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Verification of Horizontal Flow Grit Chamber Performance at Various Load Conditions

Tamas Karches[1] and Daniel Szelpal[1]
[1]*National University of Public Service, Faculty of Water Science*
Bajcsy-Zsilinszky Str. 12-14, HU-6500 Baja, Hungary

Abstract: Horizontal flow grit chambers are widely used in wastewater treatment in order to separate the grit as well as the grease and decrease the settleable inert material load flowing to downstream units. Design of grit chambers is based on engineering assumptions, empirical formula, mainly taking into account only one design flow. In case of changing flow condition entering the grit chamber the performance may differ from the design performance. With the help of numerical flow analysis the settled solid, thus the capability of the system could be determined cost-effectively in design phase. In this paper an existing horizontal flow grit chamber performance was tested at dry weather average, dry weather peak and wet weather peak flows. It was concluded that different load condition had effect on particles, which diameter is less than 0.2 mm, reducing the settling efficiency from 99% to 95% or less.

Keywords: gritchamber, hydrodinamics, horizontal flow, phaseseparation

I. Introduction

Mechanical pre-treatment of wastewater generally consists of screening, grit and grease traps, which aims to separate debris, mineral solid, FAG (fat, oil and grease) content from the receiving raw wastewater [1]. These units are responsible for protection of subsequent processes from clogging and reduce the maintenance cost of the overall plant if it is designed properly. With the removal of inorganic particles the accumulation in biological tanks or digesters can be also prevented. Grit and FAG can be separated in one combined unit, based on the specific weight difference between the particles and the fluid. There are many types of grit removal; aerated grit chambers, vortex-type systems and horizontal flow grit chambers are used generally, but examples can be also found for hydrocyclones. The selection of the appropriate unit should take into consideration many factors like the downstream processes, head loss, removal efficiency, type of the wastewater (e.g. organic/inorganic content) and also the volume/surface required [2].

Vortex type grit chambers are generally used in small plants (usually the capacity is less than 10 MLD). Two designs are common: flat bottom with small opening and sloped bottom with large opening. Inlet can be straight or streamlined. The ideal velocity range is in between 0.8 to 1 m/s during peak flow, 0.3-0.4 m/s at average flow. A minimum velocity of 0.15 m/s is also introduced since low velocities can not carry the grit into the system [3]. Aerated grit chambers are fed with air bubbles produced by coarse bubble diffusers in order to create a spiral flow pattern, where the heavier particles could be accelerated and separated from the streamlines. The particles dropped out from the main flow are accumulated at the bottom of the tank. The residence time required in such a system is from 3 to 10 minutes. Aeration is only introduced due to hydrodynamic reasons and not designed for preventing the septic conditions may occur. Horizontal flow grit chamber is the traditional way of designing grit removal [4]. Heavier particles settle to the bottom of the channel, where a scraper mechanism helps to collect the grit [5]. Generally, an inlet velocity of 0.3 m/s is considered and applied at dry weather condition in the design. However, the sizing is necessary to be tested for other flow conditions.

A wastewater treatment plant receives the raw wastewater unevenly; it has a diurnal and a seasonal pattern. Diurnal flow variation is due to uneven water usage and also depends on the collection system. Peak factor is determined by applying the highest hourly flow divided by the daily average flow. Peak factor for a small plant can be as high as 2-4, whereas in large plant it can be reduced to approximately 1.4-1.6, which may overload the grit chamber. Not only the overloading, but underload could also occur. Proper design of a grit chamber considers various load conditions, which has a following procedure: (i) calculating the design volume and dimensions assuming average conditions, (ii) verifying the design for extremities. Latter may require a lot of field testing, which is time consuming and not cost-effective. A simpler method is to build up a numerical model, which could predict the settling efficiency of the grit chamber based on the flow field calculated by hydrodynamic simulations.

Aim of this research is to present the above mentioned state-of-the-art method with which the operation of grit chambers could be optimized and verified at different flow conditions. The methodology and the model setup is described in Section 2, the results are presented in Section 3 and the conclusions drawn are in Section 4.

II. Materials And Methods

Computational fluid dynamics is a tool to describe the flow behavior within a process unit. Velocity field is described at each simulation point, which takes into account the mass and momentum conservativity with turbulence effect in the domain simulated [6]. Simulation procedure is the following: (i) drawing the geometry, (ii) spatial discretization of the domain, (iii) setting the physical conditions, boundary and initial conditions, (iv) selecting the numerical solver, (v) calculation procedure and (v) evaluation of the result. Based on the flow field calculated sedimentation can be predicted applying Lagrangian-approach [7]. Force balance is calculated for each particle and the fate of the injected particles are followed. Performance testing calculations were carried out in an existing horizontal flow grit chamber design, the dimensions are summarised in Table I.

Table I: Dimensions of thehorizontalgritchamberapplied in themodel

Length	21.60 m
Width at the inlet	0.85 m
Width at the outlet	1.25 m
Floor area	38.40 m^2
Perimeter	46.68 m
Height at the inlet	0.5 m
Height at the outlet	0.71 cm
Volume	12,95 m^3
Outer wall thickness	0.3 m
Inner wall thickness	0.2 m

The inlet structure has multiple small tubes with 150 mm length and 80 mm inner diameter. The tube arrangement is assymetric; the top and bottom line have 6, the middle line has 7 tubes (see Fig. 1). The flow outlet is a weir with the length of 1.5 m and height of the overfall is 5 cm. The bottom of the grit chamber has a slope of 1% ending in a sump with a depth of 28 cm (Figure 1).

As a result of the spatial discretization the entire volume was divided to 360 908 sub-volumes which has 74822 nodes. In the model the boundary conditions were the following: inlet as a mass flow inlet, outlet as a free outflow, surface as a zero-shear wall condition.

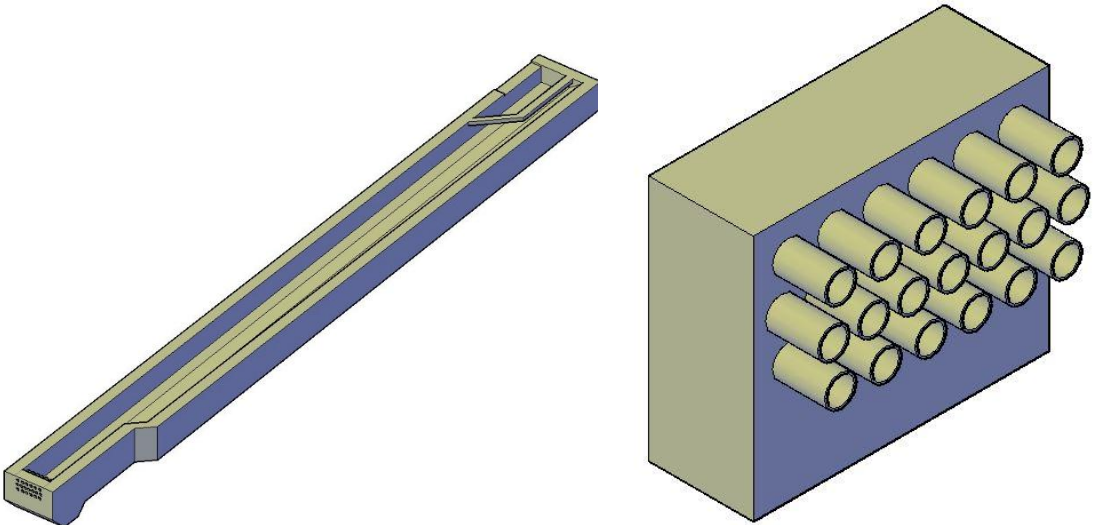

Figure 1: Isometric view of the horizontal grit chamber (left), inlet structure (right)

III. Results

Simulations were performed applying various wastewater discharge: dry weather average flow was 30 000 m^3/d, dry weather daily peak flow was 43 500 m^3/d and wet weather average flow was 60 000 m^3/d, which resulted 0.26, 0.18 and 0.36 m/s volumetric average velocities inside the grit chamber respectively. It means that even in the case of high flow the velocities are little higher than the 0.3 m/s design value in the examined horizontal flow grit chamber.

For the evaluation of the performance the actual velocities are not enough. Model particles with the physical properties of sand (density=2650 kg/m^3) were injected and their pathline was observed and summarized the number of particles reaching the outlet (non-settleable particle) and the particles reaching the bottom (settled particle). The bottom wall worked as a trap, the side walls were set as a reflecting surface in the model. The results are summarized in Table II-Table IV, where different flow conditions and various particle diameters were assumed. It can be seen that some of the particles showed an incomplete pathline at the end of the simulation, therefore the number of these particles were substracted from the injected particles. Settling efficiency was determinded by dividing the number of settled particles with the number of particles with completed pathline.

Table II: Settling efficiency at dry weather peak flow

Diameter	***0.05***	***0.1***	***0.2***	***0.5***	***1***
	[mm]	***[mm]***	***[mm]***	***[mm]***	***[mm]***
Injected model particles	14953	14953	14953	14953	14953
Non-settleable particles	3666	2398	106	0	0
Settled particles	11250	12516	14779	14871	14762
Uncertain/ Incomplete pathlines	37	39	68	82	191
Settling efficiency	75,48 %	83,96 %	99,29 %	100 %	100 %

Table III: Settling efficiency atwet weather peak flow

Diameter	***0.05***	***0.1***	***0.2***	***0.5***	***1***
	[mm]	***[mm]***	***[mm]***	***[mm]***	***[mm]***
Injected model particles	14953	14953	14953	14953	14953
Non-settleable particles	3729	2912	674	0	0
Settled particles	11184	11984	14210	14864	14820
Uncertain/ Incomplete pathlines	40	57	69	89	173
Settling efficiency	75,06 %	80,53 %	95,49 %	100 %	100 %

Table IV: Settling efficiency at dry weather average flow

Diameter	***0.05***	***0.1***	***0.2***	***0.5***	***1***
	[mm]	***[mm]***	***[mm]***	***[mm]***	***[mm]***
Injected model particles	14953	14953	14953	14953	14953
Non-settleable particles	3394	1526	2	0	0
Settled particles	11513	13389	14890	14846	14745
Uncertain/ Incomplete pathlines	46	38	61	107	208
Settling efficiency	77,30 %	89,79 %	99,99 %	100 %	100 %

Simulation results revealed that sand particles with a diameter of 0.5 mm or 1 mm can be separated independently from the flow condition. One of the grit chamber design criteria suggests the cut-off diameter of separation is 0.2 mm, which means the particles having a 0.2 or larger diameter should be separated [8]. Based on simulation results the grit chamber modelled fulfil this requirement, having an acceptable 95.5% removal efficiency at wet weather discharge. The particles with smallest diameter (0.05 mm) settle less efficient, but the performance didn’t depend on flow condition, which indicated that this type of grit chamber is a robust solution and did not have performance changes due to flow variations.

Separation of FAG (Fat, Oil & Grease) was also examined. Assuming 850 kg/m^{3}inert particle density and particle diameter in the range of 0.1 mm to 0.3 mm, 127 particles were injected at peak flow condition. The separation efficiency were between 75% to 82% depending on the particle size.

IV. Conclusion

Horizontal flow grit chamber performance was examined with the tool of numerical flow simulations at various discharges. The grit chamber was originally designed for average flow, but computational analysis pointed out that various flow conditions can be modelled cost effectively. After the flow field calculation performed, model particles were injected and the separation efficiency was investigated. As a result, sufficient removal efficiency is achievable for thethe desirable particle diameterseven at wet weather condition and separation of FAG content is also resonable.

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References

[1]. Metcalf andEddy, *Wastewaterengineering: treatment and reuse* (New York, McGraw-Hill, 2003).

[2]. T.R. Camp, Gritchamber design, *Sewage Works Journal*, 1942, 368-381.

[3]. J.Q. Wang, W.T. Jiang and G. Wang,Grit Removal Efficiency of New TypeHigh-effectiveRotationalFlow GritChamber, *ChinaWater and Wastewater 23*(15), 2007, 98.

[4]. J.M. Sawicki,Aeratedgritchambershydraulic design equation, *Journal of environmentalengineering*, *130*(9), 2004, 1050-1058.

[5]. K. Osei and R. Andoh,Optimalgritremoval and control in collectionsystems and attreatmentplants. In *World Environmental and WaterResourcesCongress 2008: Ahupua'A*, 2008, 1-7.

[6]. J.H. Ferziger and M. Peric, *Computational methods for fluid dynamics* (Springer Science and Business Media, 2002).

[7]. A. Berlemont, P. Desjonqueres and G. Gouesbet,ParticleLagrangiansimulation in turbulent flows, *International Journal of Multiphase Flow, 16(1)*,1990, 19-34.

[8]. I. Horvath,*Hydraulics of Sewerage and Wastewater Treatment* (In Hungarian)(Vizdok. Budapest, 1976).