Technical Article

Fully HF Welded Helical Finned Tubes in Combined Cycle Power Plant

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Abstract

Environment friendly industrial fin tube boiler used a heat recovery system generator (HRSG) is the core facility of a combined cycle power plant (CCPP) that recycles thermal energy from a gas turbine and creates high temperature and high pressure gas. Serrated finned tubes and solid finned tubes are two types of helically finned tubes made by high-frequency resistance welded (HFRW). Solid and serrated fins are widely consumed solutions for improving heat transfer in fired heaters. The important fact that designers or engineers often overlook while selecting the fins is that serrated fins can provide larger surface area and significantly higher fin efficiency compared with solid fins. Carbon steel and alloy steel tube according to ASTM A192 and ASTM A213. As well as carbon steel and alloy steel coil strips according to ASTM A1008 and ASTM A240-TP409. International standard for tests of high frequency resistance welded fins according ASME and ASTM used for metallography fusion weld, tensile strength and hardness. This paper presents the microstructures welding of helically fin tube boiler, with particular emphasis on HFRW.

Keywords: Helically Finned Tube, High-Frequency, Electric Resistance Welded, Combined Cycle Power Plant.

1. Introduction

Combined cycle and cogeneration power plants have been popular for a number of years due to their high efficiency, low emissions, and a number of other reasons. Due to its ability to start up quickly and respond to demand changes rapidly, the combined cycle power plant's popularity has increased even more in recent years. [1] In the fin tube welding process, rolled steel strip is continuously welded in spiral form on the outside diameter of a tube. The weld produced in this process is a true forge, blacksmith weld.

This type of weld is comprised of a fusion between two portions of parent metal without the introduction of a filler material. The weld is simply produced by heating the interfaces to be joined to a plastic state and applying pressure. Finned tubes used a HRSG is the core facility of a combined cycle thermal power plant that recycles thermal energy from a gas turbine and creates high temperature and high pressure gas. Finned tubes are the heart of any gas–gas or gas–liquid type of heat exchanger. Finned tube banks are compact units of robust and corrosion-resistant construction the type of finned tube is chosen (ie, the fin type and combination of materials) depending on the specific requirements of each process equipment unit. Commonly, tubes currently have circular cross-section fins.

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Convective heating surfaces with circular, square, or helical fins represent tube bundles or tube banks with staggered or in-line arrangement of tubes in cross-flow. [2]

Increase the rate of heat exchange in the heat recovery steam generator (HRSG) tubes, the surface area on the outside of the tubes is extended by finning. There are many variations of fin design available.

A commonly employed finning process is where the fin is fabricated from strip of metal.

The longer leg of the strip is slit and the strip is wound and welded in a spiral around the tube. This result in the slits of the protruding long leg spreading out is wrapped around the parent tube.

The HRSG recovers the waste heat available in the combustion turbine exhaust gas. The recovered heat is used to generate steam at high pressure and high temperature, and the steam is then used to generate power in the steam turbine/generator.

In professional industries have taken an interest in being more environmentally friendly, it is important that all adopt a unified standard regarding environmental preservation.

There are several technologies of making fin tubes (Fig. 1). [3]

The HRSG is basically a heat exchanger composed of a series of preheaters (economizers), evaporator, reheaters, and super heaters. The HRSG also has supplemental firing in the duct that raises gas temperature and mass flow.

This section is intended to provide turbine operators with a basic understanding of HRSG design and operation.

The HRSG absorbs heat energy from the exhaust gas stream of the combustion turbine. The absorbed heat energy is converted to thermal energy as high temperature and pressure steam.
The high-pressure steam is then used in a steam turbine generator set to produce rotational mechanical energy.
The shaft of the steam turbine in connected to an electrical generator that then produces electrical power.
Most large HRSGs can be classified as a double-wide, triple-pressure level with reheat, supplementary fired unit of natural circulation design, installed behind a natural gas fired combustion turbine.
The steam generated by the HRSG is supplied to the steam turbine that drives the electrical generator system.
A heat recovery steam generator (HRSG) is the core facility of a combined cycle thermal power plant that recycles thermal energy from a gas turbine and creates high temperature and high pressure gas.
A combined cycle power plant recycles the hot exhaust gas from the gas turbine into HRSG to use it as the heat source to generate high temperature and high pressure steam to operate a steam turbine and generator to produce secondary electricity.
A combined cycle power plant consists of a single cycle power generator that uses a gas turbine and HRSG to maximize plant output and efficiency. [4]

2. Experimental Procedure

2. 1. Combined Cycle Power Plant (CCPP)

HRSG is a major component of a Combined Cycle Power Plant (CCPP).
A combined cycle power plant recycles the hot exhaust gas from the gas turbine into HRSG to use it as the heat source to generate high temperature and high pressure steam to operate a steam turbine and generator to produce secondary electricity.
A combined cycle power plant consists of a single cycle power generator that uses a gas turbine and HRSG to maximize plant output and efficiency. [5]
The function of the combined cycle heat recovery steam generator (HRSG) system is to provide a method to extract sensible heat from the combustion turbine (CT) exhaust gas stream. The heat is converted into usable steam by the heat transfer surfaces within the HRSG.
The usable steam is generated in three separate and different pressure levels for use in a steam turbine (ST) generator set and for power augmentation of the CT. [6].The pressure levels and their associated components are:

- High pressure (HP)
- Intermediate pressure (IP)
- Low pressure (LP)
- Reheat (RH)
- Feed water preheater (FWPH)

All generated steam from the HP, RH, and LP systems is supplied to the steam turbine, except for some LP steam used for desertion, The IP steam is mixed with the cold RH return loop prior to being admitted to the steam turbine. Typical heat recovery steam generator circuits have four major components.

- Super heaters
- Evaporators
- Economizers
- Drum

Since we are operating a triple-pressure system of HP, IP, and LP, we have these components for each associated pressure.
These components (with the exception of the drum) are arranged in series in the gas flow path within the HRSG. Essentially, this means that the heat transfer boiler circuits are not in parallel with one another with respect to CT exhaust gas flow.
The gas, after having been used to heat the water/steam in the HRSG is released to the environment through a stack. [7]
(Fig. 2).

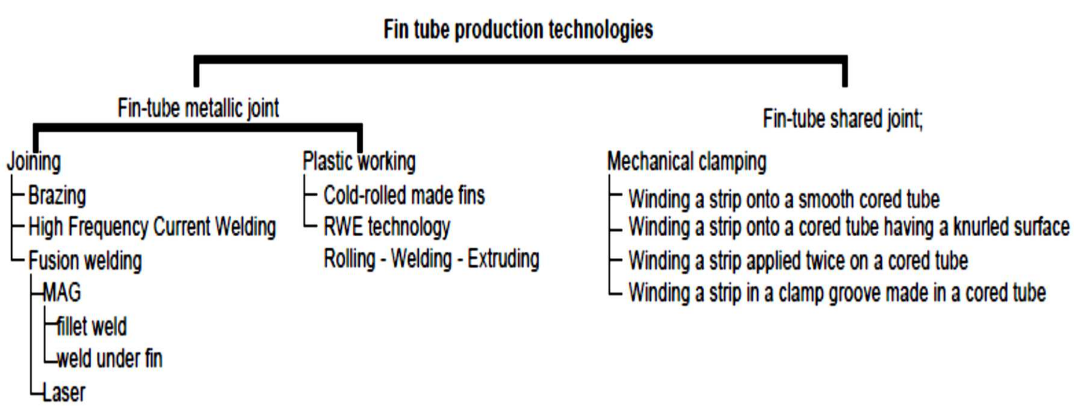

Fig. 1. Division of fin tube production technologies [3].

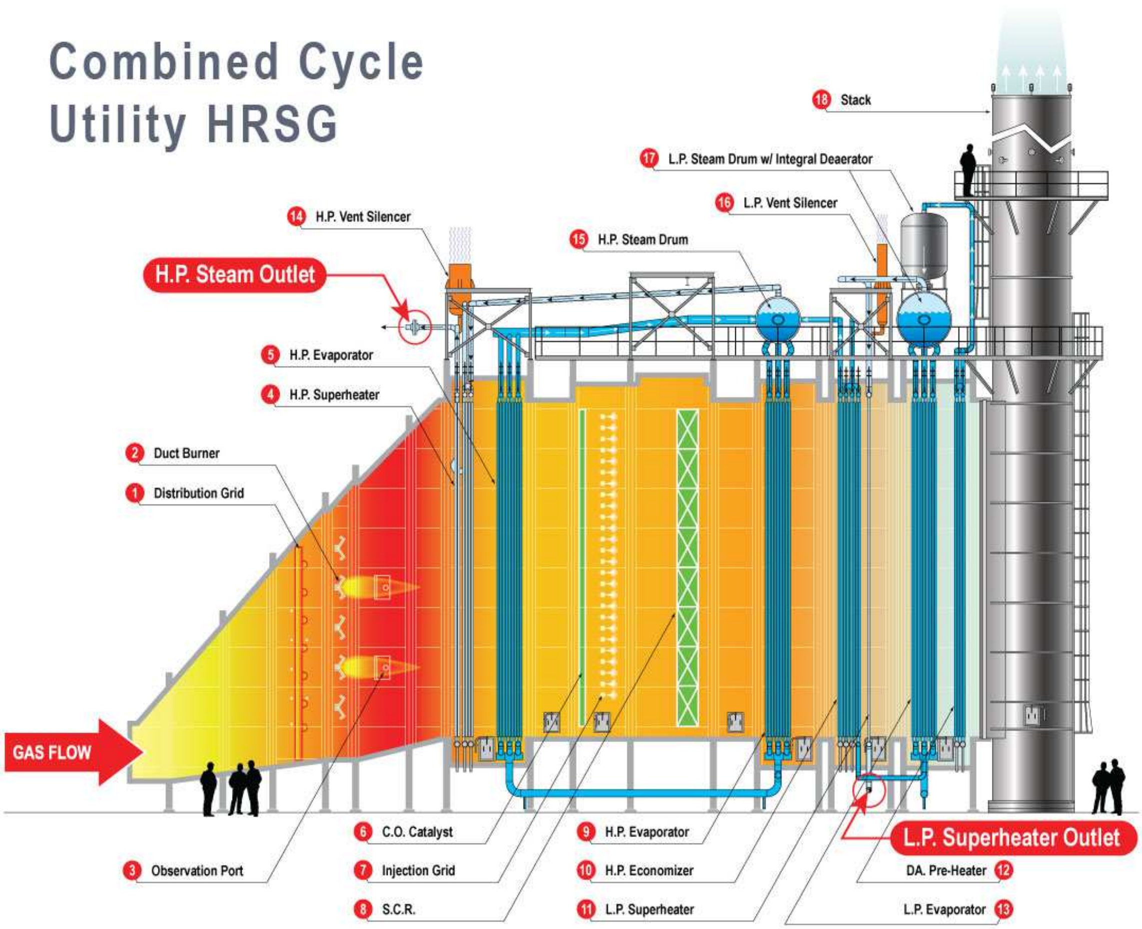

Fig. 2. Combined Cycle Utility HRSG Components [6].

2. 2. Helically Finned Tubes Welding

Finned tubes with continuous rib or serrated, depending on the operating parameters of the working medium and the flue gas can be used as: heaters, economizers or super heaters. The fins greatly enhance the heat transfer surfaces, allowing the full optimization of heating surfaces of the boiler, which is achieved by reducing the dimensions of the boiler, and thus reducing its weight.

The efficiency of the heat exchanger tube depends on the thermal conductivity between the pipe wall and the fluid and the surface area of the tube. [8]

The figure below shows Automated line for the welding of fin tubes by high-frequency welding machine.

This system is for continuous fin feeding so as to weld the tube without machine stop.

This device is for loading and supplying fin to main machine continuously by 2 sets of uncoiler.

Fig. 1. Automated line for the welding of fin tubes by high-frequency welding machine.

Finned tubes are used in applications involving the transfer of heat from a hot fluid to a colder fluid through a tube wall.

The rate at which such heat transfer can occur depends on three factors: (a) the temperature difference between the two fluids; (b) the heat transfer coefficient between each of the fluids and the tube wall; and (c) the surface area to which each fluid is exposed. In the case of a bare (un-finned) tubes, where the outside surface area is not significantly greater than the inside surface area, the fluid with the lowest heat transfer coefficient will dictate the overall heat transfer rate.

When the heat transfer coefficient of the fluid inside the tube is several times larger than that of fluid outside the tube (for example steam inside and oil outside), the overall heat transfer rate can be greatly improved by increasing the outside surface of the tube. In mathematical terms, the product of heat transfer coefficient for the outside fluid multiplied by the outside surface area is made to more closely match the product of the inside fluid heat transfer coefficient multiplied by the inside surface area. So the whole concept of finned tubes is to increase the outside surface area of the tube. By increasing the outside surface area of the tube, the overall heat transfer rate is increased, thereby reducing the total number of tubes required for a given application. This reduces the overall equipment size and the cost of the project. In many cases, one finned tube replaces six or more bare tubes at less than 1/3 the cost and ¼ the volume. [9] Manufacture heat exchangers with finned tubes, due to the increasing competition requires the implementation of new technological solutions in the production area. The technology of finned tubes is high frequency welding.

In modern boilers are increasingly being used finned tubes made in the technology of HF. The use of concentrated high frequency power allows for a significant increase in connection speeds, ensuring the quality of the connection required by the technical regulations and standards. Welding contact currents frequency (HF) is a variation of resistance welding which uses high-frequency properties of the welded contact surface heating elements to melt temperature, and combinations thereof by pressure. In this method, it is important to fine-tune current switch position. The typical non-compliance includes local burnout and flooding the surface of objects and weld splatter of molten metal.

Welding Part is the system for welding fin with tube and consists of cooling nozzle for fin tube, high frequency output transformer, up and down table for adjusting the position of transformer, fin guide roller and tube break roller with strong and stable systems. Guide roller which is easy to connect and change fin with tube is air cylinder type for more efficiency. [10]

Serrated finned tubes and solid finned tubes are two types of spiral wrapped finned tubes used HF technology as illustrated in (Fig. 4.).

Fig. 3. The welding process currents of high frequency.

The figure below shows the difference between serrated and solid fins.

Fig. 4. Tube with serrated fins (to the left) and tube with solid fins (to the right).

Solid and serrated fins are widely used solutions for improving heat transfer in fired heaters. The important fact that designers or engineers often overlook while selecting the fins is that serrated fins can provide larger surface area and significantly higher fin efficiency compared with solid fins. Fin Parameters:

• Fin thicknesses vary from 0.8 to 2.5 mm.

• Maximum pitching can be as high as 310 fins/m with 0.8 mm fins.

2.3. Materials and Methods

Metallography Sample of fusion weld tests, tensile strength and hardness tests shall be prepared as illustrated in (Fig. 5.).

Fig. 5. Sample preparation of Finned Tubes Welding (metallography, tensile strength and hardness tests).

Welding Chemical requirements for alloy steel coil strips given in Table. 1. (According ASTM A240-TP409) [11].

Table. 1. Chemical requirements for alloy steel coil strip according to ASTM A240 (wt.%) [11].

Grade	C	Mn	P	S
A240-TP409	0.080	1.000	0.045	0.045
	Si	Cr	Ni	$Ti_{(max)}$
	1.000	10.500-11.750	0.500	0.500

As an example, ASTM A213 has the Seamless Ferritic and Austenitic Alloy Steel for Boiler, super heater, and Heat Exchanger Tubes. The standard actually covers 14 different grades of ferritic steels and 14 different grades of austenitic steels. The 2.25 Cr-1Mo steel is grade T22. Because the grade is used in tubing for boilers and heat exchangers, it is also part of the specification system of ASME. The ASME code is SA213 type T22. The ASTM and ASME grade (type) T22 has the following composition in Table. 2.

Table. 2. Chemical requirements for alloy steel tube according to ASTM A213 (wt. %) [12].

Grade	C	Mn	P	S
A213-T22	0.050-0.150	0.300-0.600	0.025	0.025
	Si	Cr	Mo	Ni
	0.500-1.000	1.900-2.600	0.870-1.130	0.025

3. Results and Discussion

The microstructure of a typical ASTM A213 grade T22 steel (ASME SA213 type T22) is shown in the figure Fig. 6. .

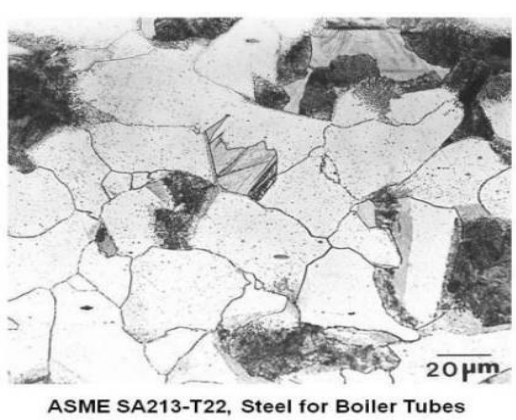

Fig. 6. Microstructure of a typical ASTM A213 grade T22 steel (ASME SA213 type T22) steel for boiler tubes.

The microstructure consists of ferrite (light etching constituent) and a small amount of pearlite (dark etching constituent).
Light tan areas are martensite. It is interesting to note that if the same steel was used for a forging or plate, it may have a different microstructure because of the different specified heat treatment.
Even for tubes (ASTM A213), it can be furnished in the full-annealed, isothermal annealed, or normalized and tempered condition. Each condition would have a different microstructure.
Standard specification for fin tube technologies, Inc. is ASTM A498 and ASME Standards used for Metallography fusion weld. As well as the optic microscopic Fig.7. illustrated that coil strips ASTM A450 grade 409 which this steel had ferrite type microstructure.

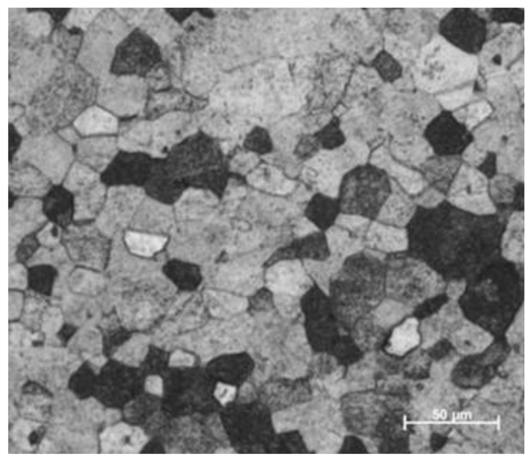

Fig. 7. The optic microscopic coil strips(ASTM A450 grade 409).

Tube material is Carbon Steel SA192/SA178A with the tubing outside diameter (O.D) sizes specification is usually 38.1mm (1.5 inch) and minimum wall thicknesses (M.W.T) is 2.4mm to 5.0mm. After mock up test sample are prepare Metallography with
$HCl + HNO_3 + CH_3COOH$.
Microstructure and tensile strength should be survey fusion weld and accepted accordance of standards specification.
International standard for tests of high frequency resistance welded fins according ASME and ASTM used for metallography fusion weld, tensile strength, hardness.
Tube material specifications are Carbon Steel (C.S) such as SA192/SA178A , alloy steel such as SA213-T22 and Stainless Steel (St-St)such as SA213TP304 with outside diameter (O.D) sizes is usually 38.1mm or 50.8mm and minimum wall thicknesses (M.W.T) is 2.4mm to 5.0mm.
After mock up test sample are prepared for metallography (C.S) with (Nital 2%) HCl+HNO3+CH3COOH and alloy steel HNO3+HCL+H2O according to ASTM E340-18.

Microstructure should be survey fusion weld and accepted accordance of standards specification. (Fig. 8). [13]

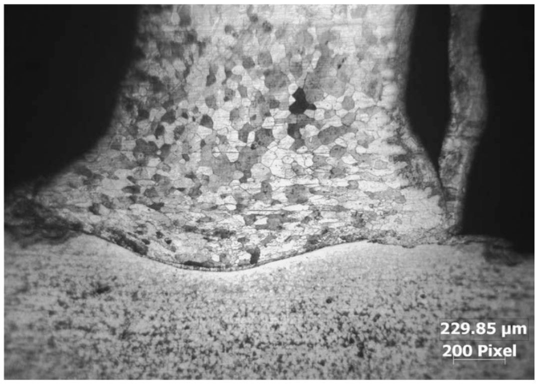

Fig. 8. Microstructure of the tube-fin joint and fusion weld tests of HFRW tube to fins alloy steel to alloy steel (SA213T22 to A240-TP409) according to ASTM E340-18 [7].

Tensile tests shall be performed on finned samples. A section of one wrap of fin with a maximum width of 50% of bare tube diameter shall be placed in a tensile testing machine with suitable grips in accordance with ASTM A370-18 (ASME Boiler and Pressure Vessel Code, Section VIII, Division I, Part UG-8). The fin shall be pulled radially from the tube and the maximum force, F, recorded. The tensile strength of the weld, S, is calculated as follows: [14]

$S=F / (T\times W)$

Where:

S is the tensile strength, ksi (MPa)

F is the maximum tensile force, lbs. (N)

T is the measured fin thickness, inches (mm)

W is the width of the fin section inches (mm). The tensile strength calculated shall be no less than:

Carbon steel fin material: 40 ksi (275 MPa)

409 stainless fin material: 45 ksi (310 MPa)

304 stainless fin material: 50 ksi (344 MPa)

Alloy steel and Stainless Steel are needs Micro hardness HV1 (Vickers diamond 136° indenter) according to ASTM E384-18. Hardness shall not be over max. 400Hv, hardness at heat affected zone (HAZ) shall be under 150Hv for fin (tube) [15].

5. Conclusions

1. A heat recovery steam generator (HRSG) is the core facility of a combined cycle power plant (CCPP) that recycles thermal energy from a gas turbine and creates high temperature and high pressure gas.
2. The use of welded finned tubes in the power equipment leads to savings in energy and cost savings in the operation of industrial boilers, heat recovery condensing and its deliberate use and minimizes energy losses by lowering the temperature of the flue gases.
3. High frequency welding process methods, despite its advantages, which include first of all a combination of continuous tube-fin, which significantly increases the thermal efficiency, characterized by high productivity and the possibility of the occurrence of low imperfections such as: incomplete fusion, no weld penetration, spatters, etc.
4. Finned tubes are used in applications involving the transfer of heat from a hot fluid to a colder fluid through a tube wall and the whole concept of finned tubes is increase the outside surface area of the tube.
5. In many cases, one finned tube replaces six or more bare tubes at less than 1/3 the cost and 1/4 the volume so that high frequency welding finned tubes, which ensures a level of quality welded joints increase in production efficiency that is unified standard and environmentally friendly.

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