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Inclined Drain Structure on the Combi Boilers Main Heat Exchanger

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Abstract - Combi boiler main heat exchanger process converts the potential energy of the combustion gas into heat energy by oxidizing the mentioned gas and turn this energy into useful energy that can be used to heat a space. During this process, the condensation water can cause galvanic and pitting corrosion. There are five ways to prevent the carrion formation which are optimising the design, material selection, monitoring, preventative maintenance and processing. This study presents an inclined drain structure on the heat exchanger of the combi. The main objective is to prevent the condensate water corrosion effects on the heat exchanger by preventing condensate water pond. To achieve the drawback, the main heat exchanger of the combi boiler bottom cover is revised and validated. Three dimensions design is performed on 3DS Solidworks 3D CAD data software. Accelerated life tests were applied during the validation step to observe how the old and revised versions performances under various field conditions.

Keywords: combi boiler, main heat exchanger, durable, corrosion proof

1. Introduction

This study presents an inclined drain structure on the combi boiler main heat exchanger. The main objective on this is to prevent this condensate water corrosion effects on combi boiler heat exchangers by avoiding condensate water pond. Gas burning combi boilers are widely used in household in terms of heating both central heating circuits and domestic hot water demands. There are two types of combi boiler which are conventional and condensing systems [1]. Conventional systems are known as non-condensing systems. Comparing to the state-of-the-art condensing boilers, conventional boilers flue gas temperatures are higher approximately around 70 °C. Condensing boilers can transfer latent heat into the water which is circulating inside the plumbing system around the household. To take the extra heat energy, a phase transformation of water from vapour form into liquid form must be occurred. This transformation both have positive effect on efficiency of the combi boiler and negative effect due to the acidic characterisation of condensing water. Condensing water's acidic character comes the various compound occurring due to the combustion of the methane gas such as Sulfuric acid, Hydrochloric acid, Nitric acid etc [2-4]. The condensation water causes corrosion in general. Since the nature of the condensation water is acidic characteristic, condensation water erodes the contacted materials [5]. The higher the rate of condensation water formation rate, the higher the level of corrosion occurs. Condensation corrosion is hard to observe with naked eye, it might degenerate the other corrosions such as galvanic corrosion and pitting corrosion.

The products resulting from the combustion reactions accumulate on the steel exchanger and can cause the steel material to thin in thickness. These accumulated materials act as rust on the steel, generating a voltage difference between it and the steel itself and causing the steel to melt in the form of a pit by removing electrons from the steel itself and thus causing erosion.

Pitting corrosion mechanism can occur with different types. These types are; penetration mechanism, adsorption mechanism and film breaking mechanism. The type most seen in combi boiler main heat exchangers is the absorption corrosion mechanism. Figure 1 discloses the main mechanism of the pitting corrosion from left to right. When the passive corrosion current density is higher than the ionic current density metal starts to erode and cause pits. Due to the electrolyte presence, a voltage difference occurs between metal and electrolyte and causes a current. This current conduces the metal and its oxide film loses electrons. Thus, the metal starts to erode like a pit [6-8].

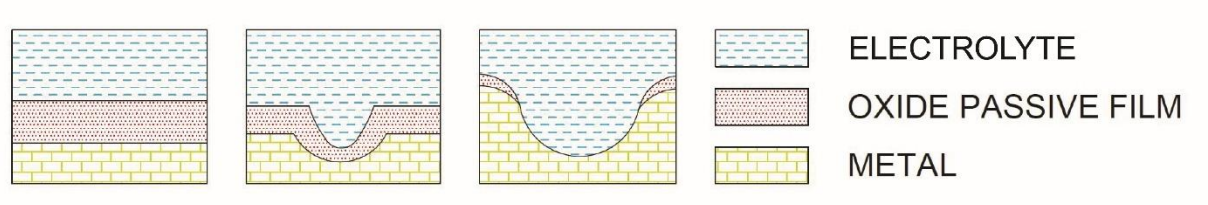

Fig. 1: Pitting Corrosion Mechanism

The other corrosion type may be observed in the combi boilers main heat exchangers is the galvanic corrosion. Other than the pitting corrosion, galvanic corrosion occurs within two metal types. In main heat exchangers these two materials are aluminium and steel. Since there is a voltage difference between those two materials, aluminium parts which has lower voltage current lose electrons and start eroding. This corrosion is also fastened by a strong electrolyte such as condensation water [9-11]. It's not easy to eliminate corrosion in environments where electrolyte materials are present. There are several options that can be used to minimize or even eliminate corrosion. The easiest way to minimise the risk material change or a special coating must be considered. One of the solutions to eliminate the corrosion damage is the change the producing method of the related products. As surface roughness smoothens, it might be more difficult for condensate water to adhere to the metal surface. However, making products that are already of good quality smoother could be much more costly, as stated in the previous suggestion. The other solution is to have a special coating to the surfaces that can contact the condensate water. Another solution is to have revision on the part which can eliminate the condensate water being formed as a pond. It can be done by revising bottom cover of the main heat exchanger with a 3D Cad data software such as 3DS SolidWorks. Despite the high initial investment cost, the design revision method is preferred because it is more adaptable to mass production and much more affordable than other solutions.

2. Materials and Methods

In this section, the effects of corrosion on the main heat exchanger of the combi boiler, how the condensate pond is formed and the improved design practices on how to prevent this condensate pond from forming will be discussed.

2.1 Corrosion Effects on Combi Boiler Main Heat Exchangers

Due to the galvanic and pitting corrosion, components in the combi boiler main heat exchanger are eroding via time. This phenomenon is inevitable regarding the material's nature. In combi boiler heat exchanger various type of materials in use such as stainless steel, aluminium, engineering composites etc [12]. Galvanic corrosion occurs when two metals are in direct contact with each other and a voltage difference occurs between these two metals. In case of the combi boiler heat exchangers those two materials are stainless steel (AISI 441) and aluminium (EN AC 46000) [13-14].

Figure 2 discloses the test results when direct contact with stainless steel, aluminium parts tents to corrodes due to the galvanic corrosion. Electrolyte presence is boosting the galvanic corrosion, the test is performed in condensation water. Aluminium and stainless-steel couple immersed into a cup of condensation water which is around 80 °C. After a month of continuous test, aluminium part corrodes due to the voltage difference between steel and aluminium. In regular installation method, a combi boiler heat exchanger aluminium and stainless-steel parts do not touch with each other directly. Instead avoid the contact silicon type of adhesives are used. In this test in order to understand the condensation water effect, silicon is not applied.

Fig. 2: Galvanic Corrosion between Aluminium and Stainless Steel

Other corrosion which occurs in the combi boiler main heat exchanger is pitting corrosion. Similar with the galvanic corrosion, condensation water accelerates the pit formation. Figure 3 is showing an aluminium part which erodes due to the pitting corrosion under the accelerating effect of condensation water.

Fig. 3: Pitting Corrosion of Aluminium under Condensation Water

2.2 Formation of Condensation Pond

Combi boilers are installed by hanging them on a wall using screws. Due to the condition of the wall the installation that mentioned could be done with some leaning angle to the front. In this case regarding the leaning angle, small condensation pond occurs at the in front of the combi boiler heat exchanger. Figure 4 indicates that

the place where condensation water accumulates in the main heat exchanger of the combi boiler to form a condensate water pond. Condensation water accumulates in the area indicated with the red circle.

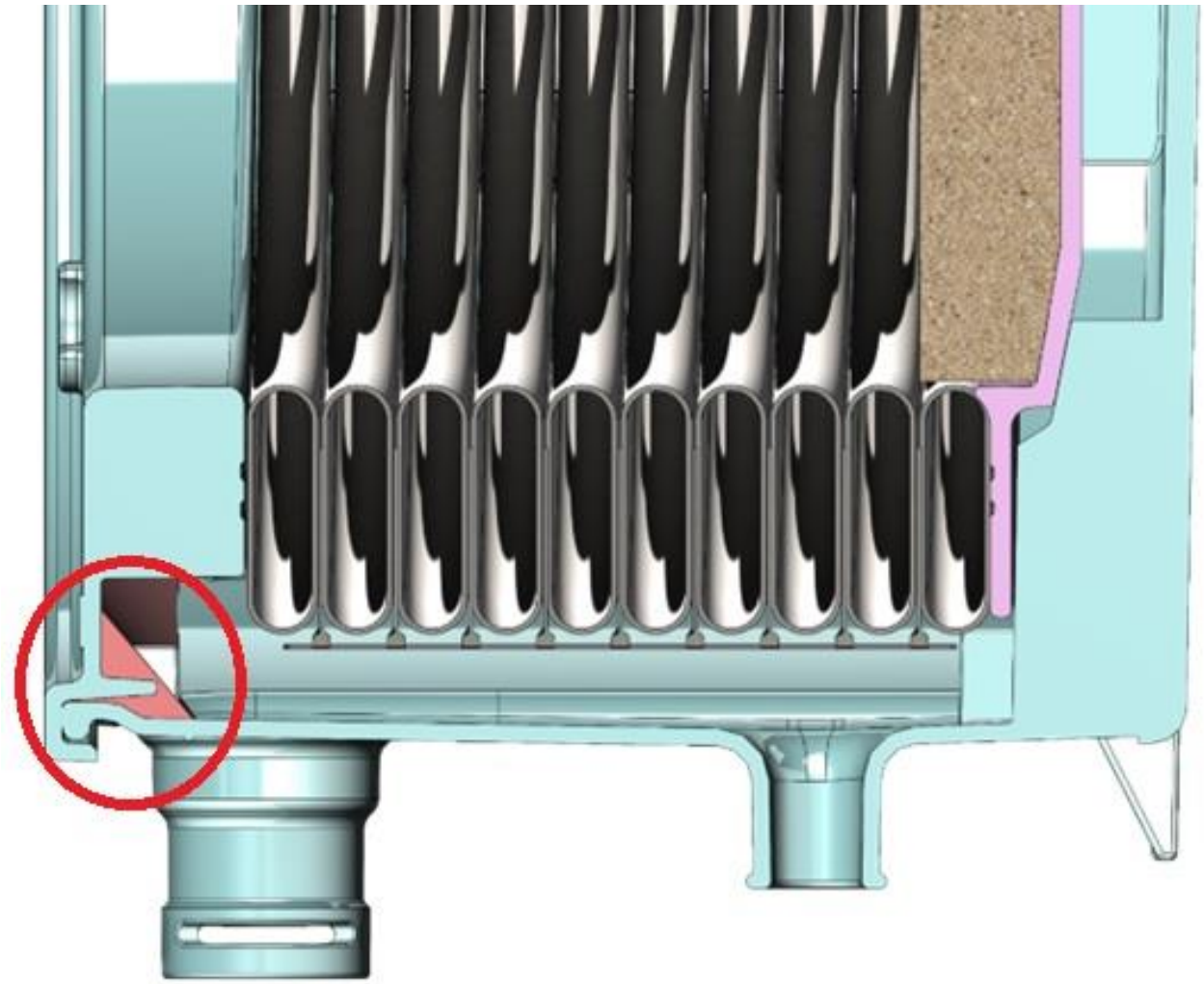

Fig. 4: Condensate water pond formation

2.3. The Improved Design

The improved the design procedure has carried by 3DS Solidworks 2023 computer aided design software [15]. There are two kinds of thoughts on solve galvanic and pitting corrosions on combi boiler heat exchangers. A solution can be considered via moulding revision. As can be seen from Picture 5 that condensation drain has no angle with respect to combi boilers bottom sheet metal. It's not easy to prevent the condensation water to flow over and easily drained from the heat exchanger. The formation of a condensate water pond as indicated in Figure 4 cannot be prevented. Figure 6 discloses the new design which has a 7° inclined draining port on the combi boiler main heat exchangers bottom cover. This solution prevents condensate water pond being formed.

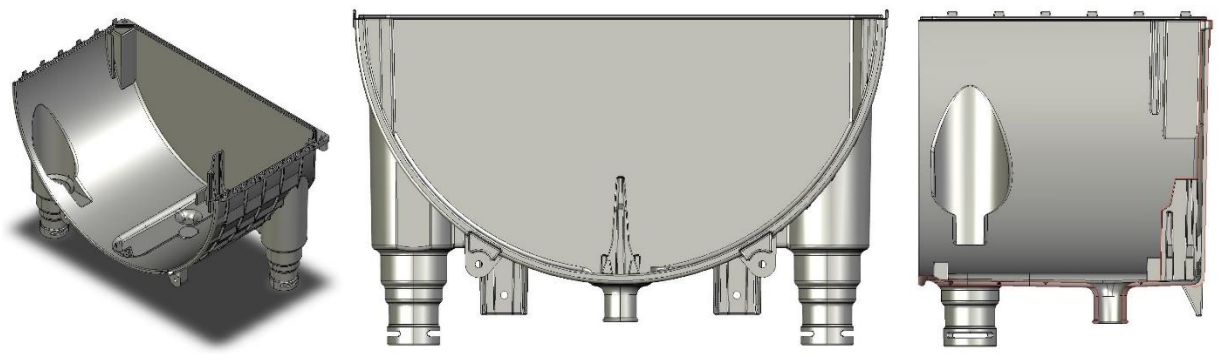

Fig. 5: Old Design of the bottom cover

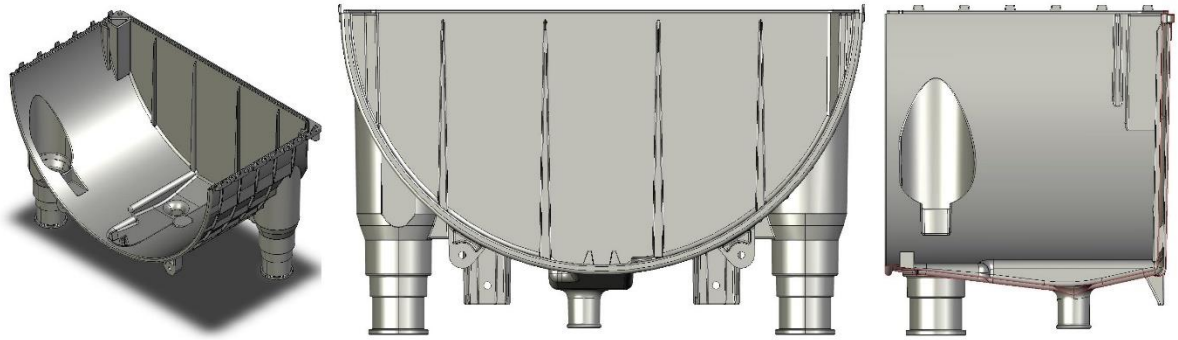

Fig. 6 : New Design of the bottom cover

3. Results

The improved design provides; enhancement to the lifespan of a combi boiler heat exchanger on the field by preventing condensate water pond being formed achieved through bringing a new design to its bottom cover. The effect of the new design, accelerated life cycle time tests initiated. In this test two combi boilers which has two different types of heat exchangers installed on the test bench with a 5° angle leaning toward forward.

Table 1 indicates the corrosion level observed after the accelerated life test of old and improved design heat exchangers. Accelerated life testing was carried out for 3 months. As a result of the tests, high amounts of corrosion were observed in the old design, while no corrosion was observed in the improved design.

Figure 6 shows the revised design of the bottom cover of the combi boilers main heat exchanger. As parallel with the figure 7 pitting and galvanic corrosion is not observed. Thanks to this new design condensation water could not form a pond in related area which will cause corrosion.

Table 1. Accelerated lifetime test table

#	Type of Heat Exchanger	Duration	Corrosion
1	Old version design of heat exchanger	3 Month	Severe
2	The Improved design of heat exchanger	3 Month	No

Fig. 7: The snapshot of the improved design of heat exchanger surface

4. Conclusion

As mentioned at result section, the tests showed that the life expectancy in the field of the old design of the combi boiler main heat exchangers would be less than 10 years. With the improved design, the formation of condensate water pond was prevented and the electrolyte accumulation between aluminium and stainless steel is prevented. By eliminating the presence of electrolyte, pitting corrosion formation was minimized. In the tests, it was observed that the new design condensing combi boiler main heat exchanger provided a 10-year field life expectancy.

The improved design of combi boiler main heat exchanger bottom cover, formation of a condensate poon observed in the old design prevented thanks to the 7° degree slope used in the improved design. Thanks to the improved design, it has also been observed that the field life of the combi boiler main heat exchanger will increase.

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