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Cavitation Detection and Prevention in Professional Warewashing Machines

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Abstract

Cavitation is a phenomenon characterised by the presence of vapour bubbles in the fluid led by a local drop in pressure. In literature it is well known the impact on cavitation of pressure and temperature of pure water, but there are only few studies analysing how the presence of certain components of detergents and additives can influence the phenomenon. The impact of detergents and additives could be explained by the modified viscosity and rheology of the solution but also by the variation in the vapour tension. Most of these effects are due to the presence of surfactants and polymers in the solution. Cavitation in dynamic pumps is an important aspect that needs to be monitored and prevented, because it can cause damages affecting pump performances and inducing an increment in the level of vibration and noise. In professional warewashing machines, as for example the models of Electrolux Rack Type, this phenomenon can affect the operating functionalities of the machine. An experimental pump test rig has been realized with the aim of studying and monitoring the influence of these parameters on cavitation inception. This test rig permits measuring the pump performances at various operating conditions, in order to obtain its characteristic curves, and also forcing cavitation to measure its Net Positive Suction Head required (NPSHr) at different flow rates. The pump test rig allows also testing various configurations of the pump at different cavitation conditions, obtained by changing not only the suction pressure and temperature of the fluid but also its properties, adding detergents and additives. Cavitation inception can be detected measuring both the corresponding prevalence decrease and the change of vibration and noise level.

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Keywords: Cavitation ; Detergents ; Polymers; Professional warewashing machines;

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1. Introduction

In the hydraulic circuit of a warewashing machine, fluid flow circulation and the kinetic energy needed for the soil removal are supplied by a centrifugal pump. The fluid is a solution of detergents and water, and the cleaning process is performed in three main steps. The first step is based on a physical process and chemical reactions that aim to displace the soil from the substrate. A second phase has the function of dispersing the soil into the cleaning medium. The last phase aims to prevent the soil re-deposition. The cleaning process is then guided by four main factors that are chemistry, mechanics, temperature and time. These factors and their interactions are visible in the Sinner's circle [1]. The actual trend in professional appliances is to reduce the time needed for cleaning process, with short washing cycles conducted at low temperatures [2]. This requires a concentrated chemistry for having good washing performance, and high concentrated chemistry could impact also on pump performance, especially on cavitation. A cleaning product is characterized by different components as surfactants, alkalis, acids, builders and other substances. Basically the detergent action in warewashing machines is made by the action of the builders and surfactants. Surfactants, builders and other detergent components could affect the water-detergent solution properties in such a way that it can also no longer be considered a Newtonian fluid, like pure water [3], [4]. These can have an influence particularly on the cavitation inception [5], but in literature there are only few studies on cavitation with detergent solutions, [6], [7], [8], [9], [5], [10], [11]. The present work presents first a literature research on the main parameters affecting cavitation inception which are modified due to detergents components. The wide range of variables affecting the phenomenon has then pushed the necessity to realize a test rig that permits to study cavitation in centrifugal pumps at the different operating conditions and with the detergents used in the professional warewashing sector. The test rig allows to change all possible parameters that can affect cavitation and to test different fluid solutions.

Nomenclature

p_k	Pressure, k stands for undisturbed liquid at distance of the object (*0*), critical (c), vapour (v);
p_{tk}	Threshold pressure amplitude, k stands for oscillation (v), for a nucleus to grow by rectified diffusion (d);
p_A^k	Vapour tension, k stands for partial of the solvent (p), pure solvent (ps);
v_0	Relative velocity between immersed object and surrounding liquid;
C_k	Concentration of gas, k stands for actual (∞), saturation (0);
S	Surface tension;
$NPSH_k$	Net Positive Suction Head, k stands for available (a); required (r);
ρ	Density of the liquid;
σ_i	Incipient cavitation number;
R_k	Radius, k stands for bubble (b), initial bubble (n);
p_{l0}	Ambient or mean liquid pressure;
x_A	Molar fraction of the solvent;
m_k	Moles, k stands for water (H_2O), potassium caprate (PC);
MM_{PC}	Molar mass of potassium caprate (PC);
w_{PC}	Weight of potassium caprate (PC);

2. Brief analysis of cavitation inception phenomena

Cavitation inception happens when bubbles appears in the fluid flow. Tab 1 classifies hydrodynamic cavitation cases according to [5].

Table 1. Classification of hydrodynamic cavitation

	Characteristics	Zones
Travelling cavitation	Individual transient bubbles which expand and shrink. When bubbles enter in a region of high pressure they collapse.	Bubbles appear in low pressure zones along solid boundaries, or in moving vortices.
Fixed cavitation	Develops after inception. Flow detaches from the rigid boundary of an immersed body or a flow passage.	Bubbles appear in highly turbulent surfaces, in particular in the low pressure side of the blades.
Vortex cavitation	Bubbles form in low pressure cores of vortex regions of high shear.	Bubbles appear in open and ducted propellers.