PC-BASED PIPE STRESS ANALYSIS PROGRAM

New generation software, when used with a PC, permits sophisticated pipe stress and pulse analyses to be integrated with three-dimensional process piping design and automated drafting

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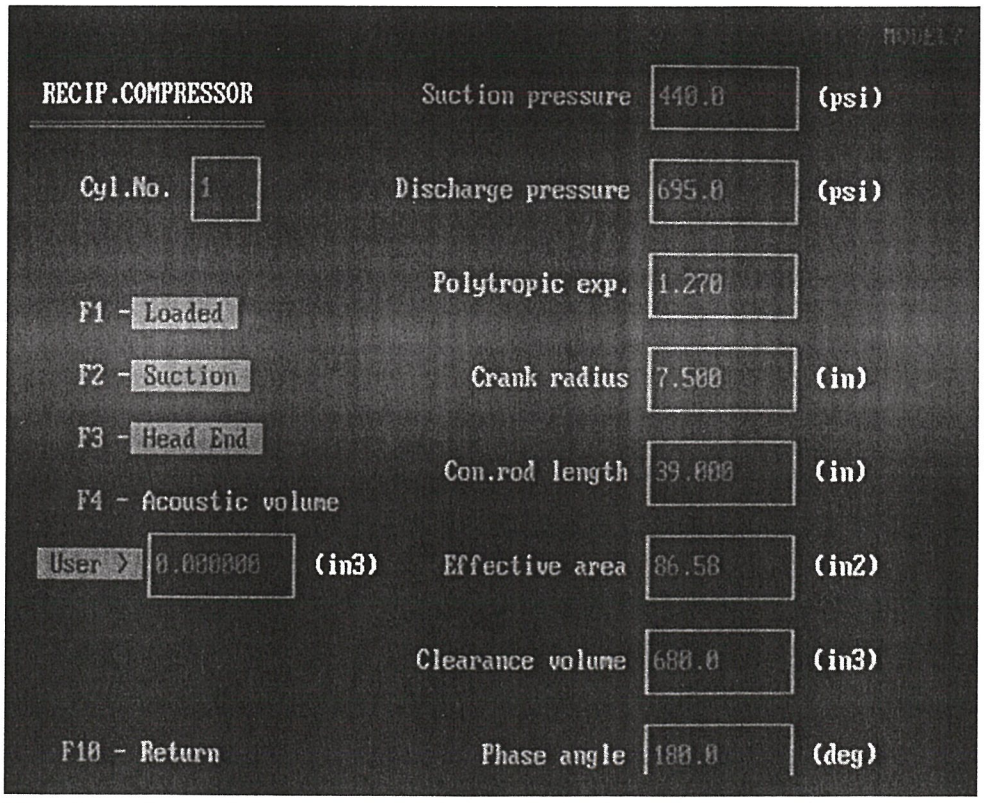
Pipes and their supporting structures must be designed to withstand loads generated by the weight of the pipe itself and its contents, thermal expansion, wind, and possible seismic disturbances. In the past, stress analysis was performed on piping with hand calculations that were extremely tedious and thus usually used only on the few areas in which failure was thought to be the most critical. Limiting analysis in this way made it necessary to use very conservative design practices that increased the cost and size of the plant. With the rise of the nuclear industry, a number of mainframe computer-based stress analysis programs designed for piping analysis were developed. These programs required that piping layouts be entered in node by node, which was quite time consuming. They also demanded a detailed knowledge of analysis on the part of the user.



Menu for reciprocating compressor pulsation excitation definition.

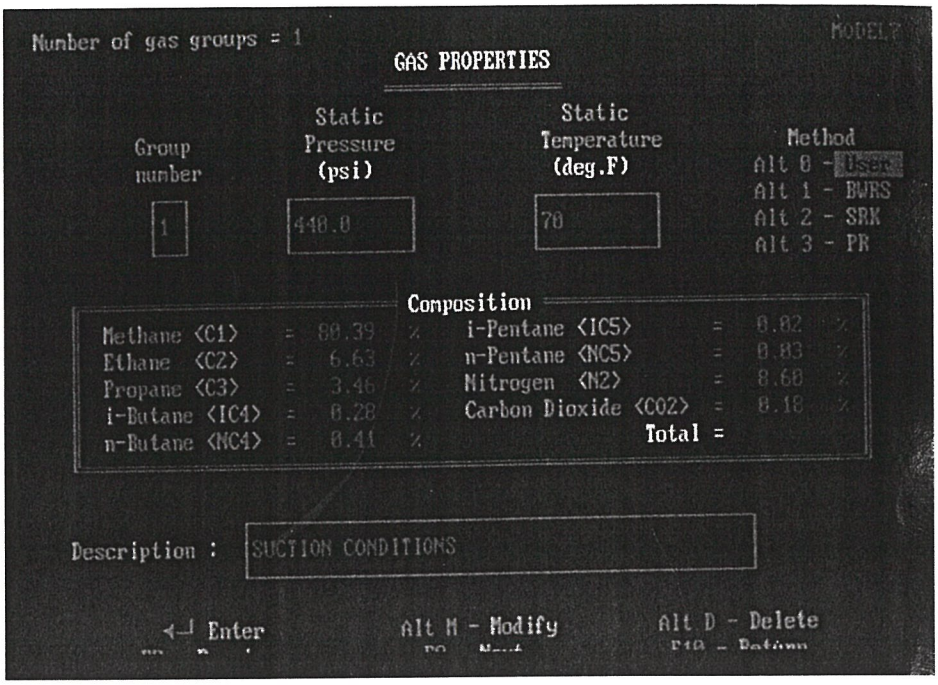
Now, personal computer-based stress analysis programs are coming onto the market, which when a pipe layout is created with a program using the AutoCAD engine, can extract the basic geometry to perform the analysis with a minimum effort. The interface performs automatic node numbering and extracts materials, cross sections, and other data necessary for analysis. These new programs make it possible for piping designers to perform stress analysis from the pipe layout without more than a cursory knowledge of stress analysis fundamentals. Stress engineers are still used to perform the detailed analysis, but the amount of time required on their part is drastically reduced. This makes it pos-

sible to use less conservative design assumptions and thereby significantly reduce construction costs without compromising safety.

Designing a plant

The availability of these new programs is having a major impact on the plant design process. The designer can now lay out the entire plant in a three-dimensional environment. Three-dimensional geometry is a key requirement for stress analysis. Stress ISOs or other representatives are no longer needed to convey the pipe route to the CAE specialist. This CAD-to-CAE interface eliminates the need for the design to be recreated in a later phase. Important textual information, such as component tags, dimensions, pipe wall thickness, etc., can be entered in a textual database that is linked to the piping layout. This information can be entered by the designer or by clerical personnel working from specification sheets. This information is also required for stress analysis and isometrics, so entering it at this stage also avoids a significantly greater effort later. When this information is entered at the design stage, the new generation of integrated stress analysis programs is capable of largely automating the process. Besides time savings, another advantage of using the design information for stress analysis is that it greatly reduces the possibility of data entry errors.

A key element in this process is a translation program that converts three-dimensional model geometry from the piping design program into the stress analysis program. The translation program deconstructs the physical model into corresponding analytical members in accordance with a user-defined mapping table. For example, olets and tees become rigid links after translation. If all the necessary data was entered during the design process, no user input is required. If data are missing, the program will prompt the user for the required information. A complete finite element model is generated with the only additional steps required to perform the analysis being assignment of loads and support stiffnesses. Studies have shown that normally over 66 percent of the stress analysis effort is consumed by model building; thus, the time savings achieved from this approach are dramatic. Another benefit is that the translated model accurately reflects the plant layout, thereby greatly reducing the need for checking.



Menu for convenient input of system gas properties.

In situations where the stress analysis is performed by someone other than the piping designer, attention should be paid to coordinating these two activities. A small amount of time invested in the design phase can save a considerable amount of time later. For example, a number of plant design software packages make it possible to enter operating conditions such as temperature. These data were rarely used in the past, so most designers never bothered to enter the information. Likewise, in many cases, plant designers didn't pay a lot of attention to entering specifications accurately such as the weights of valves. This information is critical to the stress analysis process. If it is not entered during the design phase, the person performing stress analysis not only has to enter it but also has to spend a fair amount of time tracking it down. The ideal approach is clearly defining the responsibilities of the piping engineer or clerical personnel to include entry of all data that will be required for subsequent analysis activities.

The software

The new generation of integrated stress analysis packages contains a comprehensive and extensible library of material properties and piping components. Typical items in the components library include pipes, reducers, tees, valves, flanges, flexible connectors, anchors, spring and constant force hangers, limit stops, guides, dampers, tie-rods, inclined springs, etc. Most packages offer both linear and nonlinear analysis. The most advanced packages provide advanced dynamic analysis features such as calculation of mode shapes and frequencies with three independent spectra, which satisfy NRC

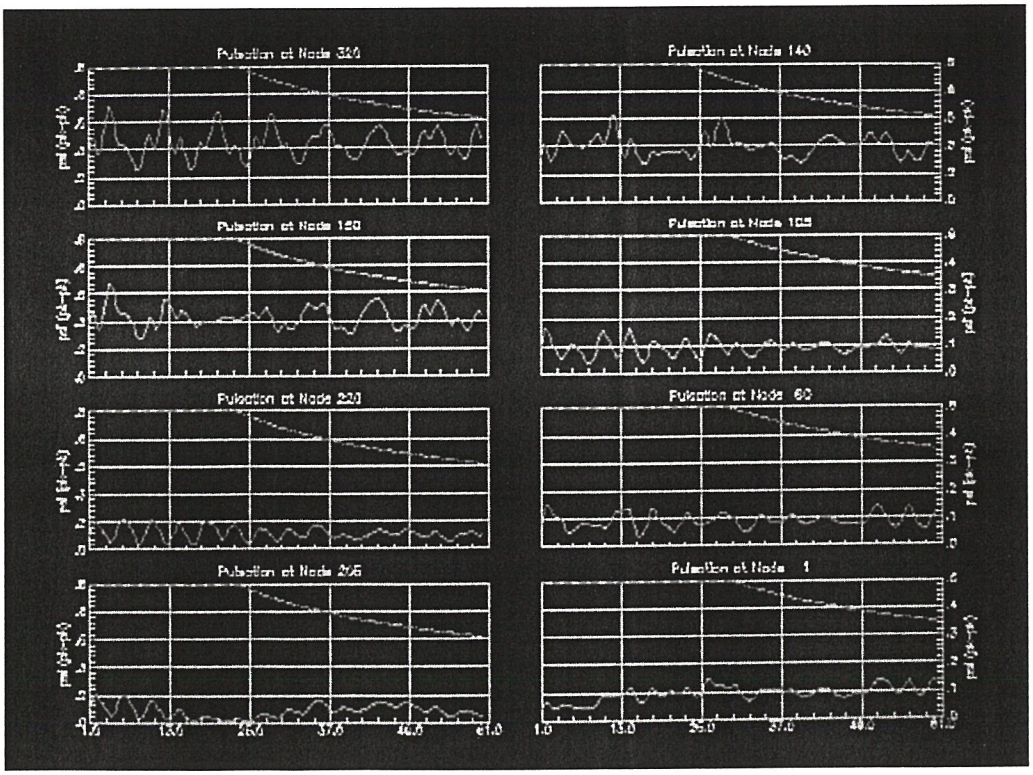
spectra, seismic, seismic anchor movements, and Code Case N411 capability. Other advanced capabilities offered by the newest PC-based packages include wave loading for offshore oil platforms, wind loading for modeling indoor/outdoor piping runs, force spectrum loading for modeling shock loading caused by relief valve discharges, and phased harmonics that allow analysis of shaking forces from pulsation programs.

When a reciprocating compressor drives gas through a piping network, there is the possibility of setting up an acoustic resonant condition. This resonance sets up pressure pulsations that produce unbalanced forces and can cause premature fatigue failure. Basically, the fluid becomes coupled to the mechanical system at the discontinuities. A new personal computer-based approach has been developed for predicting pulsation levels and solving related performance problems in pipeline systems compressors, control valves, and meter stations. This approach is extremely valuable for pipelines and can perform evaluations consistent with API 618 Approaches 1, 2, and 3. The critical inputs include the magnitude of the pulse, the length and diameter of the fluid columns involved, and the speed of sound in the fluid. All of this information can be obtained from the same three-dimensional model used to lay out the plant, perform stress analysis, and generate isometrics. Thus, the additional effort required to perform pulsation analysis is minimal.

The software uses a nodal approach to model the piping network. Nodes defining the system geometry are assigned. The system is modeled by a series of transmission or source elements such as pipes, tees, valves, compressors, and orifices that connect the nodes. In addition to the piping network geometry, the program requires the physical properties of the fluid, acoustic boundary conditions, and the frequency range and resolution desired. The program generates reports, including fluid properties, pulsation pressures, pulsation volume, velocity, impedance, and shaking forces. The program performs a Fast Fourier Transform, which determines the components of the force at each frequency—called the harmonic loads—and saves them for export to stress analysis. The stress analysis program determines the resonant frequency of the piping network and is thus able to calculate the effects of the forces at each frequency level.

Conclusion

The personal computer-based plant design market has long been dominated by AutoCAD software, which does not offer any specific plant design features. More recently, third party vendors have moved into the void to provide add-on packages to AutoCAD that provide needed plant design capabilities such as stress analysis, pulsation analysis, bill of materials, automatic generation of isometrics, interference checking, etc. A battle royal seems to be shaping up in the plant design software market now as low-cost personal computer-based plant design packages add the major capabilities of mainframe-based systems and offer them at a far lower price. Today, it is possible to provide a process piping designer with a personal computer CAD workstation with sufficient computing power to develop a 3D model and document a complete design for a large process plant for a fraction of the cost of a comparable mainframe system. Ω



Screen image of results: peak-to-peak pressure pulsation versus frequency.