Calculation of thermowell strength to ASME PTC 19.3 TW-2010

By K Grabenauer, WIKA

In December 1995, a serious accident occurred in a sodium coolant circuit of the Japanese nuclear power plant in Monju. It was caused by the break of a thermowell, even though the specifications of ASME PTC 19.3-1974 had been observed. As a result, the basics of the thermowell calculation to ASME PTC 19.3-1974 were revised and brought in line with the latest state-of-the-art.

Increasing safety awareness and serious accidents in the past have led to a revision of the thermowell calculation ASME PTC 19.3 TW-2010. Significant changes to the calculation basics have allowed a significantly improved simulation of the real operating conditions of the thermowell. The safety awareness of all users has led to a continuously increasing demand for thermowell strength calculations over the last few years. The calculation of ASME PTC 19.3-1974 based on the principles established by JW Murdock has acquired worldwide importance.

Contents of the thermowell calculation

The revised ASME PTC 19.3 TW-2010 is only used for bar stock thermowells in tapered, straight or stepped designs for welding or screwing in, and in flange or Van Stone design. The most important innovation compared to the previous thermowell calculations is the superimposed oscillation of the thermowell perpendicular to the flow direction of the medium in the pipeline (lift oscillation) and in the flow direction (drag oscillation) (see *Figure 1*).

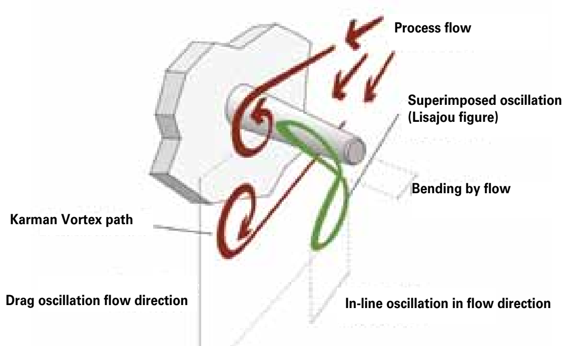

Figure 1: Representation of the oscillation directions.

The two oscillations are superimposed at an approximate amplitude ratio of 10:1 in which the ratio of the resonance frequencies of the two oscillations is approximately 1: 0.5 (see *Figure 2*).

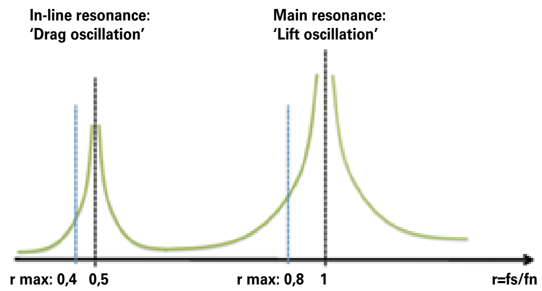

Figure 2: Representation of the in-line and main resonances.

The thermowell breakdown in the Monju power plant was due to an overload of the thermowell in the drag oscillation resonance in the process flow direction, which had not been considered by any of the previously established calculation processes.

Further innovations of the ASME PTC 19.3 TW-2010 include the shielding by the flange nozzle of the thermowell and the effect of the viscosity of the process medium on the calculation.

Evaluation of the calculation results

ASME PTC 19.3 TW-2010 is divided into dynamic and static calculation results. The evaluation of the dynamic results is made using the damping factor NSC (Scruton Number). For gaseous media, a characteristic value is NSC > 2,5; fluids typically have an NSC < 2,5. The Scruton Number NSC has a direct relationship to the permissible frequency ratio 'rmax' of the wake frequency fs to the natural frequency fn. Whereas for gaseous media the previous limit frequency of rmax = 0,8 is still valid, for liquid media the newly introduced limit frequency of rmax = 0,4 for in-line resonance now applies (see *Figure 3*).

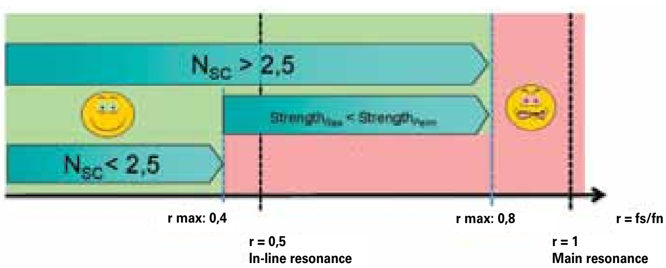

Figure 3: Evaluation of the calculation results.

ASME PTC 19.3 is a thermowell stress calculation, which serves as mathematical proof that the material chosen and the mechanical design will not fail given the effects of the operating conditions. The calculation provides guidance for establishing a comparison between the shedding frequency and the natural frequency of the thermowell.

Whether the frequency ratio - r < 0,8 - can also be used as an evaluation limit with liquid process media, is determined through a consideration of the permissible stresses in the thermowell material with respect to the actual stresses at resonance. In addition, an evaluation of the strength of the thermowell material with respect to the flexural fatigue stress in the area of the thermowell clamping is carried out. The static results of ASME PTC 19.3 TW-2010 are the maximum permissible process pressure, depending on the process temperature and the geometry of the thermowell, and the bending stress in the area of the thermowell root, caused by the incident flow on the thermowell, depending on the shielded length of the flange nozzle.

Comparison of the results of PTC 19.3-1974 with those of PTC TW2010

By way of example, 2,571 thermowell calculations based on real data of thermowell calculations carried out in the past were evaluated. The results from ASME PTC 19.3-1974 differ from those of the current ASME PTC 19.3 TW-2010 as follows:

	ASME PTC 19.3-1974	ASME PTC 19.3 TW-2010
Limit frequency r max = 0,4	n/a	76,7%
Limit frequency r max = 0,8	100%	23,3%
Calculation not passing the test	24,74 %	31,66%

The comparison of the results shows that the probability of a thermowell calculation not passing the test with respect to the dynamic consideration in the examples under investigation increases by 27,9 %.

Limits of the calculation

Analogously to Appendix 2 of DIN 43772, ASME PTC 19.3 TW-2010 also expressly allows operation of thermowells above one and a half times the main resonance. However, the required calculation certificates are not contained in this standard and must be obtained by means of further considerations such as Finite-Element calculations (see *Figure 4*).

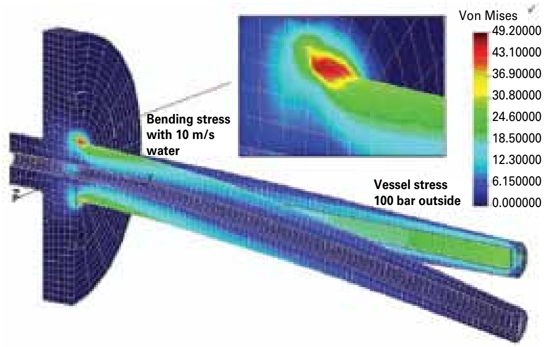

Figure 4: Finite-Element representation with lateral incident flow.

The dimensions of bar stock thermowells are described in *Table 1*. Thermowells having a rough surface in the incident flow area or, for example, a hard coating are excluded from the calculation.

	Tapered and straight designs		Stepped design	
Description	Minimum	Maximum	Minimum	Maximum
Insertion length L	63,5 mm	609,6 mm	127 mm	609,6 mm
Bore diameter d	3,175 mm	20,9 mm	6,1 mm	6,7 mm
Tip diameter B	9,2 mm	46,5 mm	...	...
Taper ratio B/A	0,58	1	...	...
Step ratio B/A for B = 12,7 mm	...	...	0,5	0,8
Step ratio B/A for B = 22,2 mm	...	...	0,583	0,875
Bore ratio d/B	0,16	0,71	...	...
Cross-sectional ratio L/B	2	...	2	...
Length ratio Ls/L	...	...	0	0,6
Min wall thickness (B-d)/2	3 mm	...	3 mm	...

Table 1: Design specifications of ASME PTC 19.3 TW-2010.

Conclusion

When a thermowell calculation does not pass the test, the non-linearity of the calculation formulae of ASME PTC 19.3 TW-2010 makes it difficult to find an easy solution by changing the thermowell dimensions. In general, a shorter insertion length L and larger thermowell dimensions give a better result, but both changes may have an adverse effect on the response time of the temperature measuring point.

While a support of the thermowell in the flange nozzle through a support collar is not explicitly mentioned in ASME PTC 19.3-1974, this widely used design solution is generally not recommended in ASME PTC 19.3 TW-2010. It is argued that the thermowell must be supported with an interference fit in the nozzle by means of the support collar, which cannot easily be achieved during mounting. If nevertheless the thermowell insertion length is to be shortened by means of a support collar in special cases, it may be necessary to take the damping effects of the liquid in the annular gap between support collar and nozzle wall and the modified natural frequency of the thermowell into consideration by means of suitable calculation methods that are outside the scope of ASME PTC 19.3 TW-2010.

Figure 5: Thermowell TW10 with extra strong root diameter.

Kai Grabenauer is the product manager (thermowells, electric temperature) at WIKA in Klingenberg, Germany.
Enquiries: Tel. 011 621 0000 or email sales@wika.co.za.

About the author