COMMUNICATION SKILLS 2 HOMEWORK
Master of Science in Computational Mechanics
Master Métodos Numéricos en Ingeniería

CFD ANALYSIS ON STRATIFICATION FOR MARKET-STANDARD SWIMMING POOLS

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Summary. *Simulated swimming pools varying the number of inlet jets and their depth to take conclusions on best configurations for less temperature stratification.*

1 ABSTRACT

A series of standard-like shaped swimming pools are simulated varying the number of inlet jets as well as the depth in which they are located in order to try to take conclusions on which are the best configurations which led to less temperature stratification. The knowledge on the market of the firm Fluidra gives confidence on how the sample selected is reliable.

It is used the Comsol Multiphysics framework to calculate via Computer Fluid Dynamics with Finite Element Methods simulations. The stationery simulations are carried out for swimming pools of width from three to six meters, in a non-uniform mesh coupling Navier-Stokes equations and heat transfer equations.

Results obtained on how the depth of the jets affect the stratification match expectation, however, results on relation between number of jets and stratification are not the expected initially. Knowledge on how these parameters are to be combined to reduce stratification is intended to be implemented in current simplified software used to offer for sale. The conclusions are that there is no 'magical' configuration for neither of the four pool shapes. The power requirements match the current simplicated software results within a 10% margin, expecting them to be much more refined and thus being profitable if a customer desires them.

2 INTRODUCTION

Usually heating a swimming pool is associated with luxury, however at ©FLUIDRA the selling lemma has always been it takes the cost of one coffee a day to maintain heated an already existing pool. Currently, ©Fluidra holds a -simplified- code with its own program in order to easily calculate the heating requirements for a swimming pool. This program takes into account the evaporation, conduction, convection, and renewal of the water pool to deliver the power requirements, and thus, to offer a variety of heating systems of the firm, ensuring desired temperature in all conditions.

To do so, a series of data is required, such as the dimensions of pool, if it incorporates winter cover, the maximum filtration hours, desired temperature and finally the climatic zone with which are obtain the weather conditions.

The main objective of this work is to add an in-depth CFD study with which it can be offered a whole new service to the customers. Because ©Fluidra is world's leader at swimming pool products, knows that offering a complete CFD study involving motion of water and temperature is not commonly offered. This kind of study has economical, design quality and reliability improvement implications. The stationery CFD study let us know if stratification is formed and also if uncomfortable vortices are formed.

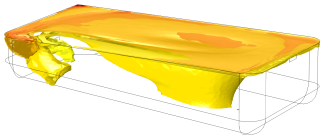

Figure 1: Multi-layer isothermals sample

The purpose of the project is to offer this CFD simulation service to the customer who claims for it and, if possible, to try to import conclusions of these in-depth study in order to add them to the simplified existing code. It is possible that no such generalised conclusions can be taken and that only with a purposed CFD study for every pool to study can offer answer to these questions.

A model with COMSOL Multiphysics ® is used coupling turbulent flow and heat transfer in fluids with different geometries and inlet water jets and skimmers distribution.

Of course, it have been done before a large amount of swimming pools CFD studies, such as the ones offered by CFD Freelancing [1] , which are taken as reference. However, the present work has the purpose to add the know-how of Fluidra on the business and knowing the common designs. Anyway, is contemplated the possible outcome is that it may not deliver a reliable conclusion on design constraints.

3 METHODOLOGY

The standard dimensions of a rectangular shaped swimming pool are those which:

$$L/W = 2 \tag{1}$$

being 'L' the length of the pool and 'W' its width. Also 'D' depth follows rule:

$$D = (L + 3)/10 = (2W + 3)/10 \tag{2}$$

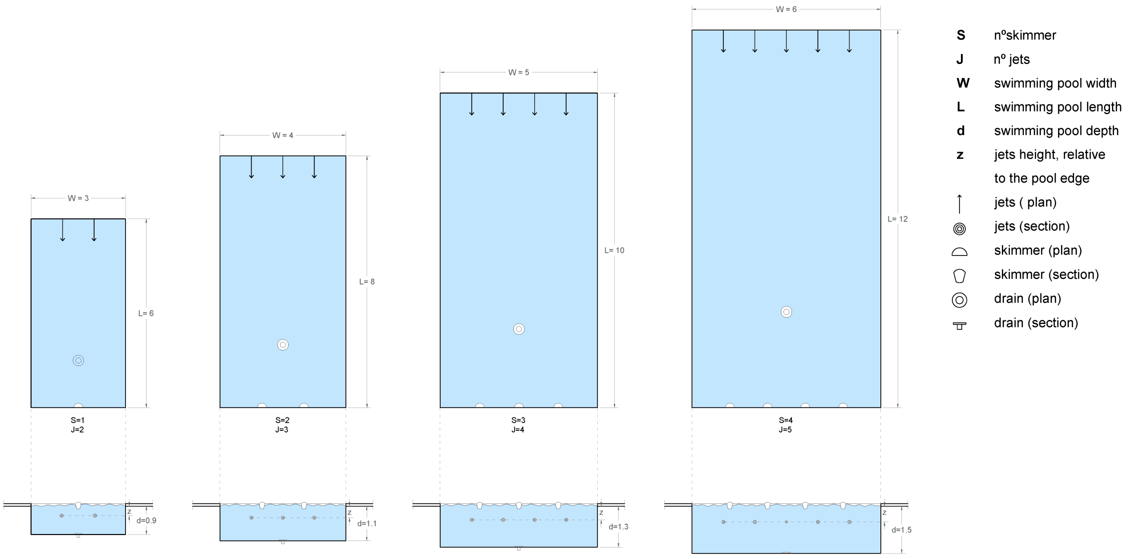

Figure 2: Sheme followed showing the four diffrent pool shapes, market widespread

These settings are well established at the market and so will not be considered as configurable settings. Current work takes into account most common widths W=3,4,5,6 m cases, which determine length and depth. The scheme is always the same, water enters through jets and leaves through the sink and the opposed skimmers which are located at the opposite side, and whose purposes is to collect dust. The number of jets and skimmers as well as their depth are the variables which might be found as possibly optimized. Number of jets and skimmers can vary, however, there is non-written rule for the market, in which normally:

$$S = |W| - 2 \tag{3a}$$

$$J = S + 1 \tag{3b}$$

being ' 'J' the number of skimmers and jets, dependant on the rounded to natural number value of the width of the pool. The depth 'D' and depth of the jet 'Z' usually follows the following equation, with N=3 as common value but to be configurable at the present work:

$$Z = D/N = (2W + 3)/(10N) \tag{4}$$

The variables to be optimized are thus ‘J’ and ‘Z’ (or ’N’). Local stratification is measured in the form of maximum gradient of temperature along the z-axis.

A non-uniform mesh is built for each mode, varying from 180000 to 326000 tetrahedral elements while increasing width.

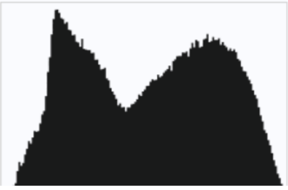

Figure 3: Quality of the elements histogram

The model used is a coupled Incompressible turbulent flow, with following equations:

$$\rho(u \times \nabla)u = \nabla \times \left[-pl + (\mu + \mu_T) \times (\nabla u + (\nabla u)^T)\right] + F \tag{5a}$$

$$\rho \nabla(u) = 0 \tag{5b}$$

$$\rho(u \times \nabla)k = \nabla \times \left[(\mu + \frac{\mu_T}{\sigma_k})\nabla_k\right] + P_k - \rho_\epsilon \tag{5c}$$

$$\rho(u \times \nabla)\epsilon = \nabla \times \left[(\mu + \frac{\mu_T}{\sigma_e})\nabla_\epsilon\right] + C_{e_1}\frac{\epsilon}{k}P_k - C_{e_2}\rho\frac{\epsilon^2}{k}, \epsilon = ep \tag{5d}$$

with the equations of Heat transfer in fluids:

$$\rho C_p u \times \nabla_T + \nabla \times q = Q + Q_p + Q_{v_d} \tag{6a}$$

$$q = -k\nabla_T \tag{6b}$$

4 RESULTS

All 36 stationery calculations are done with COMSOL, considering jets at 30°C and water initially at 28°C. Filtration (water flow) in constrained by requirements of biological removal and filtration hours, this is four volume renewals a day following Regulation on Thermic Installations [2] for each sample. The air is at 15°C and no wind is considered. Conduction losses and possible radiation gains are neglected. Postprocessing enables to pick up stratification ’S’ at each point of the swimming pool surface.

$$S_L = max\left|\frac{\delta T}{\delta z}\right| \tag{7}$$

Then, global stratification can be also obtained. This value is the one it has been taken to consider stratification for every calculated model, being the purpose to reduce it as much as possible.

$$S_G = \frac{\displaystyle\int\int_{\Omega} S_L \, d\Omega}{WL} \tag{8}$$

Table 1: Results on global stratification

	W=3			W=4			W=5			W=6		
N	J=1	J=2	J=3	J=2	J=3	J=4	J=3	J=4	J=5	J=4	J=5	J=6
2	3.2	5.2	9.3	2.2	4.5	7.3	3.2	3.5	4.3	0.2	2.5	3.3
3	4.5	5.3	10.1	3.2	5.2	8.2	3.1	4.2	5.2	1.2	3.2	4.2
4	5.2	8.2	12.0	4.7	6.1	9,1	3.2	5.2	6.4	2.2	4.2	5.4

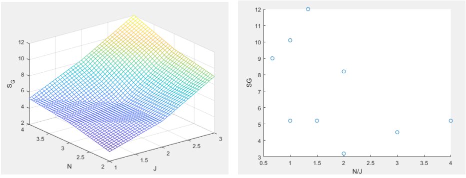

Figure 4: Global stratification depending on N,J and their ratios for width 3m

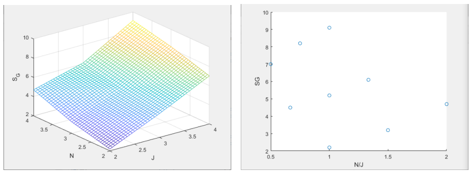

Figure 5: Global stratification depending on N,J and their ratios for width 4m

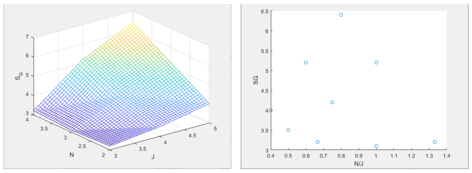

Figure 6: Global stratification depending on N,J and their ratios for width 5m

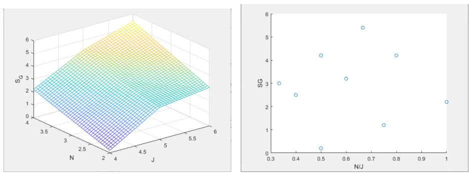

Figure 7: Global stratification depending on N,J and their ratios for width 6m

The first results might not be expected for J, given that greater number of jets generally would imply more mixture and so less stratification. With N, expectations are matched, given that lower N means that jets are closer to bottom of the pool and further from surface, delivering mixture because warmer water now tends to go upwards.

Also, in order to obtain profitable information, stratification is compared to the J/N ratio for each width.

5 CONCLUSIONS

Stratification tends to form beacuse of the diference on the densities of warm and cold water. Less mixture implies more stratification, while having the jets closer to surface might imply that this warmer water does not tend to mix with the colder water of the bottom, which is denser. Analyzing data leads to this counterintuitive conclusion in which increasing the number of jets increases the stratification. This was not expected and can be taken as one of the most important conclusions of this work. It however ratifies the intuition on N-S behaviour was right. On the combination of both J and N, unfortunately, is inconclusive on whether a determined configuration is better or not. This CFD studies might be carried out anyway to get detailed information on the power required. Such calculations differ on ratios of +-10% from current studies done with simpliflied ©Fluidra's software, however must be taken as much more reliiable given the simplications of current ©Fluidra's code.

6 ACKNOWLEDGMENTS

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