HEAT TRANSFER ENHANCMENT EMPLOYING SIMPLE MACHINE ELEMENTS

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Abstract Recent developments of energy costs demand efficient heat transfer apparatus. The question addressed here is: Can simple machine elements like wire springs be employed to enhance heat transfer of plate heat exchangers significantly? Experimental investigations using Particle Image Velocimetry (PIV) and measurements of global features of a generic heat exchanger show that this is indeed the case.

Introduction and experimental facility

Optimization of standard design types such as tube bundle and plate heat exchanger is of great interest. Recent literature offers a huge amount of new ideas to enhance heat transfer by comparable little increase of pressure loss. However, the success of the majority of these techniques is very often only demonstrated employing single tubes or plates. Here we go a step further and employ a test rig to explore the potentials which simple wire springs offer to enhance the heat transfer in a complete heat exchanger.
The ILK heat exchanger test rig provides two crossing air streams. In the intersection a heat exchanger ($400\times400\times100$ mm³) of either cross or counter flow type can be mounted. Temperature and pressure are measured in each of the two entering and the two leaving air stream. Additionally flow rates and air humidity are measured. The hot air stream can be heated up to 120°C and is conducted in a closed loop. The cold stream uses fresh air in an open loop. The relative experimental error is ± 4% for Reynolds number Re, ± 5% for heat flux q and ± 7% for pressure loss coefficient ζ.

Experiments and results

Experiments were undertaken in a Re_{cold}-range between 2500 and 9000 and at Re_{hot}=3000, 3700, 4300. PIV measurements showed that the influence of a single wire spring lasts at least three to four spring diameters downstream from the spring rear end (Fig. 2). Therefore twelve springs with an average center-to-centre distance of 30 mm were mounted in each heat exchanger passage of 9 mm height. Wire diameter was in all cases 0.5 mm and spring pitch was 4.2 mm in test case 1 and 6.4 mm in test case 2. Baseline for all comparisons was the empty heat exchanger without any springs.
Our experiments showed that an increase of the specific heat flux per unit volume is achieved in any case (Fig.3 left). However, it is more difficult to be successful when the heat transfer enhancement is valued against the increasing pressure loss. Not before the pressure losses are reduced sufficiently by enlarging the pitch TPP_3-values can be achieved larger than unity throughout the entire Reynolds number range investigated (Fig. 3 right). This finding at the same time offers opportunities for further optimization.

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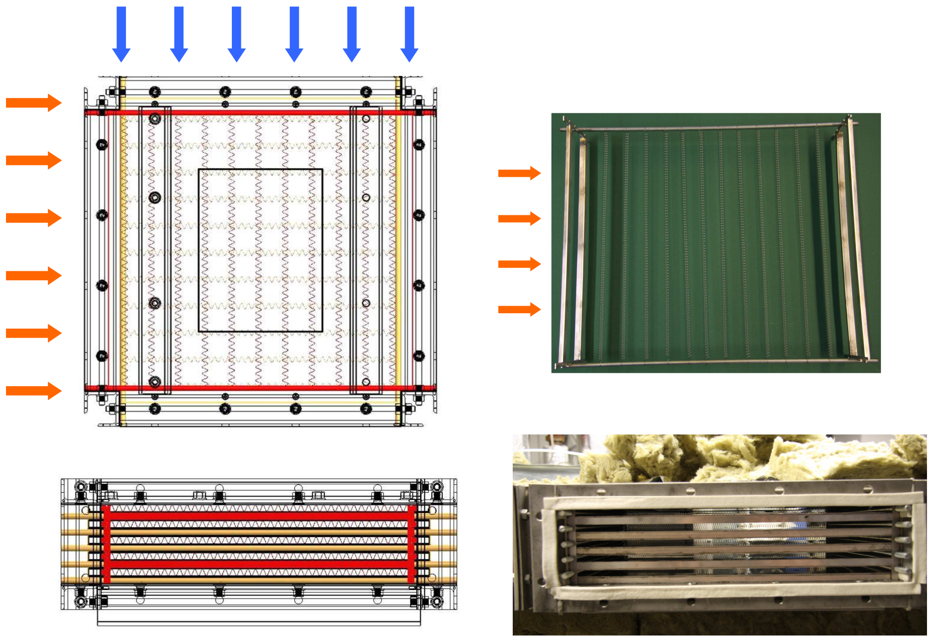

Fig. 1 Experimental facility (clockwise: topview of heat exchanger bloc including springs (sketch), spring array held by support system, view of test rig during backfitting with springs visible in each passage and front view (sketch))

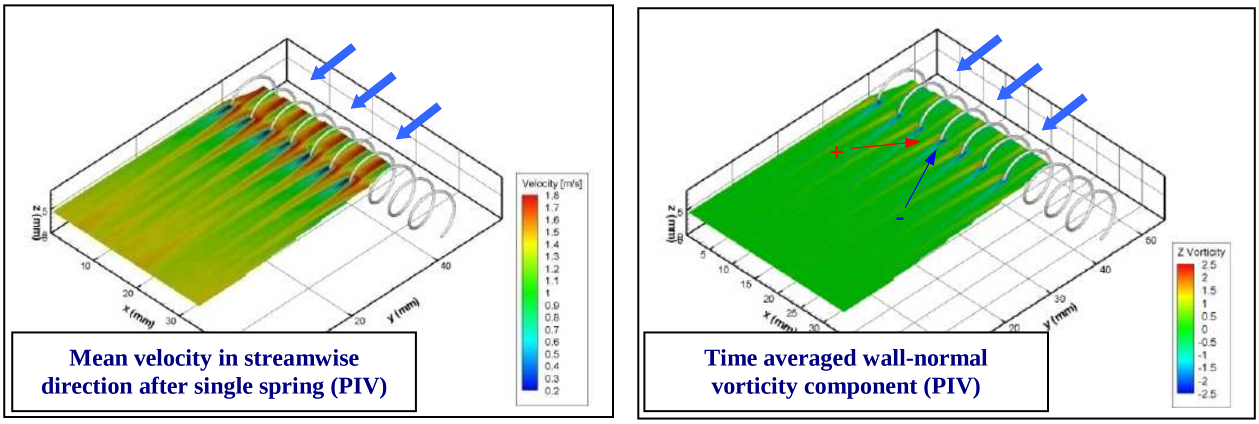

Fig. 2 Particle Image Velocimetry for single wire spring inside heat exchanger channel

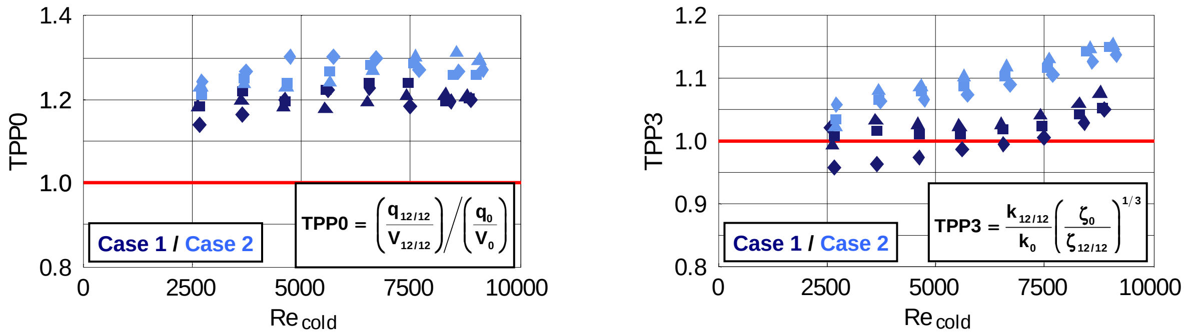

Fig. 3 Thermal performance parameters comparing heat exchanger with springs and base line test case without springs
▲ Re_{warm}=3000, ■ Re_{warm}=3600, ♦ Re_{warm}=4700,