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DEVELOPMENT OF ORC UNIT FOR MICRO-COGENERATION DEVICE

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This paper presents technology which uses the so-called Organic Rankine Cycle (ORC) to convert low-potential heat into mechanical energy. The steam engine will be connected to the cycle as a source of mechanical energy. Description of the basic design ORC facility at the initial stage of development is considered, as well as the advantages and disadvantages of involvement of the steam engine.

Klíčová slova: ORC, steam engine

Introduction

Simultaneously rising energy prices the interest to alternative energy sources and more efficient conversion of various types of energy sources is growing. Recently ORC technology is being widely investigated for the possibility to convert so-called low-potential heat to mechanical (electric) energy. In contrast to the conventional Rankine cycle (Clausius-Rankine Cycle) the medium is not water. These media allow use of a greater pressure declivity at lower temperature conditions than is the case of water. This means that in the event of the expansion of the saturated vapor to pressure of the condensing may remain in a state of superheated steam.

ORC technology type options are commented in the first chapter. Advantages and disadvantages of the use of steam engine compared to the steam turbine are described in chapter two. Chapter three focuses on the specific parameters of the investigated devices and analyzes of the economic aspect in the design of the device. In chapter four some media used for a small temperature gradient are shown. Also aspects relating to the selection of suitable media for the device are considered.

1. ORC device options – types

From a structural and thermodynamic point of view the types of equipment ORC can be divided into several types. Four basic types are listed below.

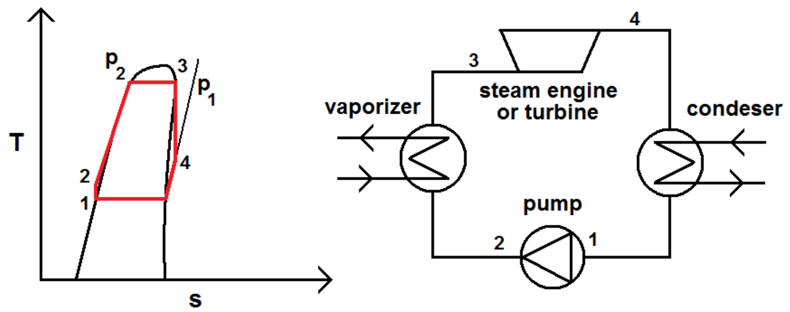

Figure 1: Basic design of ORC device

The figure 1 shows the basic design layout. In this case the medium is heated only in the evaporator. The medium is supplied to the engine in a state of saturated vapor.

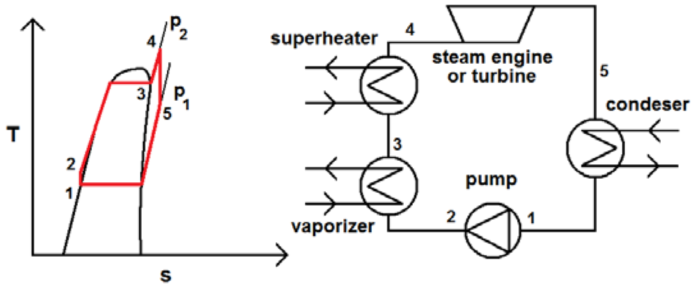

Figure 2: Modified design of ORC device - superheater

The figure 2 shows the modified design of the base. In this case the medium is heated in the evaporator and superheater. The medium in this case usually leaves the steam engine or turbine temperature greater than the basic configuration of the system. In case of the same temperature gradient is this system less efficient.

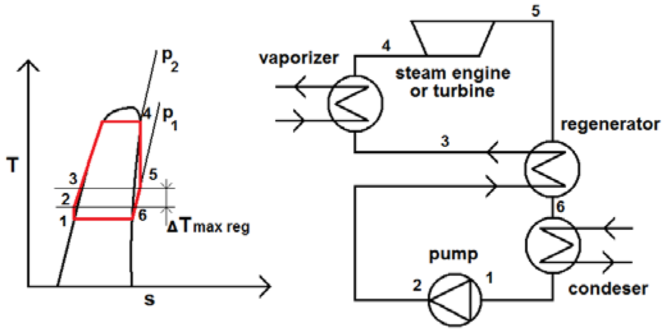

Figure 3: Modified design of ORC device - regenerator

The figure 3 shows the basic design with the regenerator. Because the media usually leaves the steam engine or turbine with higher temperature than the condensing temperature is possible to use a special heat exchanger for regeneration of part of heat - regenerator.

The figure 4 shows the design of system with superheater and with regenerator. In case using of superheater the pressure differential in regenerator is usually greater than in case of basic design. For this reason, it is more convenient to use the regenerator in than in case design without a superheater.

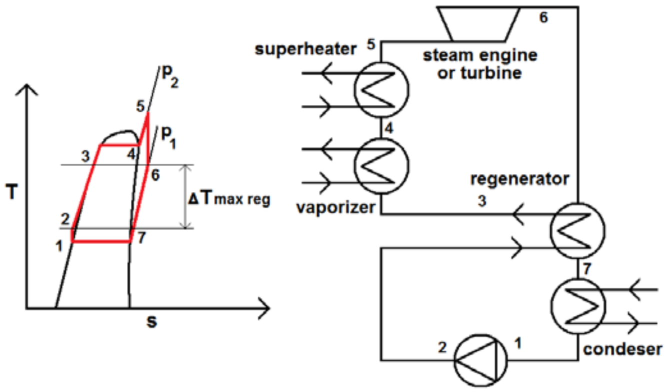

Figure 3: Modified design of ORC device – superheater and regenerator

2. ORC cycle with steam engine

The steam engine has the disadvantage cause pressure pulsations in the full facility, compared to the turbine. These pulsations may be caused by shock pressure at the opening of sluice valves or valves, are also caused by non-continuous feeding media into the engine cylinders. The advantage of the steam engine is a relatively wide regulatory ability and ability to work in a wide range of power. Thermodynamic description of the process is also more difficult.

In the case of expansion-type steam engine, the working part of the cycle is divided into two steps. In the first stage inlet valve is opened and in ideal case, the cylinder is filled by fluid under constant pressure. The second expansion part of working process is at the sealing off the media in the cylinder. The medium is expanded to a pressure which is closed to the pressure in the condenser.

From a constructional point of view it is necessary to take into account the pressure pulsation in the design of equipment and design of regulation.

3. Economic aspect of equipment design

One of the most important points in the design of ORC device is properly defining of working temperatures – vaporization temperature and condensing temperature. Selection of appropriate media is determined mainly according the temperatures. For economic reasons it is appropriate that the critical point temperature of the medium is higher than the temperature of evaporation. The estimated quantity of media for unit is of the order of several hundred kilograms to 100kW heat of vaporization. To select the media must be taken into consideration price of the media, media influence to the environment, toxicity, effects to health and fire safety.

Selection of appropriate media for re ORC equipment is relatively limited. Development of ORC is a relatively modern matter therefore it is usually chooses media which is produced primarily for use in refrigeration and air conditioning technology. At present there is only one medium that is produced primarily for the purpose of ORC - R245fa.

Ideal media has a critical point temperature slightly higher than the temperature in the evaporator, is flame resistant, non-toxic and does not endanger the environment in the event of leakage. If these conditions are not met, it means increased costs for equipment, to minimize leakage. It should also take into account handling and storing media.

It is also important thermodynamic properties, which determine the arrangement of equipment and chemical properties that determine the materials that are in contact with the medium.

4. Media used for ORC equipment

The following table summarizes the thermodynamically suitable media for the ORC device with vaporization temperature around 100 ° C. These media are easy to get in market in the Czech Republic.

ODP factor is ratio comparing harm the ozone layer with refrigerant R12.

GWP factor is ratio comparing the impact on the greenhouse effect with CO2.

Tab 1: Suitable media

Media	name	Crit. Temp. [°C]	Crit. Press. [bar]	Toxicity	Flammability	ODP	GWP
R125	Pentafluoroethan	66.18	36.3	Low	Not Flammable	0	3500
R134a	Tetrafluoroethan	101.06	40.6	Low	Not Flammable	0	1430
R227ea	Heptafluoropropan	102.8	29.8	Low	Not Flammable	0	3220
R245fa	Pentafluoropropan	154.1	36.4	Narcotic effects	Not Flammable	0	1030
R290	Propan	96.7	42.5	Low	Extremly flamable	0	3.3
R600	Butan	152	38	Low	Extremly flamable	0	4
R600a	Isobutan	134.7	36.4	Low	Extremly flamable	0	3
R717	Amoniak	132.4	112.8	Highly toxic	Flamable	0	0

Conclusion

This article contains basic information about the so-called ORC facilities. Basic types of design arrangements have been summarized together with the corresponding essential ideal thermodynamic descriptions. Furthermore, the idea of using of a steam engine for ORC devices is introduced together with aspects of using steam engine. It is not left out an economic aspect, the aspect which is considered particularly in the initial stage of development facilities. This applies particularly to the selection medium. The next phase of development must be focused mainly on the method of regulation, thermo-mechanical description of the equipment and legislative regulations concerning the ORC.

Literature

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