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Power generation from waste heat in a food processing application

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ABSTRACT

In this paper, the potential of recovering waste heat from the fryer section and exhaust stream sent to the stack of a typical potato crisps or chips manufacturing plant and using the heat to drive an Organic Rankine Cycle (ORC) system for power generation has been presented. Five different ORC system Options (A, B, C, D and E) were considered. The first two options (A and B) make use of the waste heat from the foul gas and exhaust to stack respectively for power generation using a single ORC system each while the third option (option C) makes use of a novel dual heat source single ORC system where the low temperature waste heat from the foul gas is used to provide preheating and the high temperature waste from the exhaust to the stack used to provide the evaporation. Option D also shows a dual heat source ORC system where the high temperature waste heat to the exhaust stack is used to provide the preheating while the lower temperature foul gas is used for the evaporation (reverse of option C in terms of waste heat usage) while option E makes use of a reheat cycle where the waste heat from the foul gas is used to provide the reheating of the working fluid exiting the turbine. In terms of waste heat usage, the combination of options A and B can be compared with options C, D and E.

The simulation result shows that in terms of net power generation, cooling water requirement, and working fluid (R245fa) requirement, the combination of Options A and B gives the best power generation result and this is similar as the result produced by Option C. Following option C is option E which gave a better result than option D. The entropy generation analysis showed that the entropy generation is inversely proportional to the power output.

It was also observed that the net power generation for the ORC configuration adopted in this paper (option C) meets the average daily power requirement of the crisps manufacturing process as well as 98.58% of the daily peak power requirement.

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1. Introduction

The present work concerns the thermodynamic design of an Organic Rankine Cycle (ORC) system for power generation using the waste heat from the fryer section and exhaust stack of a potato crisps or chips manufacturing plant.

Commercial crisps manufacturing is a well established market which involves a series of recipes in order to transform the raw potato from the farm to the finished desired product. The sequential processes involved in crisps production includes de-stoning, washing, peeling, drum washing and inspection, slicing, cold washing, hot washing, de-washing, frying, and inspection, flavouring and packing.

In 2005, crisps consumption in the UK was estimated to be as high as 10^5 packets which represents more than half of the crisps sold in the European Union [1]. Despite many campaigns by some health organisations, crisps consumption has always been on the increase.

Associated with the increase in crisps consumption is an increase in energy consumption during crisps manufacturing. Crisps manufacturing is an energy intensive process [2]. Processes like the hot washing and peeling requires hot water and steam respectively while the packing hall requires to be heated. Space heating accounts for about 20% of the total energy and are produced using boilers which makes use of boiler fuels [2]. The frying operation is the most energy consuming unit operation and consumes more than 65% of the total energy use (in form of electrical energy). This comprises of the electrical energy used in driving the conveyor systems, foul gas fan, pumps and other auxiliaries. Fig. 1 shows a typical day hourly electrical energy

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