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Editorial

Advanced Heat Exchangers for Waste Heat Recovery Applications

Hussam Jouhara

Heat Pipe and Thermal Management Research Group, Brunel University London, Uxbridge UB8 3PH, UK; hussam.jouhara@brunel.ac.uk

The incentive for industrial waste heat recovery, which has attracted much research interest in recent years, has been twofold: the obligation to reduce greenhouse gas emissions in line with climate change targets and the need for processes to reduce overall energy consumption in order to remain commercially competitive. The latter became even more of an issue in 2022 as a result of rapidly increasing energy prices worldwide. The five papers in this Special Issue on advanced heat exchangers for waste heat recovery applications cover very different topics [1–5].

The first, by Doraghi et al. [3,4], considers the use of thermoelectric generators (TEGs) in a hot waste stream. For more than a quarter of a century, TEGs have been proposed for electricity generation in remote locations, where supplying electricity would normally be difficult (for example, see [6]). Recent interest in the use of TEGs has been stimulated by climate change measures and the need for energy efficiency; Olabi et al. [7] considered the potential applications of TEGs in waste heat recovery. By definition, TEGs have to operate in a temperature gradient to generate power, resulting in the matter of thermal stresses arising. In the current paper [4], the authors examined different geometries for thermoelectric elements, and established that a diamond shape minimises thermal stresses.

Heat pipes have been implemented in many applications of waste heat recovery, for example, with flue gases [8]. In certain cases, such as the radiant cooling of ceramic tiles [9] or steel wires [10], it is convenient to use multiple heat pipes in parallel, connected top and bottom with headers, in a flat configuration. This approach is taken a step further in the current paper [1]. Miniature parallel tubes were embedded in a heat mat and the resulting heat sink was capable of both maintaining an optimal temperature for electricity generation through a photovoltaic module, as well as also utilising approximately 80% of solar radiation not converted to electricity, in order to provide heat to a domestic hot water system.

Waste heat recovered during an industrial process can often not be used immediately, which necessitates thermal energy storage. Systems based on sensible heat storage suffer the disadvantage of a large temperature variation during operation. In contrast, latent heat thermal energy storage (LHTES) systems utilising phase-change materials (PCMs) can operate with a relatively narrow temperature band between charge and discharge. Many LHTES systems use paraffin wax. However, this material has a rather low thermal conductivity, potentially resulting in lengthy charge and discharge processes. Many researchers have attempted to improve the conductivity of PCMs using carbon-based additives. In the current paper [5], the authors describe the impact of introducing nanoparticles in the form of graphite-based platelets. They improved the behaviour of a PCM, particularly the speed of its charging and discharging times.

Preheating air to be subsequently used in combustion processes has been shown to be a very effective use of waste heat (for example see [8]). This is demonstrated in the fourth paper of this Special Issue. Koh et al. [2] found that when they added an air preheater to flue gas from the boiler of an oleochemical plant, in addition to a conventional economiser, the outcome was a 17% reduction in natural gas consumption and a reduced emission of

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149 tonnes of CO_2 per annum. Moreover, CO_2 levels in the highly populated area adjacent to the plant decreased.

Idealised descriptions of heat engines providing the maximum theoretical efficiency assume reversible processes, particularly infinitesimally small temperature differences and infinitely long times for heat exchange. In practice, neither of these assumptions can be validated, and real heat exchange processes and other factors introduce irreversibility into the cycles. The final paper [11] considers optimal solutions for thermal machines with real heat transfer processes, and establishes their boundary conditions.

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