Warszawa, dn. 23.06.2022 r.

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Streszczenie rozprawy doktorskiej nt.:

„Investigation of thermal and flow processes in low-pressure rotary lobe expanders"

The research presented in this thesis focuses on rotary lobe expanders, which are machines that use compressed gas energy to generate mechanical energy that is discharged through a shaft and used to drive machinery or transferred to an electrical generator. So far, these machines have been used mainly in the mining industry, where they replaced electric motors in explosive conditions. Due to the growing interest in energy production from waste sources and micro-cogeneration systems, rotary lobe expanders are an attractive alternative to other thermal machines operating in systems of a few to several hundred kilowatts. Several heat engines on the market are being researched for use in micro-cogeneration, but as yet, no leading technology has emerged. The opening section of the thesis provides an overview of the engines used in micro-cogeneration, together with the rotary lobe expanders' characteristics. Each technology presented has advantages and disadvantages. Therefore, the validity of applying specific machines is linked to an extensive parameter analysis of the target system.

The primary work objective was to investigate thermal and flow processes in low-pressure rotary lobe expanders, leading to the expander computational model development. The work was performed in five stages. The first stage involved developing a thermal-fluid processes mathematical model within the rotary lobe expander using numerical fluid mechanics. The model developed involves the transient simulation with a time-varying computational domain geometry, with two interlocking rotors in rotational motion. Then, in stage two, the developed model was adapted to the industrial machine's geometry and operating conditions and then validated based on the manufacturer's characteristics. Stage three involved a geometry design parameter analysis using the model developed. The critical work issue that emerged at this stage was the relatively high level of working medium loss due to machine clearances. Stage four involved the study and determination of expander leakage characteristics. Within stage four, several dozen numerical simulations were carried out on selected expander regions, investigating leakage in the machine for different thermodynamic medium parameters and varying rotor interlock angles. The fifth work stage involved the development of a multi-stage expander analytical model, including the calculated leakage characteristics. The model uses iterative methods to obtain a solution, allowing the efficiency and working medium consumption and also the steam thermodynamic parameters at the inlet, outlet and between the stages in the expander to be determined. It is also possible to solve the inverse task, i.e. to determine the design parameters ensuring the highest efficiency under specified operating conditions. Within the fifth stage, the multi-stage expander design characteristics were determined for a range of parameters such as power, internal efficiency, piping height, clearances, and stage number.

Available scientific and technical literature was consulted at all work stages. The preliminary literature review began when the motivation to start research on the rotary lobe expanders arose. An extensive literature on numerical modelling of rotating equipment and gas flow through machine clearances was also analysed. In the final part, the calculation results were compared with the available literature at the stage of developing the expander's constructional characteristics and evaluating the individual parameters' influence on the machine's performance. The resulting dependencies are in line with previously published expansion device characteristics.

The conducted research on thermal and fluid processes in low-pressure rotary lobe expanders finds a place in the distributed energy development as low-pressure gas energy conversion units. The paper also covers further research planned and a critical reflection on the work performed.

Słowa kluczowe: rotary lobe expander; transient CFD; leaks in a rotating machine

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