



The Characteristics and Application of Explosive Joint on the Tubes-to-Tubesheet in the Heat Exchangers of Power Plants

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ABSTRACT

In present, The power heat exchangers such as nuclear steam generator, high steam pressure heat exchangers etc., demand to the improvement of life time in heat exchanger through the reliability of joining on the tubes-to-tubesheet and demand to simplification of the manufacturing process, to decrease the manufacturing cost. The factors which affect the life time of heat exchangers are material properties, uniformity of tubes-tubesheet joining and bonding strength of tubes-tubesheet, which affect the manufacturing cost are process simplification and speed.

The purpose of this topic is to examine the quality characters of joining portion on the tubes-tubesheet with explosive expansion process and compare to manufacturing process and cost for explosive expansion, roll expansion and hydraulic expansion processes.

INTRODUCTION

The power heat exchangers such as steam generator, high pressure feedwater heater etc. have function to improve efficiency of machine equipment, are made up shell, tubes, tubesheet and nozzle. The factors which affected efficiency and lifetime of heat exchanger is the reliability of tubes-tubesheet bonding. Because of operate condition as temperature, pressure and fluid elements are not good condition to maintain material's life, the reliability of tubes-tubesheet bonding is important.

The important factors affect to tubes-tubesheet bonding are expansion method, bonding uniformity and operate conditions and the estimate factors of bonding conditions are bonding strength, bonding uniformity and the reliability of expansion transition region affected to operate conditions.

In general, the expansion methods used to heat exchanger tubes-tubesheet bonding are roll expanding method, explosive expanding method and hydraulic expanding method.

The roll expanding method is to expand the tubes as add to mechanical pressure, consist of cylindrical cage, tapered mandrel, electrical drive. The hydraulic expanding method is to expand the tubes as add pressure to water in the tubes, consist of mandrel, tube-lock draw-bar and added pressure equipment. The explosive expanding method is to expand as add the tubes explosive pressure by detonating explosive, consist of explosive, detonating fuse and sheath. Each company has been worked as decide to expansion methods for facilities characteristics, quality requirement and economics.

This topic will do comparison and analysis explosive expanding method with each expanding method for quality requirement, economics and will explain for explosive application part.

EXPANSION PROCESS

ROLL EXPANSION

The roll expanding method is by far the most common in the heat exchangers manufacture part, is to expanding the tubes as pressurizing mechanical pressure. Because of this method dominate shape and size of the roll, one step expansion for all expanding length is impossible, have to expansion repeatedly each expansion portion. So, expanding region cause to not uniform. Expansion process show in fig. 1.

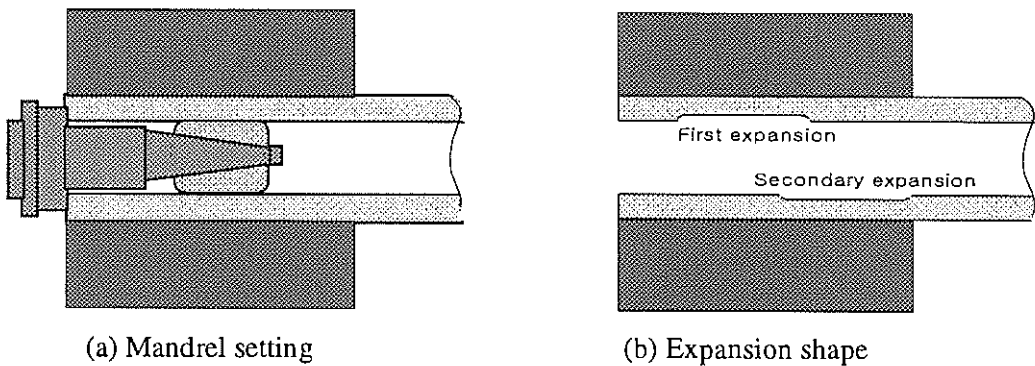


Fig. 1 Roll expanding method by mechanical pressure

HYDRAULIC EXPANSION

The hydraulic expansion is to the method expanding tubes as pressurizing water in the tubes inside and mandrel outside, consist of pressure control equipment, high pressure hose and mandrel. It has characters that expanding length is decided by length between o-ring on the mandrel and entire expansion length can expanding with one expansion, the o-ring has function prevent leakage from water in the tubes. It is much influence for size variation of the tubes. Expansion process showed fig. 2.

EXPLOSIVE EXPANSION

The explosive expansion is to the method expanding as transmit to tubes explosive force of detonating cord in the tubes inside. Because of explosive pressure act uniformly in the tubes, the tubes have uniform expansion region for entire expanding length. The detonating cord consist of PETN element besieging weave, explosive pressure is transmitted the tubes through the sheath and explosive velocity is 7000 ~ 8000m/sec.

The explosive expansion dominate by explosive quantity, material specification. The explosive expanding method showed on fig. 3.

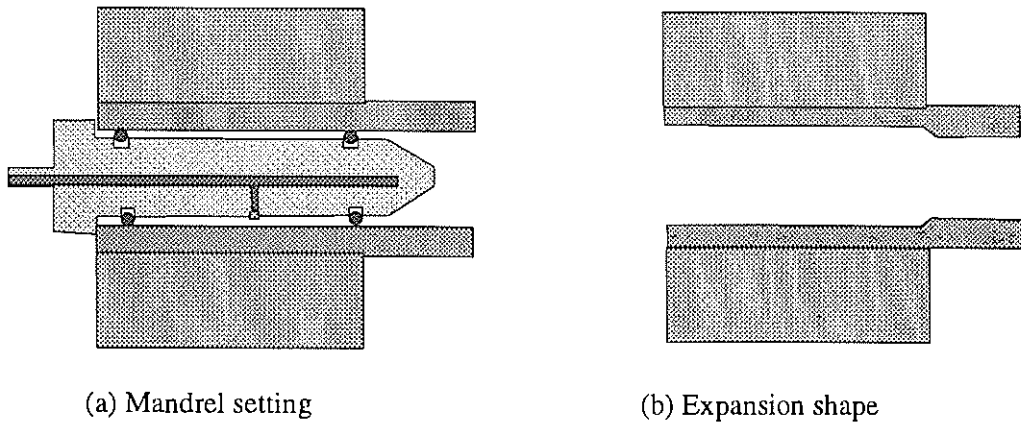


Fig. 2 Roll expanding method by mechanical pressure

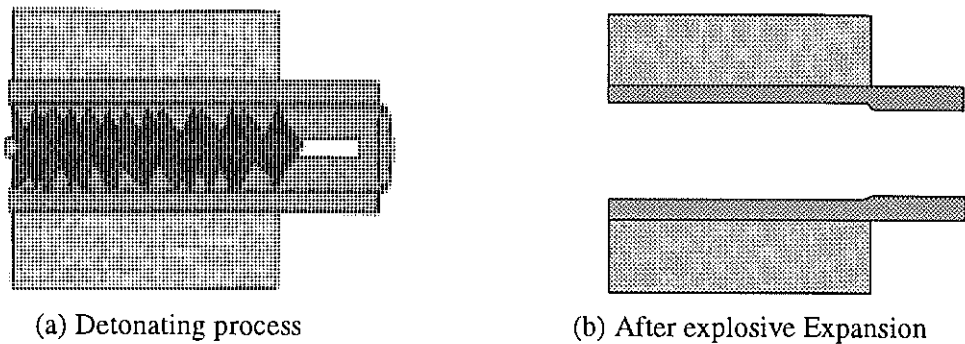


Fig. 3 Explosive expanding method by detonating explosive

EXPANSION QUALITY COMPARISON

The valuation method of tubes-tubesheet expansion quality have expansion ratio, pull-out loading, hydraulic leakage test, crevice depth and residual stress of transition region.

The expansion ratio is to estimate thickness reduction of the tubes, the pull-out loading is to imply the bonding strength of tubes-tubesheet bonding region, the hydraulic leakage test is to show the uniformity of bonding region, the crevice depth is to imply expansion extent of entire length on the tubes-tubesheet bonding, the residual stress of the transition region is to imply the reliability of the tubes for expansion.

At first, the estimate of expansion ratio measure the tubes thickness of before and after expansion, decide for below Eq.(1).

$$\text{Expansion ratio(\%)} = \frac{(\text{Hole inner diameter} - \text{tube inner diameter after expansion})}{(\text{tube outside diameter} - \text{tube inner diameter})} \quad \text{-- Eq.(1)}$$

In case of the estimate results of expansion ratio investigate, roll expansion has broad expansion ratio, hydraulic expansion can not decide expansion ratio because of the tubes length decrease without tubes thickness reduction, explosive expansion has uniform expansion ratio relatively. The test results are showed table 1.

Table 1. The expansion ratio scope to expansion methods

Class	Roll Expansion	Hydraulic Expansion	Explosive Expansion
Requirements	3 – 8%	Not	2 – 6%
Test results	3 – 8%	0 – 4%	2 – 4%

The pull-out test is to measure the load required pull-out the tubes in the tubesheet with the tensile test machine. The test results of pull-out loading, roll expansion and explosive expansion has similar results and more than hydraulic expansion. The test results are showed on table 2.

Table 2 The pull-out loading to expansion methods

Class	Roll Expansion	Hydraulic Expansion	Explosive Expansion
Requirements	Not	Not	Not
Test results	1700 – 2500 kg	1300 – 1900 kg	1800 – 2700 kg

The hydraulic leakage test is to investigate leak of water in the crevice between tubes and tubesheet, explosive expansion is the excellent result, roll expansion and hydraulic expansion has less leakage pressure than explosive expansion and test results is show table 3.

Table 3 The hydraulic leakage test to expansion methods

Class	Roll expansion	Hydraulic expansion	Explosive expansion
Requirements	Not	Not	Not
Test results	Leak more than 400 kg/cm ²	Leak more than 300 kg/cm ²	Leak more than 400 kg/cm ²

The crevice depth in the transition region is the length from secondary part of tubesheet to expanding end point as show fig.4. In case of explosive expansion, crevice depth has almost zero, roll expansion has about 3mm length, hydraulic expansion about 2~7 mm. This result imply that explosive expansion imply to high in the reliability of expansion region. The crevice depth measurement results are showed the table 4.

The residual stress of transition region measure stress value in the strain gage attached on the tubes outside of transition region. The test results is that explosive and hydraulic expansion have a similar residual stress, generate cracking more than about 40 hour, roll expansion generate cracking less than 10 hour. These results imply that residual stress in the transition region low less explosive and hydraulic expansion than roll expansion. The residual

stress to expansion methods show fig.5

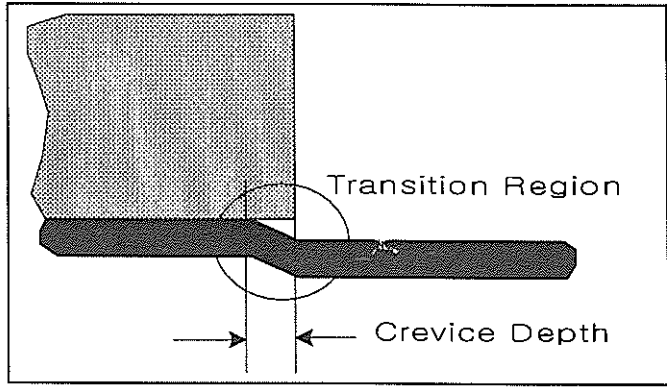


Fig.4 The crevice depth shape

Table 4 A crevice depth to expansion methods

Class	Roll Expansion	Hydraulic Expansion	Explosive Expansion
Requirements	-	3.2 ~ 6.4 mm	-
Test results	Less than 4mm	1.0 ~ 6.4 mm	Less than 2mm

The residual stress of transition region measure stress value in the strain gage attached on the tubes outside of transition region. The test results is that explosive and hydraulic expansion have a similar residual stress, generate cracking more than about 40 hour, roll expansion generate cracking less than 10 hour. These results imply that residual stress in the transition region low less explosive and hydraulic expansion than roll expansion. The residual stress to expansion methods show fig.5

The economical estimate of each expansion processes classify largely working day and cost. The working day took that the explosive expanding process less spent than roll and hydraulic expanding process. In case of manufacturing cost, explosive expanding process a little lower than roll, hydraulic expanding process. The comparison table for economical estimate is showed on table 5.

Table 5 The economical comparison to expansion methods

Class	Roll Expansion	Hydraulic Expansion	Explosive Expansion
Working day	200 MH	180 MH	40 MH
Manufacture cost	1.9 million dollar	2.3 million dollar	1.5 million dollar

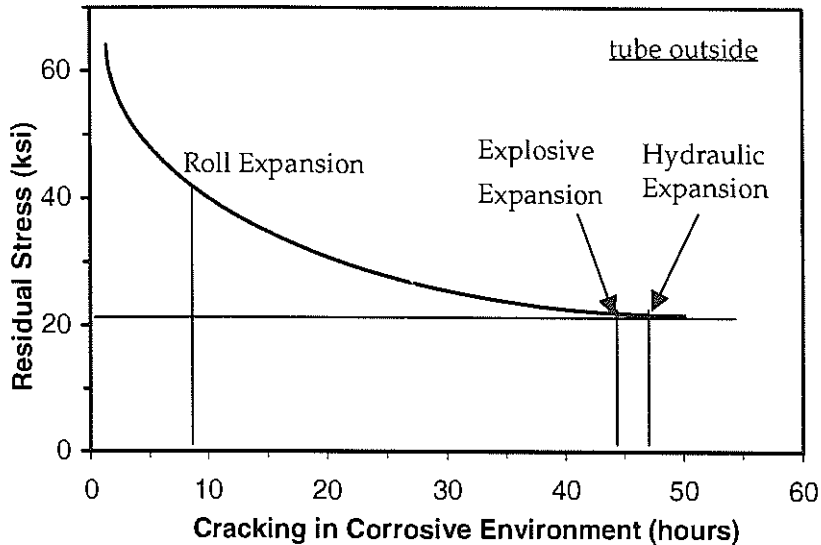


Fig. 5 The residual stress distribution of tubes outside in the corrosive environment.

CONCLUSION

The important aspects of heat exchanger manufacture are that manufacture cost has to be low, quality has to be high. So far we investigate for expansion quality and economic of each expanding process, roll expansion-explosive expansion-hydraulic expansion.

For expansion quality, explosive expanding process is equal or a little superior to other expanding processes, for economic, explosive expanding process is superior to others. In particular, expanding working day is most excellent.

The explosive application parts consist of many parts, explosive expansion, explosive welding, explosive cutting, explosive deslagging, explosive metal plastics. In now, explosive expanding method much use in the heat exchanger manufacture, explosive welding method use to welding of different metals, explosive cutting use the demolition part, deslagging technique use to remove the slag on the boiler pipe, furnace. The explosive application technique is being develop and practice, so have contributed much industrial parts.

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