperature, Larson-Miller graphs can be used. Fig. 2 shows the Larson-Miller graph for 1¼ Cr, ½ Mo steel. The graph shows that at 1,000°F, for an 11,700 psi stress (point A), the rupture time is 100,000 hr. However, for a stress of 28,500 psi (point B), rupture time is only 1,000 hr. According to ASME piping code, allowable sustained stress is taken as 67% of the average creep rupture stress at 100,000 hr. In other words, if the piping is designed within the allowable stress, it should last 100,000 hr at full temperature with a safety factor of 1.5 applied to the stress value. As given above, for 1¼ Cr, ½ Mo steel at 1,000°F, average rupture stress at 100,000 hr is 11,700 psi. Therefore, the allowable is 11,700 × 0.67 = 7,800 psi. This allowable stress value is revised periodically based on the latest available data. The current allowable is 6,300 psi.

With the piping system in Fig. 1, the correct maximum sustained stress, considering the inactive supports removed, is 18,000 psi. This greatly exceeds the code allowable. However, maximum sustained stress calculated assuming all supports are active, as performed by some popular computer programs, is only 5,800 psi, which is within the piping code allowable. The difference between these two results is very significant. The piping may have been checked to be in compliance with the code by some computer programs, when in reality it is highly overstressed.

With an 18,000 psi actual sustained stress, the pipe will rupture in about 20,000 hr (Fig. 2, point C) without any safety factor applied. If a safety factor of 1.5 is applied to the stress, then piping safe operating life is only about 10 thousand hr. This is much less than the 100,000 hr intended by the code. It is apparent here that the piping analyzed by assuming all the resting supports are active, as in the cold condition, can create a real hazard to the plant.

Evaluating supports correctly. When piping lifts off from the support during operation, its sustained weight stress should be calculated considering the support as inactive. This common sense is not recognized by many engineers. It is even more puzzling that this situation is not handled correctly by some popular computer programs. Some engineers have argued that the pipe will eventually settle to the support either by yielding or by creeping. This may or may not be true, depending on the amount of uplift and the piping configuration.

Even if the pipe eventually settles to the support, it still raises three major issues: The piping is still not in compliance with the piping code, which requires that the sustained stress be within the allowable all the time, not just some of the time; before the pipe is eventually supported, it may already have been sufficiently damaged; and when the pipe settles to the support at operating temperature, usually huge stresses and loads will be generated during the cool down. This is because the support will prevent the pipe from moving downward as required by the shrinkage due to cool down.

The most common and economical approach in dealing with the countless piping in a process plant is to rest the piping on pipe racks and other support structures. Using this approach, combined with some commonsense engineering, many safe plants have been constructed. However, since the use of powerful software packages, these resting supports have been misinterpreted to have some magic functions that do not exist. Validated by the computer, engineers have been improperly designing many piping systems with resting supports. They may have already created numerous hazardous situations waiting to compromise the plant safety. Therefore, it is imperative that owners and operators of these plants evaluate these support situations thoroughly to ensure that the investment and safety of the general public are protected. HP

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