Vibration / Forced Vibration	Vibration of Piping due to Gas-liquid Two-phase Flow	Plant

Object Machine

Piping subjected to gas-liquid two-phase flow (26B to 16B). No fluid machinery such as pumps. (Fig.1(a))

Observed Phenomena

On piping that a fluid (gas-liquid two-phase flow) is transferred to a distillation tower by means of a potential energy from a tank installed on an elevated position, irregular large vibrations generated. The piping vibrations became large when the amount of injected gas increased. The piping diameters were 26B (outer diameter about 660mm) to 16B (outer diameter about 406mm). According to the FFT result, the magnitudes of piping vibrations were about 740μm p-p for 1.25Hz component, and about 240μm p-p for 8Hz component, while the maximum instantaneous magnitude of vibration waveforms reached about 3,300μm 0-p, with 1.25Hz component being dominant.

Cause Estimation

Potential energy is utilized for fluid transportation, thus there is no fluid machinery to generate an excitation force. Major components of pressure variations of fluid in the piping are 1.25Hz and 23Hz. 23Hz component of pressure variations is considered to be caused by shock waves due to air bubbles characteristic of gas-liquid two-phase flow that appear and disappear, while the cause of 1.25Hz component was unknown. On the other hand, major components of piping vibrations were 1.25Hz and 8Hz. 8Hz is identical with the natural frequency of piping, so that it is thought to have occurred by excitation of shock waves of the fluid in the piping, while the other major component of 1.25Hz was assumed to have occurred by forced excitation of pressure variations of the fluid in the piping.
After close check of the piping with a total length of about 36m, a reducer (tube diameter 26B -> 16B) was found on the horizontal portion of the piping on the bend outlet near the center. Judging from the fact that the upstream side (26B) of this reducer has a structure to accumulate gas easily, and also that piping vibrations are largest around here, it was assumed that 1.25Hz of slow pressure vibrations occurred in the internal fluid due to a vibration system consisting of liquid (mass) and accumulated gas (spring), or sloshing of the gas accumulated part. Also, the excitation force was estimated to be a random excitation due to two-phase flow.

Analysis and Data Processing

Fig.3 shows the measurement results of in-tube pressure variations and piping vibration waveforms before taking countermeasures. 1.25Hz piping vibrations in Y-direction at the reducer were most prominent.
Measurements and calculated results of the piping natural frequency are given in Fig.2. In order to estimate the fluid excitation force of 1.25Hz component, (1) the piping natural frequency (8Hz) and the mode were compared with the measurements, to determine the piping rigidity, (2) as 1.25Hz is apart from the natural frequency, comparison was made with the measured displacement with a static load applied to the piping, so as to estimate the fluid excitation force due to pressure variations. And based on this excitation force, support reinforcement was designed.

Countermeasures and Results

The fundamental countermeasure is to take for 1.25Hz pressure vibrations as the piping excitation force. Therefore, in order to remove gas accumulation, (1) all the piping sizes were standardized to 18B (outer diameter about 457mm) to eliminate pipe diameter changes, (2) horizontal portions of piping layout were inclined a little to avoid gas accumulation. Moreover, to ensure these countermeasures, the piping layout was modified that bend portion is reduced to one from two. And also the piping support was reinforced/added (Fig.1(b)). Consequently, 1.25Hz component was eliminated, though higher frequency components of the pressure vibrations still remain, and the momentary maximum piping vibrations 3,300μm 0-p went down to about 160μm 0-p (Fig.4). As these are irregular vibrations, there is no piping vibration standard to compare with, but the results have cleared the SwRI Standard and ISO 10816-8 Standard, and the problem was solved.

Lesson

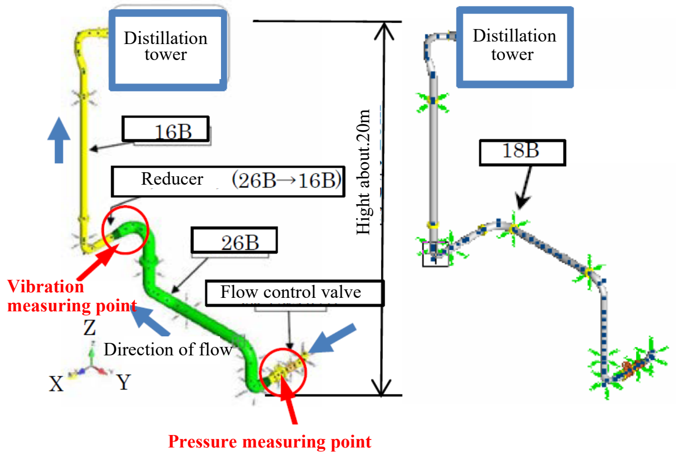
Terribleness of an excitation force of two-phase flow was realized. Reconfirmation was made of the importance of actually observing the equipment at site and considering the cause, and of raw vibration waveforms containing all the related information. *v_BASE* was also found useful.

References

v_BASE database, No.156 ("Abnormal vibration phenomena in the reciprocal pump suction piping system")

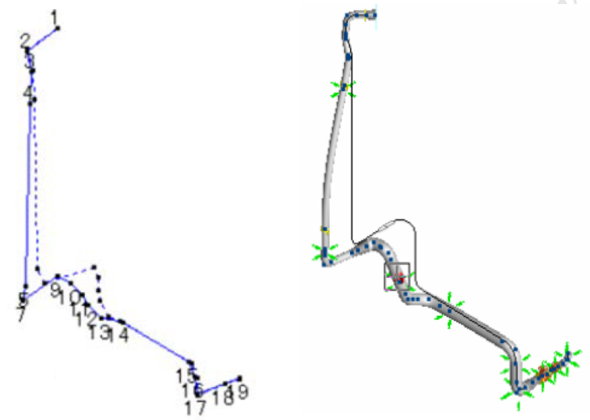
Keywords

Gas-liquid two-phase flow, piping, pressure variation, pressure pulsation, shock wave, reducer, distillation tower



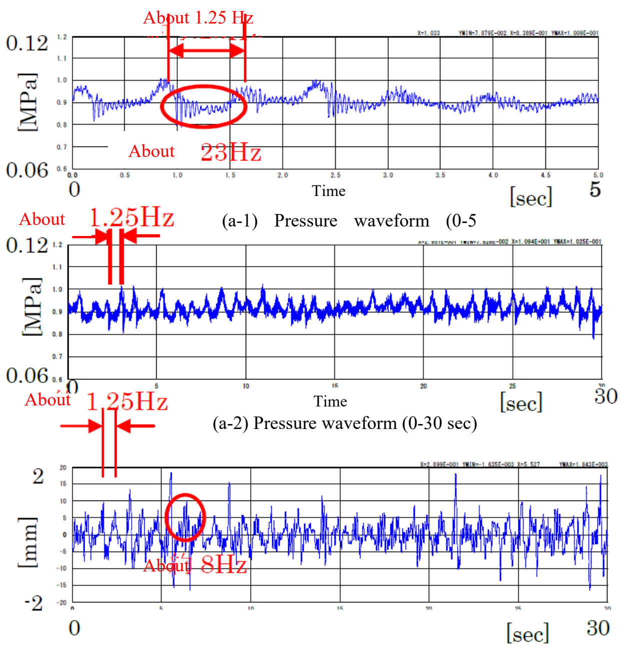
(a) Before taking countermeasures (b) After taking countermeasures

Fig.1 Piping layout (+ mark: supported position)

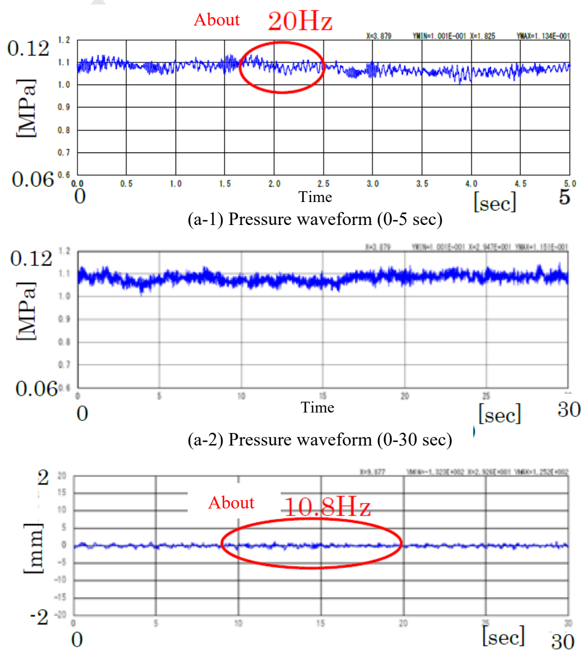


(a) Measurement: 8.1Hz (b) Calculation: 8.1Hz

Fig.2 Natural frequency and unique mode (before taking countermeasures)



(b) Piping vibration waveform (Y direction)



(b) Piping vibration waveform (Y direction)

Fig.3 Pressure vibration and piping vibration waveform (before countermeasures)

Fig.4 Pressure vibration and piping vibration waveform (after countermeasures)