



MACHINERY ANALYSIS

Important Differences in Pulsation Software

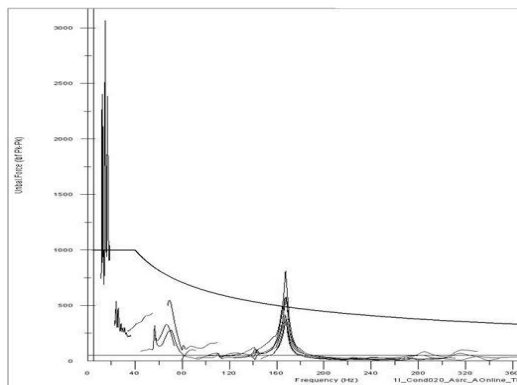
BETA was the first company to develop and use digital computer software for simulation of pressure pulsations and shaking forces in reciprocating compressor and piping systems in the 1970s. The software was based on linearized acoustic theory with the simulations carried out in the Frequency Domain, hence it became known as FD software.

The FD software was successfully used for many projects, however it was recognized by our field team that there were some important limitations to FD software particularly as the reciprocating compressor industry evolved to use higher speed compressors and new applications. The FD-based solver had limitations in accurately simulating:

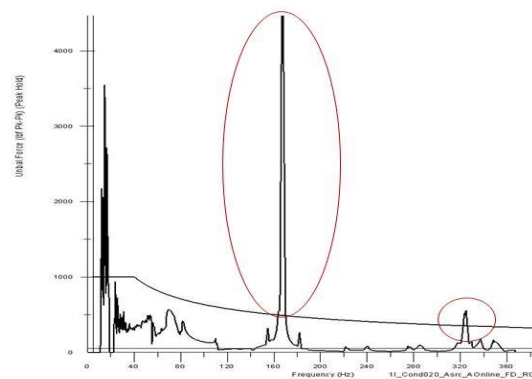
- High frequency pulsations (100 Hz to 200 Hz)
- Low compression ratio applications (less than 1.5)
- Infinite step unloaders
- Large cylinder bore compressors
- Total pressure drop in the system (mean and dynamic losses)

BETA's research team developed a more advanced simulation software tool called Time Domain Solver, or TD, in 1998 to overcome these deficiencies. The TD solver includes non-linear fluid flow elements while FD is based on linearized theory. Accounting for non-linear effects yields more accurate pulsation predictions, better pulsation control and lower vibrations in the piping system.

Below, the left chart shows the predicted acoustic shaking forces on a bottle using TD. Based on field results, the pulsations at 160 Hz are more accurately predicted with this solver compared to the FD solver (right). Note also the error reported at 320 Hz. This inaccurate result will impact performance, vibration and cost for the packager/owner.



Pulsation Forces - using BETA's **Time Domain (TD)** Simulation, a more accurate approach that includes non-linear effects.



Frequency Domain (FD) uses a linearized solver. Notice the inaccurate results at 160 and 320 Hz. This older approach is still used by some organizations.

BETA's TD solver has proven accurate after hundreds of comparisons with field data measured from different machines and applications. This solver is a key part of our MAPAK compressor and pump simulation software, and one of the reasons for BETA's global leadership.

NOTE: The older FD approach is found in commercially available pulsation simulation software and used by other vibration consultants. The accuracy limitations with FD still apply.