Advanced Materials and Application II

2nd International Symposium on Advanced Materials and Application (ISAMA 2019)

Edited by
Mosbeh Kaloop, Mohamed Ismail Bassyouni,
Wonjun Park and Chengji Xian

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Advanced Materials and Application II

2[nd] International Symposium on Advanced Materials and Application (ISAMA 2019)

Selected, peer reviewed papers from the 2019 International Symposium on Advanced Materials and Application (ISAMA 2019), January 18-20, 2019, Seoul, South Korea

Edited by

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Preface

The 2019 International Symposium on Advanced Materials and Application (ISAMA 2019) was taken place in Seoul, South Korea on January 18-20, 2019.

The objective of ISAMA 2019 is to bring together academics, scientists, engineers, postgraduates and other professionals in the area of material science and engineering technology from all over the world. It provides a high-standard international forum to introduce, to exchange and to discuss recent advances novel and practical techniques or application in the field of material engineering and application.

We would like to thank the program chairs, organization staff, and the members of the program committee for their work. Thanks also go to all those who have contributed to the success of ISAMA 2019. We hope that all participants and other interested readers benefit scientifically from the proceedings and also find it stimulating in the Process.

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- Mechanics of Materials

Materials Science
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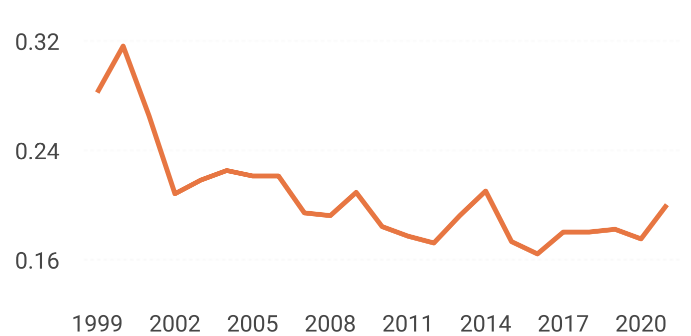

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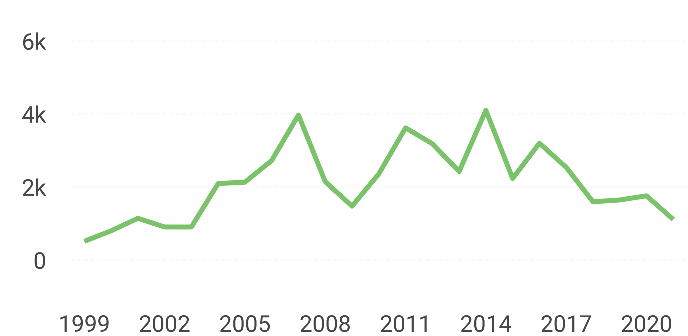

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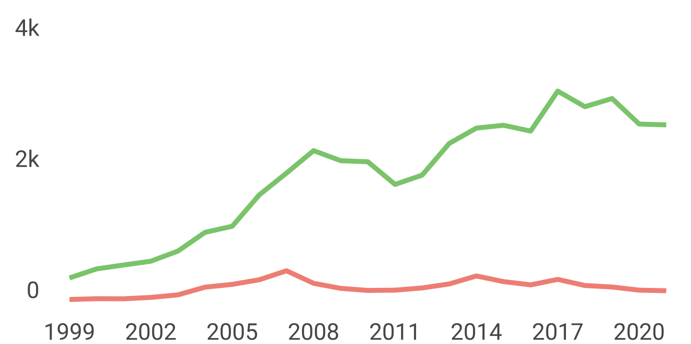

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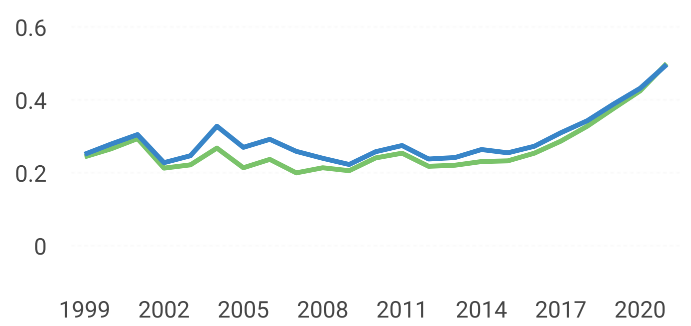

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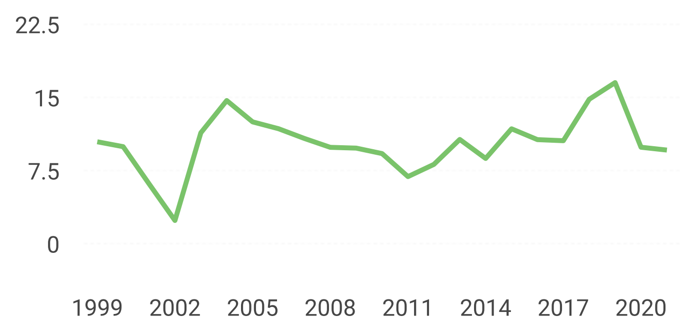

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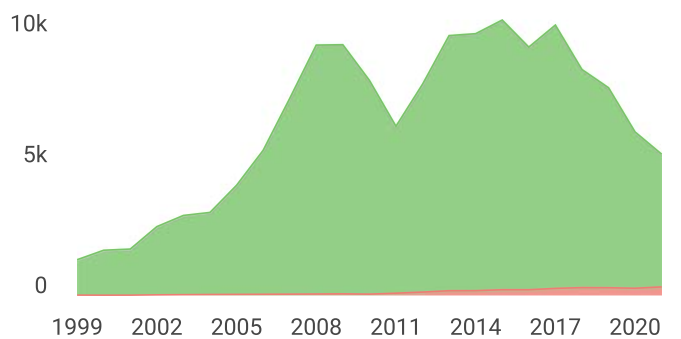

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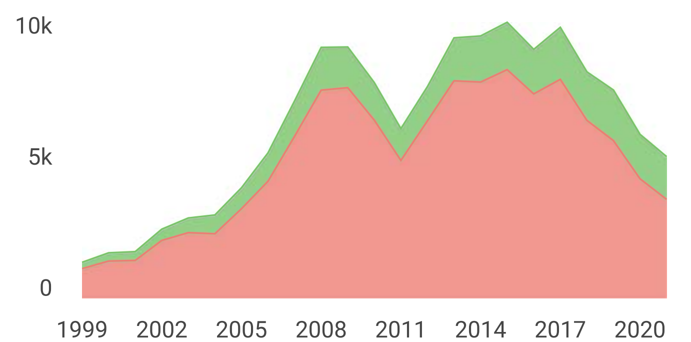

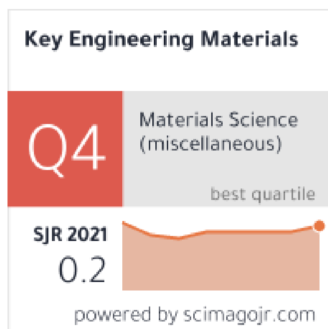

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Rita

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Dr.D.Nagasamy Venkatesh

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Abstract:

Bearing cooler coils connector of 175 MW hydropower plant experienced premature leaks after one year operation and caused an unscheduled shutdown. To avoid the same failure in the future, the leaking bearing cooler coils connector was investigated. Nondestructive tests, such as chemical composition analysis, hardness test, metallographic test, characterization of the filler brazing by scanning electron microscopy – energy dispersive X-ray spectroscopy were conducted. The results confirmed that the bearing cooler coils connector consisted of two types of material namely the flange material which was made of stainless steel 304 and the pipe material which was a Cu/Ni 90/10 and were joined together using brazing process. It was a clearly evidence that leaks occurred in the brazing area and the leakage was due to improper brazing process. It was shown by the excessive gap and a lot of porosity.

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Failure on Bearing Cooler Coils Connector of Hydroelectric Power Plant

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Keywords: Leakage, Cooler coils connector, Brazing, Joint clearance

Abstract. Bearing cooler coils connector of 175 MW hydropower plant experienced premature leaks after one year operation and caused an unscheduled shutdown. To avoid the same failure in the future, the leaking bearing cooler coils connector was investigated. Nondestructive tests, such as chemical composition analysis, hardness test, metallographic test, characterization of the filler brazing by scanning electron microscopy – energy dispersive X-ray spectroscopy were conducted. The results confirmed that the bearing cooler coils connector consisted of two types of material namely the flange material which was made of stainless steel 304 and the pipe material which was a Cu/Ni 90/10 and were joined together using brazing process. It was a clearly evidence that leaks occurred in the brazing area and the leakage was due to improper brazing process. It was shown by the excessive gap and a lot of porosity.

Introduction

Stable bearing oil temperature plays an important role for the hydropower plants operations [1]. Oil temperature that exceeds the limit causes friction, wear and corrosion and results in increased friction losses of the machine [2]. Bearing oil cooler is a coil heat exchanger, whose heat is transferred from hot oil to water as cooling fluid. The bearing temperature tends to increase during the operation due to the friction of the various moving parts. The bearing cooler needs a periodic physical inspection to ensure the normal operation. General tendencies of failures in bearing cooling coils are leaks, mineral buildup corrosion and weakening of joints due to years of vibration [3]. The leakage of bearing cooler coils can affect actuation of TRIP in the power plant unit as well as disturbance in the normal functioning system (failure in the lubrication and cooling) [4]. The other thing needs to be considered in bearing cooler system is the material. It is very important to choose the materials of bearing coolers to avoid premature failure. Stainless steel is chosen as material of bearing cooler due to the low quality of cooling water that usually comes from the river which contains high corrosive elements and sediments [5]. In this investigation, the 175 MW hydropower plant had been operated for more than 20 years and its continuous operations was stopped because of the failures bearing cooling connector leakage. This case was indicated by the rising of bearing temperatures. Hence a deep failure investigation was carried out to find out the cause of the leakage in order to prevent the same failure may occur in the future.

Experimental Method

In this study, the leaking coil connector of bearing cooler in 175 MW hydropower plant with a vertical Francis Turbine was investigated. The leaking coil connector of bearing cooler is shown in Fig. 1.

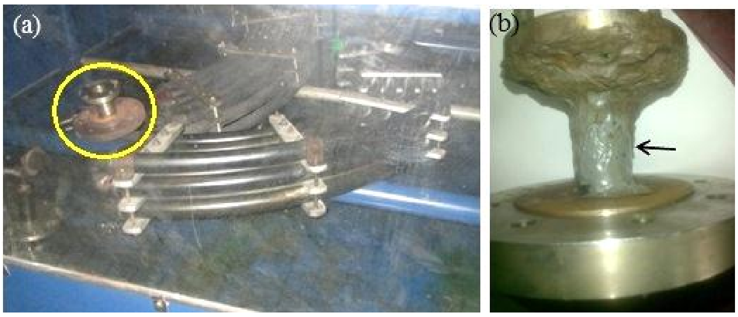


Fig. 1 The cooler coils connector in installed condition, indicated by yellow circle (a) and the investigated leaking cooler coils connector is covered by coating material as shown by an arrow (b).

Fig. 1 (a) shows the installed cooler coils connector and Fig. 1 (b) is a leaking component that is covered by coating material (indicated by arrow). The coating material was used temporarily to cover the leaking area in order to make the power plant continue to work. After the coating material is removed, the investigated cooler coils connector can be seen in Fig. 2. The coil connector has two components; the first one is a flange as a connector to the distribution pipe and the second one is a semi-circular pipe as a heat exchanger between oil and water.

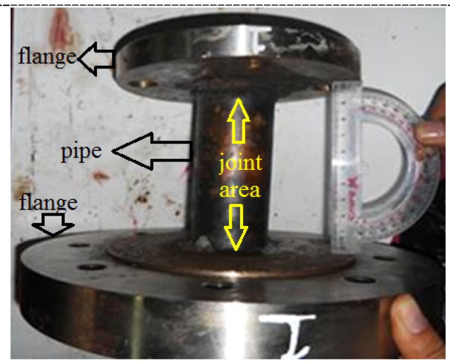


Fig. 2 (a) The leaking cooler coil connector.

Fig. 2 (b) Liquid penetrant test on cooler coils connector showed leakage in the joint area which is indicated by arrows.

Fig. 2a shows the investigated cooler coil connector after the coating material was removed. It can be seen that the joint area between the flange and the pipe is not in a good contact. No corrosion deposits are observed at the component surface. To ensure that there was a leak on that area, the liquid penetrant test was performed according to the ASTM E1417 [6] and the result in Fig. 2b is indicated by the red liquid penetrant that comes out to the surface. From the visual inspection and liquid penetrant test results, further examinations were carried out as follows:

- Chemical composition analysis was conducted using optical emission spectroscopy (OES-Master Pro-Oxford Instrument).
- Microanalysis was performed using a Nikon Epiphot optical microscopy
- Analytical SEM measurement employed a JEOL 2200 scanning electron microscopy (SEM) operated at 20 kV.
- Samples for microstructural analysis were prepared by the using of standard metallographic techniques with an etchant solution of 5% nital for steel and distilled water plus nitric acid for copper alloys.
- The Hardness of the metals was done using a Vickers Hardness Tester with load 200 g and dwell time 15 s. The samples for microstructure analysis samples were also used for hardness test.

Fig. 3 shows the cutting cooler coils connector and the samples taken for examinations. The two samples of number 1 and 2 (Fig. 3b) were taken at the flange and considered for chemical composition test and microstructural analysis, respectively. A microstructural sample in Fig. 4c was cut at the joint area near the bottom flange as indicated by red circle in Fig. 3a. The letters in Fig 3c explain the position of microstructural observation where letter A is sample location of the pipe near to bottom flange, letter B is sample location of the joint area and letter C is sample location of the connecting pipe to the upper flange. All the samples were then prepared with metallographic standard.

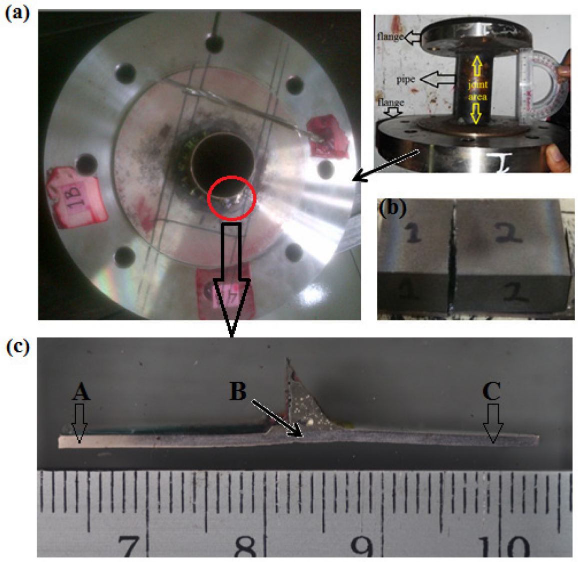


Fig. 3 (a) The investigated connector, (b) two samples taken from the flange and (c) a metallographic sample of the pipe (the letter, see the text).

Results and Discussion

Chemical Composition. Table 1 summarizes the results of chemical composition test of the investigated flange and pipe of connector compared to the specification. The flange was made of stainless steel 304 and meets the ASTM A240 specification and the pipe was a Cu-Ni type and the chemical composition conforms to grade the ASTM B111/B111M.

Table 1 Chemical composition of the flange (in %wt.).

	C	Si	S	P	Mn	Ni	Cr	Fe
ASTM 240 [7]	0.08 Max	0.75 Max	0.030 Max	0.045 Max	2.00 Max	8.00 12.00	18.00 20.00	Bal.
Actual chemical composition	0.05	0.41	0.01	0.03	1.26	8.13	18.5	Bal.

Table 2 Chemical composition of the cooler pipe (in %wt.).

	Fe	Ni	Mn	Cu
ASTM B111/ B111M [8]	1 - 1.8	9 - 11	1 Max	Bal.
Actual chemical composition	1.41	9.10	0.83	Bal.

Microstructure Analysis and Hardness. The optical microstructure of the flange is shown in Fig. 4. The microstructure exhibits a single phase of austenite with twining and frees from all grain boundary carbides. The microstructure is typical for austenitic stainless steel.

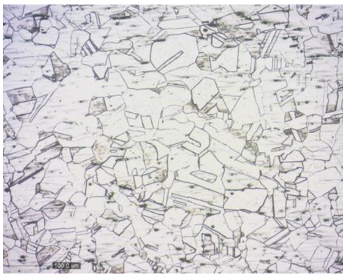
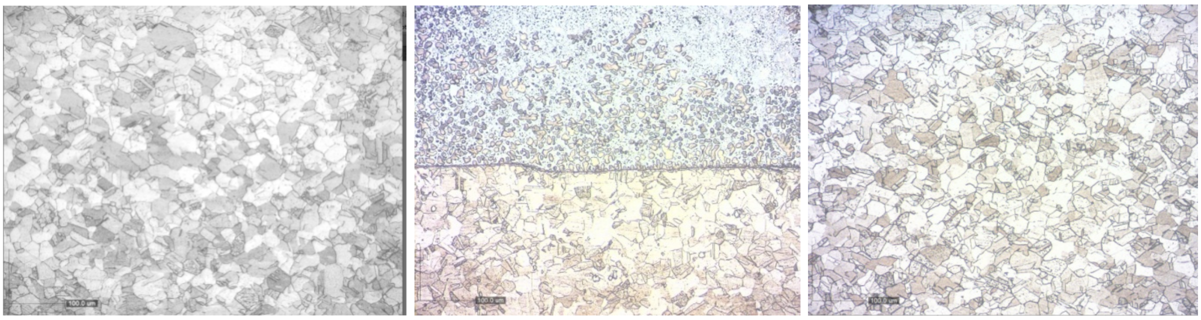


Fig. 4 An optical microstructure of the flange.

Three optical microstructures of the pipe observed from different locations are shown in Fig. 5. All the microstructures show uniform polyhedral grains of single phase alpha because copper and nickel are completely soluble in each other [9]. The microstructure analysis of the pipe supported the chemical composition results that the pipe was made of 90/10 copper-nickel. This alloy shows good resistant to stress corrosion caused by ammonia, as well as impingement attack caused by the locally high water-flow rates [10].



(a) (b) (c)

Fig. 5 Optical microstructures of the leaking pipe taken from different locations as indicated in Fig.4c.: (a) sample location of A, (b) sample location of B and (c) sample location of C.

The micro hardness of the flange was measured at 6 different locations and the result is 177.43 HV in average, which is satisfied with the standard ASTM A240. The average hardness of the pipe is 81.67 HV that was measured at three different locations as shown in Fig 3c (6 hardness data were taken from each location) and as expected, the hardness is in good agreement with the ASTM B111/B111M (90/10 copper-nickel). SEM-EDS under BSE imaging conditions (Fig. 6) were conducted on the joint area to identify the presence of elements. The EDS spectra in Fig. 7 shows the elements in the joint area are mainly Cu, Pb, Zn, Zr and Ag rich. A quantitative SEM/EDS analysis in Table 3 indicates that both the amount of dissolved Ag and the diffusion rate of Ag in molten brazing alloy were high. The SEM-EDS spectra also revealed that the concentration profiles of the Cu, Pb, Zn and Zr were heterogeneous, which was probably due to the difference in diffusion rates in molten brazing alloy.

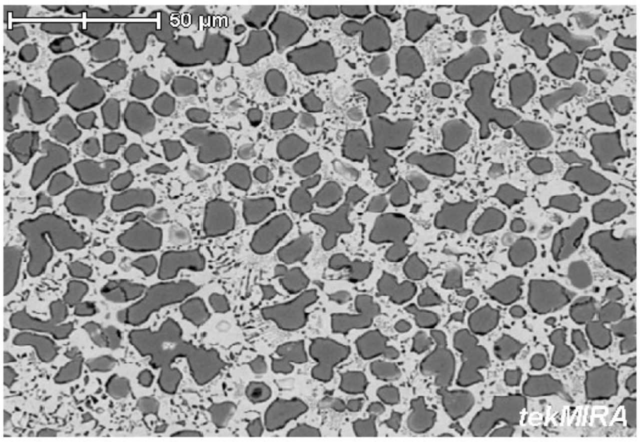


Fig. 6 A BSE imaging on the brazed area.

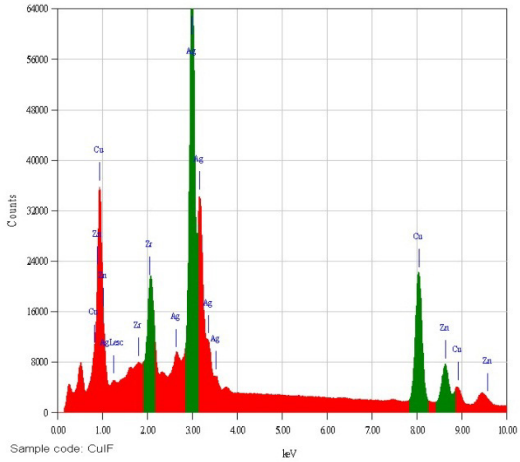


Fig. 7 The EDS spectra on the brazed area show the presence elements.

Table 3 Quantitative analysis on the brazed area in Fig. 6.

Element	%wt.
Cu	31.03
Zn	11.01
Ag	34.41
Pb	-
Zr	7.77

According to quantitative data of SEM-EDS in Table 3, it revealed that brazing process was carried out on the flange and the pipe. The content of three dominant elements namely Ag, Cu, and Zn confirmed that the joints had been brazed with butt joint using a braze filler metal. To find the cause of the leakage on the brazed joint, a secondary SEM image was taken between the pipe and the brazed area as shown in Fig. 8. It is clearly seen that the pipe is not in good contact, which is indicated by the gap (shown by an arrow) between the brazed joint and stainless steel. The Fig 8 also indicates the oxide and gas may be entrapped by the caused discontinuity within the brazed join and reduced joint strength. Due to the imperfect wettability of melted filler metal on substrate surfaces as well as entrapped gas within the joint, cavities are possible to occur there [11].

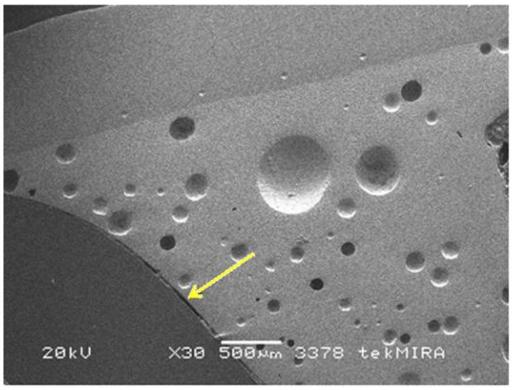


Fig. 8 A secondary electron image shows a gap between the pipe and joint area as shown by an arrow.

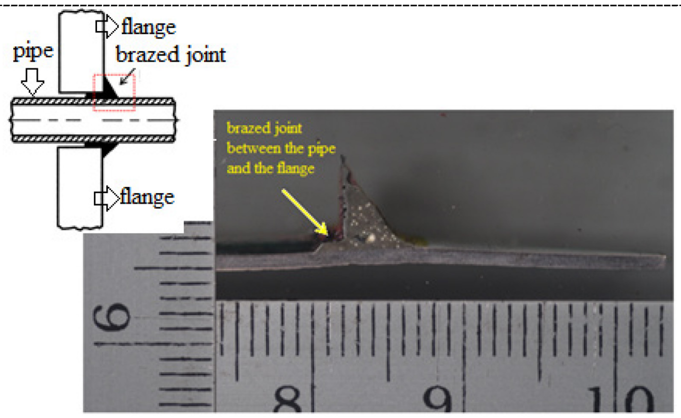


Fig. 9 The joint gap between the pipe and the flange (the top left shows the location of sample).

It is known that there is a strong correlation between the strength of brazed joint and the clearance [12]. During the brazing process, it is important to keep a clearance between the base metals to allow capillary action to work effectively. Some factors must be considered to plan the joint clearance, such as “coefficient of thermal expansion” of the metals being joined and moreover for dissimilar metals. Different metals have different rates for expansion when they are heated. Fig 9 shows the joint gap between the pipe and the brazed area of the investigated component. Observing from the Fig 9, it seems that the joint clearance is not sufficient. As the materials of the flange and the pipe are different hence they have different thermal expansion coefficient. The pipe, which is made of 90/10 copper nickel, has higher heat conductivity than the stainless steel flange. It means the copper/nickel alloy expanded more than steel when being heated and leading to a decreasing joint gap. Therefore, the gap clearance at room temperature must be designed to be much greater to ensure an optimal gap size can be reached at brazing temperature. However, in this investigation, the joint clearance between the pipe and the flange was too large (around 0.2 mm), as a result the joint strength was decreasing.

Summary

Findings from the investigation, the conclusions are as follows:

a) The cooling coil connector consists of two types of material, e.g.: the flange conforms to the standard of ASTM A240 and the pipe was satisfied with Cu-Ni 90-10.

b) The failure mechanism of the cooler coil connector is due to large joint clearance causing the excessive gap and as a result the joint strength decreases.

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