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DEVELOPMENT OF A LABORATORY-SCALE CORROSION RIG FOR TESTING PIPELINE STEEL MATERIALS IN SEAWATER

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ABSTRACT
This paper reports the development of a laboratory scale corrosion rig for testing pipeline materials in seawater environment. The design factors that were considered for the rig development include availability of the locally sourced materials used for fabrication, suitability of the material for the operating condition, volume of the water required in the chamber and coefficient of performance of the chiller. The components of the rig include plastic reservoir, flexible pipes, transparent Perspex chamber, two aphacool pumps and the designed chiller. These components were designed according to specifications that are outlined in the design calculations. The coefficient of performance of the chiller was obtained to be 3.58 while the volumes of the reservoir and chamber were determined to be 0.0776 m^3 and 0.0172 m^3 respectively. This study has shown that locally sourced materials can be used to develop corrosion rig with similar environment as those experienced by pipeline material in seawater.

Keywords: *Corrosion, Seawater, Chiller, refrigerator; rig*

1. INTRODUCTION

External corrosion related failures have been attributed to pipeline structures particularly those operating in seawater environments. The most commonly used pipeline steels are API X52, X60, X65, X70, X80 [1]. Seawater is an environment that may not be reproduced in the laboratory completely but can be simulated as close as possible. Due to cost implication and time constraints, accelerated tests are carried out [2]. In this study in order to simulate a laboratory scale seawater environment, replicating seawater corrosion in pipeline materials, a corrosion rig equipped with a chiller was developed. Chiller or refrigerating unit forms one of the most important components of the corrosion rig that was developed in this work, hence, the working principle is described in the next section.

This paper reports the development of a laboratory scale corrosion rig for testing pipeline materials in seawater environment using locally sourced materials. The paper is limited to the development of the corrosion rig as performance tests are not reported.

1.1 Chillers/refrigerating unit

Chillers which could also be referred to as refrigerating systems have similar principle of operation as refrigerators which are primarily used for storage of food and drinks. Chillers or refrigerators are designed with thermally insulated compartments and compressor that transfer heat from the inside of the generating system to external environment, thereby reducing the inside temperature below room temperature [3].

The major difference between the working principles of refrigerator and chiller is that the cooled water in chiller is pumped for a specific purpose unlike in refrigerator where cooled water, drinks and foods are retained in the compartment. Apart from its use for cooling, aquarium chiller was used in the development of a corrosion fatigue set up in [4]. Refrigerators are designed with compressor, condenser, expansion valve or capillary tube and evaporator [5]. Most refrigerators and air conditioning system use vapour-compression cycle [6]; classified by four major stages: isentropic compression in a compressor, constant-pressure heat rejection in a condenser, throttling in the capillary tube or expansion valve and constant-pressure heat absorption in an evaporator [5]. Summarily, chiller is a single unit comprising of compressor, condenser, evaporator and expansion valve. The peculiarity of the chiller used in this work is the utilization of locally sourced components for its fabrication compared to imported ones.

1.2 Review of literature on chillers/refrigerators

Chillers have been developed for several purposes. In [3], the development of a 12 kW air-cooled water chiller with a coefficient of performance of approximately 2.2 and for cooling water from a temperature of 20^{o}C to a temperature of 10^{o}C using R-134a refrigerant was reported. Absorption chillers can be categorized as one of the alternatives to compression refrigerators in which the compressors are replaced with absorber, generator and pressure reducing valve that makes them silent while in operation [6]. The working principle of absorption chiller is explained in [7]. Mechanical heat pumps using absorption principle have been mentioned to contribute significantly to ozone layer depletion and climate change [8]. However, the lower coefficient of performance and the cost involved in developing absorption chillers have been mentioned as their limitations [7], [8]. The currently available absorption refrigeration systems are expensive [9]. In [7], locally sourced materials were used for fabricating absorption chiller and these include condenser, heat sink, evaporator, wood and ammonium/water absorber refrigerant. The system was powered by 250 volts generator and the coefficient of performance (COP) was determined to be 1.21, while the refrigeration effect was 1457.99 kJ. A solar powered cooling refrigeration was also developed by [9], with the aim of reducing consumption of fossil fuels as well as significant reduction in carbon emission.

Experimental analysis of vapour-compression water chiller with different expansion devices was carried out in [10]. It was found that the highest COP was obtained with the needle valve followed by thermostatic expansion valve while the least COP was achieved with the use of capillary tube. It was also mentioned that characteristic effects of different devices could influence the performance of the system during throttling process [11], [12]. A 20 kg capacity vapour compression refrigeration system equipped with temperature control device was developed for the preservation of vegetables using R134a refrigerant [13]. The refrigeration system improved the shelf life of the vegetables by 14 days.

However, examples of the vapour compression chillers in the literature are those used for cooling in electronic devices [14] [15]; water chillers for cold drinks [16], [17], those used for hydroponics farms, and water chillers with different expansion devices under transient conditions [10]. The recent use of chiller for corrosion fatigue experiment was reported in [4]. Thu et al., [18] investigated the performance of mechanical vapour compression chiller and found that an increase of 3.5% in the COP of the chiller was observed at every increase of the chilled water temperature, while the cooling capacity of the chiller increased by 4%. Oyedepo et al., [19] investigated the performance of domestic refrigerator that was previously designed for R12 refrigerant. The refrigerant was replaced with R600a and the capillary tube length was also changed. The highest cooling capacity of 9.18% was achieved using R600a and the lowest power consumption was obtained using a 1.5 m capillary tube length; which showed that R600a performed better than R12. Recently, the performance of R600a using different capillary tube lengths: 1.0, 1.15, 1.30 and 1.45 m was investigated using a refrigerator that was previously designed for R134a [20]. The optimum capillary tube length of 1.30 m revealed an increase in COP and cooling capacity of R600a by 45% and 4.2% respectively.

In this paper, the development of corrosion rig equipped with chiller for use in seawater experiment is reported. The peculiarity of the rig is that it was used to represent a similar corrosion environment that pipelines in seawater are subjected to. The most notable difference between refrigerating systems and the chiller used