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FUNCTIONAL TEST FOR SEWAGE PUMPS

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ABSTRACT: Wet wipes cause many blockages in sewage pumps. The clogging materials of field pumps were analyzed. The clogging effect of comparable wet wipes was determined in laboratory tests to test the suitability of different types of sewage pumps. For this purpose, a conveyor circuit was constructed and fed with different wastewater concentrations (proportion of wet wipes) and conveyor flows. Two new indicators, DF and DLTF, are used to evaluate the results. A reproducible test procedure was tested and proposed.

KEY WORDS: waste water transport, pumps, wet wipes clogging problems.

1. INTRODUCTION

While personal water consumption in Germany decreased by 20% between 1990 and 2015, the consumption of wet wipes increased by 200% over the same period. This results in considerable problems for the operation of sewage systems with wastewater discharge in the sewer system, in the conveyance of wastewater, and also in sewage treatment plants.

Wet wipes are now a problem in wastewater technology and the environment worldwide (Conolly et al., 2017), (Orr, Karadagli, 2018), (Water UK, 2017).

Whereas in the past a minimum ball passage of 100 mm (ATV-DVWK-A 134, 2000) was required for sewage pumps and pipes, the susceptibility of pumps and pipelines to clogging must now be reassessed. The risk of clogging of sewage pumps must be reassessed, in particular because of the wet wipes in the waste water. (Jensen et al., 2015) also describe the clogging processes of sewage pumps. New German regulations (DWA A 120-2., 2022) require manufacturers of wastewater pumps to prove that they are insensitive to the clogging of wet wipes.

2. SOLIDS IN WASTEWATER

In a wastewater pumping station in Berlin, blockages were examined with regard to the clogged materials. In the catchment area of 15.3 km³ there are about 143000 inhabitants. The residential area is drained by a separation system. The average amount of wastewater

generated in dry weather is 18500 m³ per day. The pump is dry installed with a closed channel impeller (outer diameter 404 mm). Three blockages (flow rate reduced by 10%) from the field (summer/winter, averaged: morning, noon, and afternoon) have been investigated. The blocking material was removed, disinfected, and carefully separated by hand (Figure 1). Then the dry weight of the fractions was determined. The measured values are given in Table 1.

Figure 1 Wastewater pump and analysing clogging material

Table 1

Distribution of solids in pump blockages

Pump blockage Material In %	Nu. 1	Nu. 2	Nu. 3	Average
Spunbonded nonwowens	53	51	46	51
Staple fiber nonwowens	14	15	10	13
Wetlaid nonwowens	4	4	5	4
Feminine hygiene products	3	5	10	6
Rest	27	24	28	26
Weight in g	186	164	119	156

In 12 samples of wastewater from different catchment areas in Berlin the following ingredients were found:

2 % plastics,
3 % rest,
16 % wood leaflets,
24 % textiles,
55 % paper.

The difference in clogging material is due to the self-dissolving-process of toilet paper and an accumulation of textile material mainly from wet wipes, which are not flushable.

Therefore, the major constituent of clogs: spunbonded wipes (baby wipes, cleaning wipes, and cosmetic wipes). One reason for this is the incorrect disposal of wipes by users. Not all moist toilet wipes sold as flushable are pumping system safe (incorrect manufacturing or labeling).

Figure 2 Wipes found in wastewater systems

3. FUNCTIONAL TEST OF WASTEWATER PUMPS

3.1. BASICS

To test the functionality of wastewater pumps, they are tested with artificial wastewater (clear water with different loads of wipes). Synthetic dusters are used as wipes, which act as an indicator of the clogging behavior of the wastewater pump to be examined.

Other wet wipes that do not dissolve in water can also be used (baby wipes or other hygiene wipes). As a result, significant and reproducible differences in the functionality of wastewater pumps are determined via the individual degree of function and the degree of continuous function, which allow an assessment of their tendency to clog.

Two different tests are carried out to determine the functionality:

A single-function test with a single flow of a certain volume of artificial wastewater, in which the mass and number of wipes pumped through are determined. This test simulates the pumping out of collected dirty water, for example, in a collection shaft of a pressure drainage system.

A long-term function test in which the effluent is pumped in a circuit for a predetermined period of time, determining the changes in efficiency and the clogging mass remaining in the pump. This test simulates a pumping station in a local drainage system, to which frayed cloth has already flowed through previous pumping. In addition, the endurance function test can be used to investigate the self-cleaning effects of the pump.

3.2. PREPARATION

The waste water pump to be tested is installed on the test bench in such a way that the measurement conditions of EN ISO 9906 are met. The test circuit is switched via clog-free valves with short opening and closing times, for example via pneumatic shut-off valves.

The selected operating point (speed, flow rate, and head) of the pump is first approached with clear water and maintained during the test. Before each test, the wipes are soaked for at least 24 hours so that they are well soaked and do not float in the container. The number of cloths corresponding to the loading class (see D.3) of the artificial waste water is thrown into the dirty water tank (SWT), which is partially filled with clear water.

The SWT is then topped up with fresh water to the specified volume. It is necessary to ensure that the cloths are evenly distributed in the water.

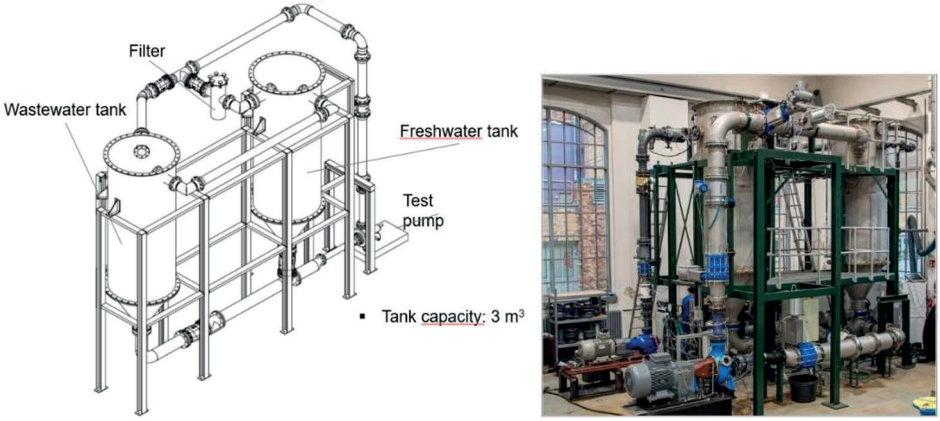


Figure 3 Functional test bench

3.3. LOADING CLASSES

To evaluate the functionality of the sewage pump, i.e., the avoidance of clogging of the pump and its ability to convey solids in the wastewater, synthetic dusters made of plastic fabric are used here. These wipes simulate the behavior of wet wipes that do not dissolve in wastewater. To simulate different loads on the pump, artificial wastewater is generated with three different loading classes (see Table 1). The quantities of wet wipes for the different wastewater classes were based on studies by (Mitchel et al., 2018) and (INDA/EDANA, 2018).

Table 2

Characteristics of artificial laboratory wastewater (Wipes as indicator)

Loading class	Specific fibre content in g/m³	Fibre material	Number of wipes per m³	Size of wipes
1 lightly loaded	95 – 108	100 % synthetic fibres	25	21 x 30 cm
2 medium loaded	190 – 215	100 % synthetic fibres	50	21 x 30 cm
3 heavily loaded	380 – 430	100 % synthetic fibres	100	21 x 30 cm

3.4. SINGLE FUNCTION TEST

The procedure of the test is shown schematically in Figure 4 and in outline point 3.6.

The artificial wastewater is pumped by the wastewater tank (SWT) into a fresh water tank (FWT). There is a filter in the drain of the FWT. The measurement is terminated as soon as the SWT is pumped empty. During the measurement, the head, volume flow, and power consumption of the wastewater pump are continuously measured.

After the measurement, the pump is opened, and the fibrous materials are removed from the pump and the filter. Any blockage is documented. Finally, the entire circuit is flushed so that no fibrous materials remain in the system. From the dry matter of the collected fibrous materials, a single degree of function is determined.

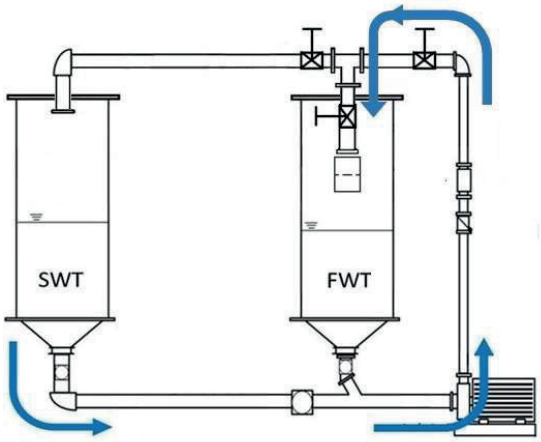


Figure 4 Configuration for single function test

3.5. ENDURANCE TEST

Figure 7 schematically shows the procedure for the endurance test. During the endurance test, artificial wastewater is pumped into the circuit. During the endurance test, the head, volume flow, and power consumption of the wastewater pump are also measured over the entire duration of the test. After 60 minutes, the test is terminated, and the pump is switched off. The pump is then opened and the fibrous materials are removed from the impeller of the pump. Finally, the artificial wastewater is pumped through the filter of the FWT and the test bench is flushed. The degree of continuous function is determined by the dry matter of the fibres taken from the impeller.

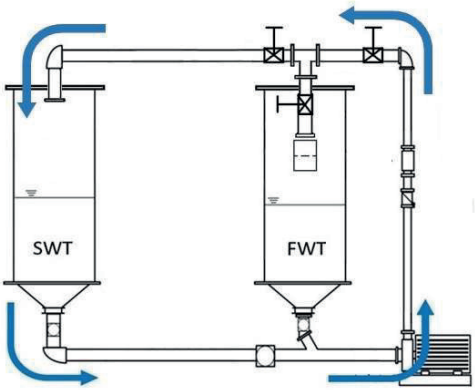


Figure 5 Configuration for endurance test

The tests are carried out for different operating points Q/Qopt= 0.8 / 1.0 / 1.2 and, if necessary, several times in order to average the fluctuations.

3.6. MEASUREMENTS FOR FUNCTIONALITY

The single function grade D_F is the ratio of the fiber dry solids (FTM) conveyed and fed during the single function test. The definition is

$$D_F = \frac{supplied\ FTM\ [g] - FTM\ in\ the\ Pump\ [g]}{supplied\ FTM\ [g]} \quad . \tag{1}$$

Pumping a defined volume - balance of the cloths (Value range 0…1)
The following procedure for the measurement of functionality was used:
Setting the operating point to be tested,
Premix of artificial wastewater,
Start the measurement,
Pump from the waste water tank into the fresh water tap through the filter,
After measurement:
Opening and documenting the pump/filter,
Flushing the circuit,
Calculate the D_{STF} functional level.

The continuous function degree D_{LTF} of the endurance test is the average value of two components, on the one hand, the ratio of the FTM pumped during the endurance test and the FTM supplied, and on the other hand, the ratio of the efficiency averaged over the test run time to the clear water efficiency at the set operating point:

$$D_{LTF} = \frac{1}{2} \cdot \frac{average\ efficiency\ [\%]}{efficiency\ at\ operating\ point\ [\%]} + \frac{1}{2} \cdot \frac{supplied\ FTM - FTM\ in\ the\ Pump\ [g]}{supplied\ FTM\ [g]} \tag{2}$$

3.7. EVALUATION OF FUNCTIONALITY

The following Figures 6 and 7 show examples of the test results for submersible pumps with several impellers.

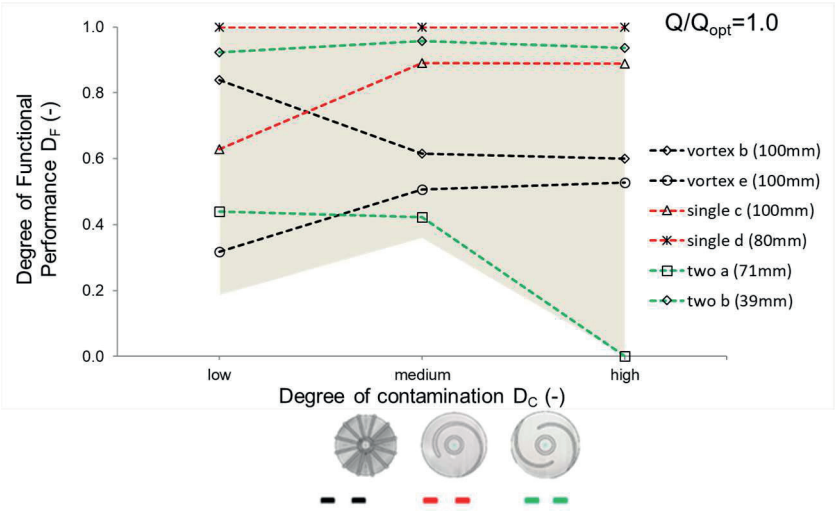


Figure 6 Degree of functional performance for several pump types

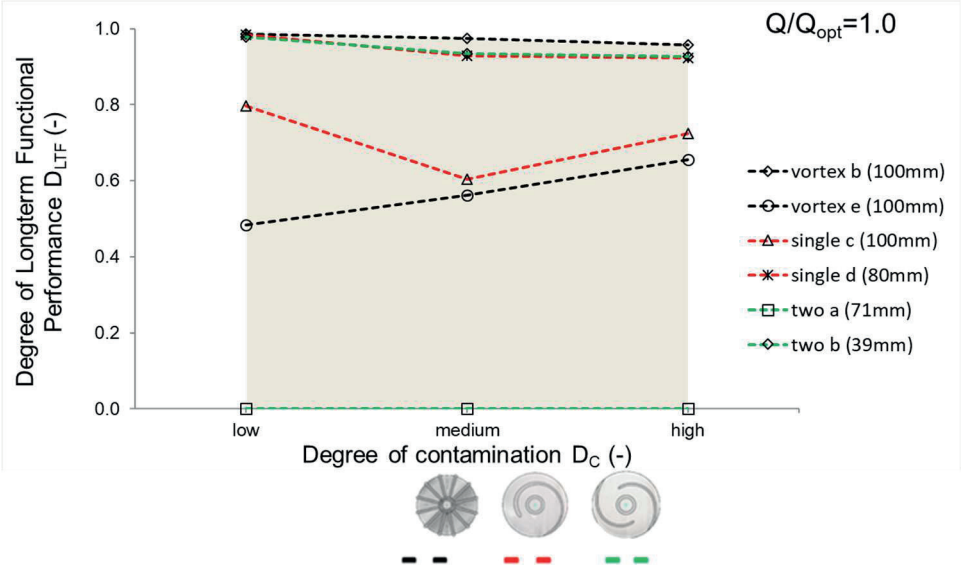


Figure 7 Degree of long time functional performance for several pump types

Poehler and Thamsen (2018) developed a method to evaluate wastewater pumps with regard to functionality and energy efficiency.The Water to wire (total) Efficiency η_{gr} is shown in Figure 8 for different impellers.

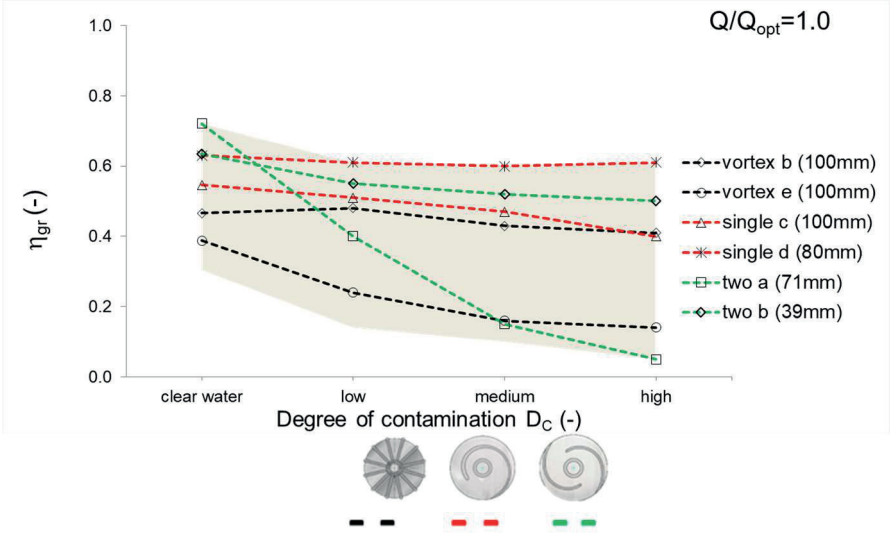
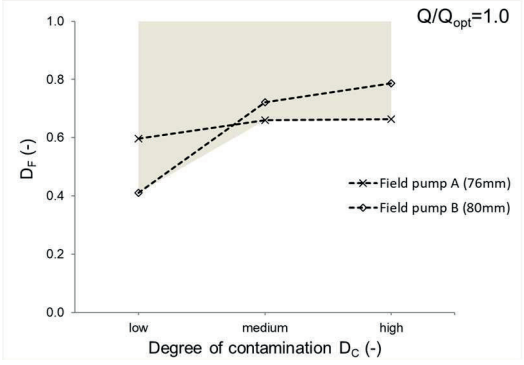


Figure 8 Water to wire efficiency for various pumps

Figure 9 shows functional level D_F and continuous function level D_{LTF} for sewage pumps from the field (blind test)

Pump A
Hours of operation per day: 1,33
MTBF = 8,75 h

Pump B
Hours of operation per day: 2,85
MTBF = 15 h



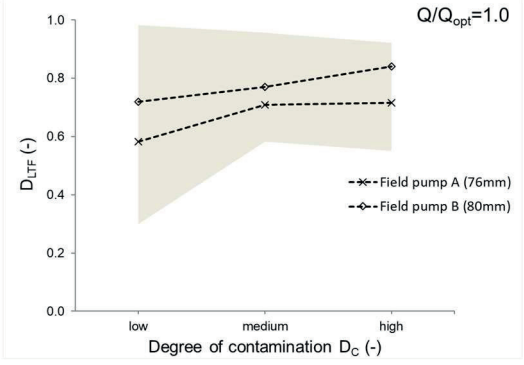


Figure 9 Wastewater pumps from the field

An overview of 24 tested pumps is shown in Figure 10

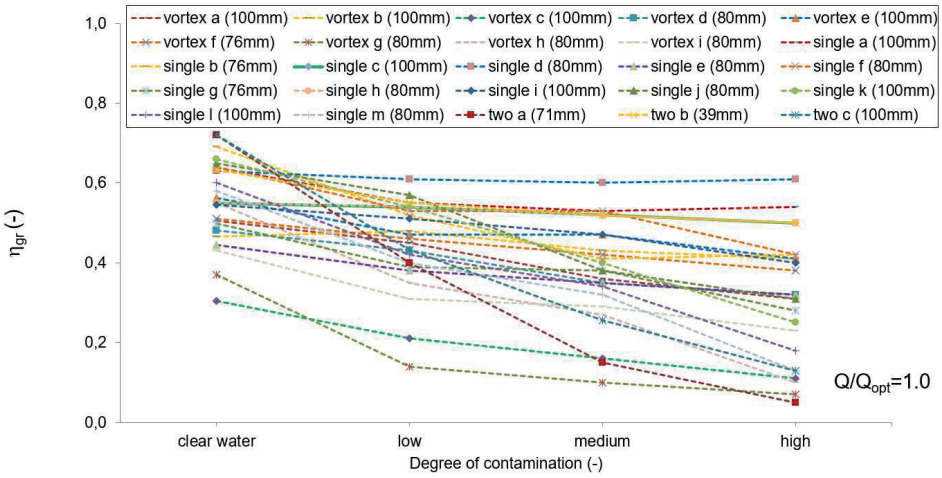


Figure 10 Water to wire efficiency η_{gr} for various pumps

4. CONCLUSIONS:

Ever increasing amounts of wet wipes in domestic wastewater led to problems at wastewater pumping stations. The previously common free ball passage is not suitable for evaluating the clogging tendency of a centrifugal pump. Functional performance is neither dependent on impeller technology nor free ball passage. Each pump shows specific behavior (own specifics and advantages/ shortcomings). Developed testing procedures and assessment allow the comparison of functional performance of wastewater pumps. From the D_F functional level and the D_{LTF} continuous functional level, the clogging behavior of wastewater pumps can be reproducibly and unambiguously described.

Both the degree of function and the degree of continuous operation for low-clogging wastewater pumps achieve values of 0.7 and better.

It should be noted that good degrees of function can be achieved by all types of impellers and are relatively independent of the free passage of the ball. The functionality of a sewage pump is achieved or not achieved by the overall design of the sewage pump.

As a result, it can be determined:

- The Functional test is recommended,
- A practicable test procedure has been developed,
- A general impeller type recommendation cannot be given,
- The values D_F & D_{LTF} should be greater than 0,7.

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