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Procedia CIRP 61 (2017) 570 – 575

www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

Qualification of aqueous part cleaning machines for the use of waste heat in industrial production companies

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Abstract

This work presents an overview of solutions how part cleaning machines can be enabled to implement an external heat supply. The proposed solutions have to meet special requirements due to contaminated cleaning media during the heat exchange process. Standard components are used during the development and implementation to reach broad operational capability in different industries and industrial companies. Comprehensive measurements and studies of a single chamber cleaning machine with external heat supply through heat recovery of machine tools reveal an energy saving potential of more than 35 %.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

Keywords: energy efficiency; aqueous part cleaning; heat recovery; linked energy systems

1. Introduction

With the final global pact of the 2015 United Nations Climate Change Conference, a consensus agreed by 196 countries (the "*Paris agreement*"), the necessity to reduce carbon output and to keep global warming turn into political objectives worldwide [1]. Germany has a pioneer role by the political decisions to force the energy transition [2]. Especially increasing energy efficiency in the industrial sector is an important element of this strategy [3]. For the target achievement efficiency measures by optimizing the use of process heat are indispensable. In 2012 approximately 87 % of totally 1,923 Petajoule supplied process heat were used in the industrial sector [4]. Large quantities of the heat are lost after the actual processes [5], and thus the potentials of heat recovery are huge. One necessary requirement is a crosslinking between heat sources and sinks in production systems. Potentials to increase energy efficiency up to 40 % are given by linked production systems [6]. However, various barriers prevent a comprehensive implementation of such measures. Missing experience or knowledge, complexity of the technical systems and mismanagement are mentioned in literature as main causes [5].

In addition to these barriers, for the utilization of aqueous cleaning machines as a waste heat sink special aspects need to be taken into account, e. g. aggressive media or fouling. The leading questions of this research paper are: how can aqueous cleaning machines be enabled to use waste heat in industrial production systems and which energy saving potentials can be realized? In order to answer these questions this paper has the following structure:

In section 2 the characteristics of aqueous parts cleaning are described. On this basis, the selection of a heat exchanger is discussed (section 3) and the effectiveness of two different concepts is calculated in section 4.1. Additionally, the possible influence on the heat exchanger performance of fouling processes is examined. Finally, the energy saving potential of a crosslinked system consisting of a cleaning machine and a machine tool is shown in section 5.

2212-8271
Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.201

2. Characteristics of industrial aqueous cleaning processes

2.1. Parts cleaning

Part cleaning processes are commonly used in the metal processing industry. In process chains there are multiple reasons for part cleaning operations [7]:

- Mechanical manufacturing, e.g. before machining, assembly, measurement, packing
- Before surface treatment, e.g. electroplating, coating
- Before heat treatment
- Maintenance and repair

These different tasks of cleaning processes cause many types of contaminations which require a specific treatment. Lubricants, coolant, grinding paste, inhibitors, solid particles, rust, oxides, old coatings and others are listed in [8] and frequently combinations can be found. In accordance with these diverse cleaning tasks many different processes of cleaning are necessary to get the required results. Aqueous and, in particular, spray or immersion cleaning are processes mainly used, according to a study of manufacturers and end users [9]. In almost nine out of ten interviewed companies aqueous cleaning processes are applied from which over 50 % use immersion and spray cleaning methods. In this paper, the most common applications of cleaning processes are examined. This ensures a high transferability.

2.2. Cleaning machine and process

In this work a standard machine for spray cleaning processes is used for further studies. The central element is the cleaning chamber with a rotating basket system for different kind of parts in a batch production system. A two-step filtration system removes swarfs and small particles with diameters larger than 100 μm. An electrical heating system is installed in the process water tank. It balances the heat losses resulting from the heating of the parts with ambient temperature and the surface heat losses of the machine, which are shown in Fig. 1. a).

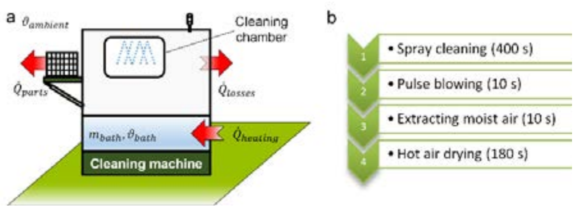

Fig. 1. (a) Heat flows of a cleaning machine, (b) Applied cleaning process

The cleaning machine has an integrated hot air drying system which prevents corrosion through residuals of process water. The defined cleaning process in combination with a batch mass of 25 kg results in an electrical power consumption on component level as given in Fig. 2.

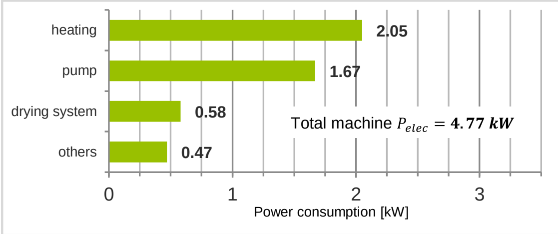

Fig. 2. Mean electrical power consumption on component level over one cleaning process

The temperature of the cleaning bath was $\vartheta_{bath} = 60°\,C$. The biggest share of the heating power is needed to compensate the heat losses with $\dot{Q}_{losses} = 1.18\ kW$. The rest is needed to warm up the part mass flow for every new batch. The mean electrical power demand for one cleaning process (for process details and timings see Fig. 1.b)) results in a total energy demand of 0.80 kWh. Detailed technical specifications needed for further examination are shown in Table 1.

Table 1. Technical specifications of the cleaning machine

Specification	Value
Tank volume	320 l
Heating capacity	10 kW
Spraying pressure pump	
Volume flow	200 l/min
Pressure	2.0 bar
Hot-blowing drying system	
Volume flow	160 m³/h
Max. temperature	90° C

2.3. Media in aqueous cleaning processes

The most important factor which influences the heat exchange conditions is the used cleaning media. Depending on the different tasks of the cleaning processes and types of contaminations the heat-transfer media consists of a mixture of many different ingredients. Inter alia cleaning active agents, polyphosphates, inhibitors, corrosion protection, emulsifiers, stabilizers, biocides are listed in [8]. Relevant for the heat exchanging process are especially solid particles in combination with liquids of higher viscosity and saponification effects. This results in a high tendency of fouling on heat transfer surfaces [10] and constitutes the major challenge to select the correct heat exchanger technology. Additionally, the cleaning media often carry aggressive substances and reduce the usable heat exchanger materials. Section 3 describes the possibilities of different heat exchanger concepts to meet this challenge. In section 4.2 the detailed effects of fouling on the heat exchange will be discussed.

3. The Selection of a heat exchanger

3.1. Challenging process

The selection of the proper components in a thermodynamic system is difficult. Multivariable influences cause complex