SUSPENDED WATER WHEEL

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A R T I C L E I N F O

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A B S T R A C T

The problem "Suspended water wheel" investigates about the behavior of a light object which, if you release it near the edge of water that is upward, you would see that it will start to rotate and also, remain stable at a level where its weight and the water momentum equal to each other. It can be concluded that changing some parameters are responsible for different set of acts for this phenomenon.

1 Introduction

The suspended water wheel concerning a light object (ball, disk, …) that by approaching the object to a stream line of water which is opposite of gravity force, it would start to spin and oscillate (Fig.1). Under certain condition this phenomenon has the stable position. There are many factors which can change its manner and are explained in two parts, theories and experiments.

The main reason which this phenomenon happens and the object stick to the water and doesn't fall down is the adhesion force. When we close the object to the water, the adhesion which exist between the water and object's surface, makes the drops of water to go around the object and makes it spin therefor by spinning the object, it becomes stable.

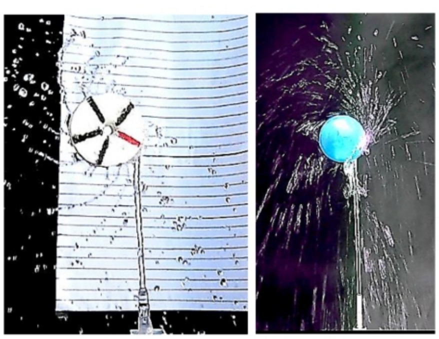


Fig.1: The structure of to show this phenomenon

2 Theory and Methods

2-1 Theoretical part

In order to explain the theories which related to this phenomenon, first we should analyze the applied forces and introduce the free body diagram (Fig.2). According to it, we have a gravity force downward which pulls the object down, the water momentum upward which pushes the object out and the adhesion force, tangent to the object which makes the object to spin.

There are some factors which help us to understand this phenomenon better and also find equations.

1. **Adhesion**, which is the tendency of particles attach to each other . This factor is the main parameter which can change the phenomenon's behavior.
2. **Angular velocity**, can be defined as the range of angular displacement. It changes as the change of some parameters and effects on phenomenon's stability.
3. **Linear momentum**, which is the systems mass multiplied by its velocity.
4. **Volumetric flow rate** that is the volume of fluid which passes per unit of time.

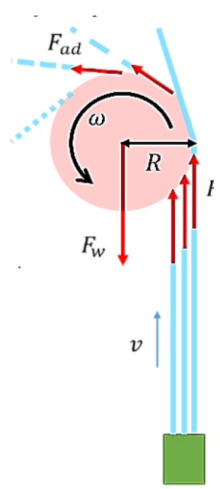


Fig.2: The free body diagram and applied forces

The force on a part of object, can be found by Reynolds equation (Eq.1) [1].

$$\frac{\delta}{\delta t}N = \frac{\delta}{\delta t}\int \eta\rho d\forall + \int \eta\rho\vec{v}\,.\,d\vec{A} \quad (1)$$

where $\eta = \frac{N}{m}$ which if we want to write this equation for the momentum, we should equal N to the P=mv .

We have a pressing force which is applied to the surface and we have a body force as weight which is written in any vector direction.(Eq. 2-4).

$$f_{sx} + f_{Bx} = \int u\rho\vec{v}.d\vec{A} \quad (2)$$

$$f_{sy} + f_{By} = \int v\rho\vec{v}.d\vec{A} \quad (3)$$

$$f_{sz} + f_{Bz} = \int w\rho\vec{v}.d\vec{A} \tag{4}$$

In these equations f_s is the surface force and f_B is the body force that, their summation would give us the total force, on the other hand in this phenomenon the mass of the water drops are very low and ignorable, so by ignoring the body force we can have the surface force on object.

By using the equation (3) in y direction with negative sign for inlet flow which water with v hits the ball from part A (Fig. 3) and also with positive sign for the outlet flow which their difference would give us the applied force to the object.

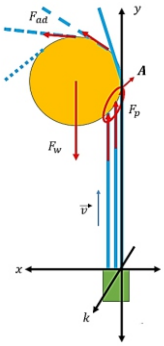


Fig.3: The free body diagram for the surface force

3 Experiments

There are many parameters that can effect on the phenomenon so in order to perform these experiments and have least errors main base (pipe, pump, …) which water could get out of it, with different nozzles and objects are used (Fig.4).

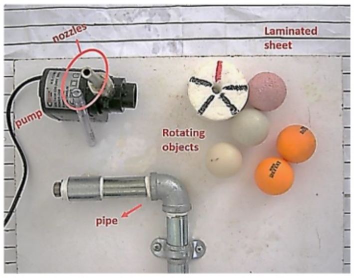
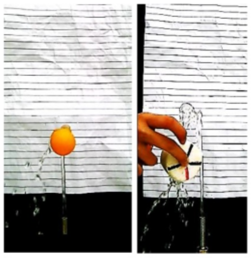


Fig. 4: Experimental setup

By recording a video and analyzing with Tracker the affected parameters on the stability are investigated. These parameters are Flow Rate , Weight , Warer Jet Nozzle and Surface Properties .

3-1 The Effect of Flow Rate

Disc and ball are used to find how they act by changing the flow rate. In our experiment ball stands and spin on water jet but it doesn't work on the disc in first step with a low flow rate (Fig. 5).



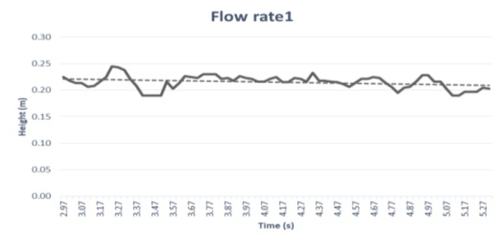


Fig. 5: First step flow rate, acting on the ball and disc

In the next posture of flow rate, we increase the velocity more than before and as the charts show ball got more vibration (Fig.6) .

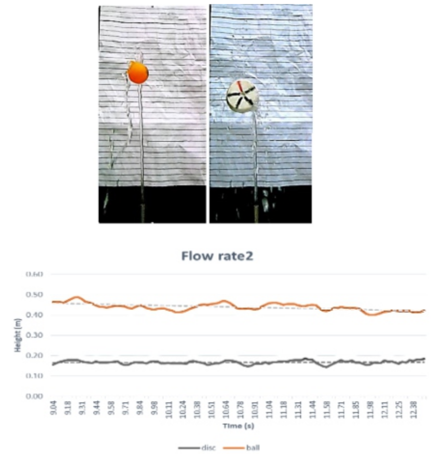


Fig. 6: Second step flow rate, acting on the ball and disc with more velocity

In the third posture, we can see by increasing more the flow rate , the turbulence that exist in lines of the water would also increase so the ball would has more oscillation than disc in our experiment (Fig.7).

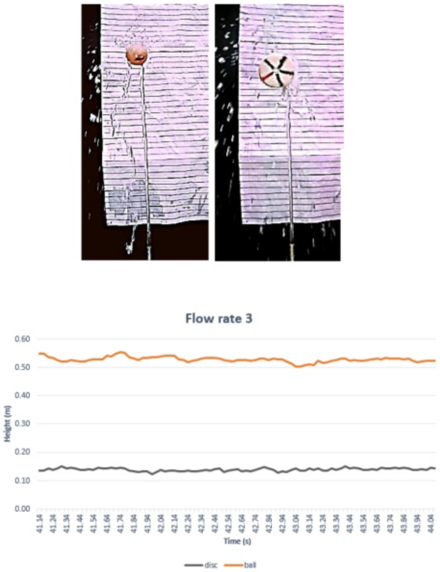


Fig. 7: Third step with higher flow rate, acting on the ball and disc

3-2 The Effect of the Weight of Object

Another experiment which somehow relates to the pervious one is the weight. It is so clear that by increasing the mass of the balls or discs, the power of water cannot handle the object overall so the greater the mass, the lower the height which would cause to fall down (Fig. 8).

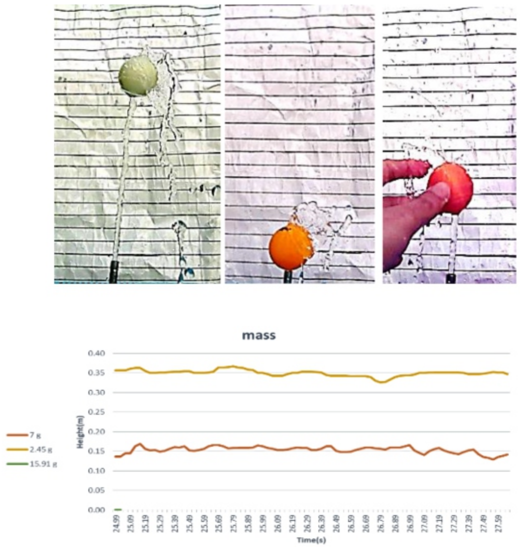


Fig. 8: Objects with different masses

3-3 The Effect of different Nozzles in Water jet

For this experiment at first a 3.5 *mm* nozzle was used for both the ball and disc. This nozzle was small so the extracted backwater was also thin. It is observed that water cannot contain the ball inside of itself and makes it to go up and down so it make the ball to have lots of oscillation and makes the disc to have the stable posture (Fig.9).

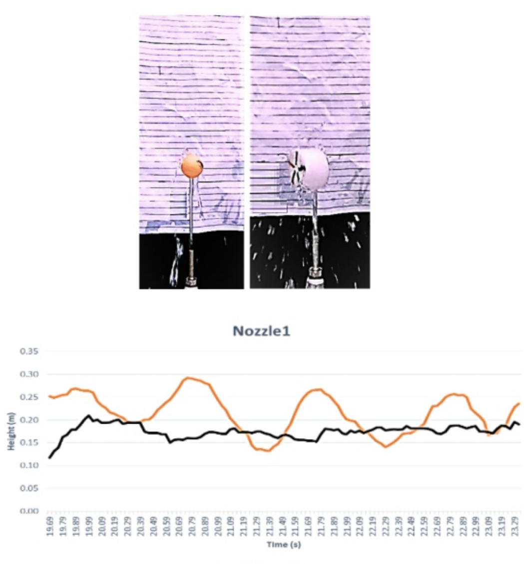


Fig. 9: The ball and disc on water jet with a small nozzle(3.5*mm*)

The second part was by a 5.5 *mm* nozzle which the ball has the ideal position for this nozzle because the volumetric flow rate is more so water can surround the ball better (Fig.10).

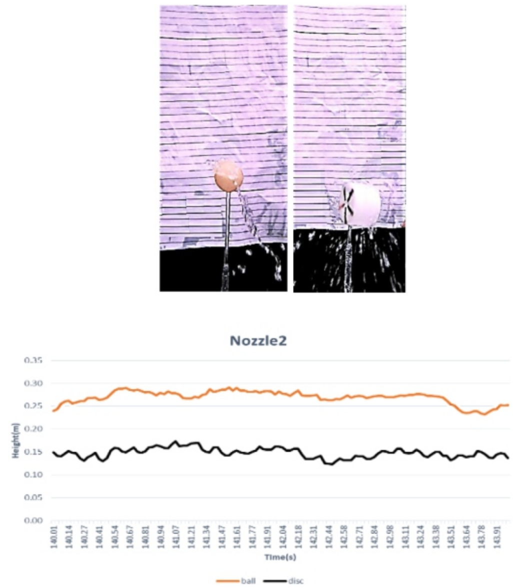


Fig. 10: 5.5 *mm* nozzle

3-4 The surface properties

This parameter has the main effect on this phenomenon . As the first posture a clean ball that actually had the best result was used and then it was covered with sand, which, due to the ripples, caused the water droplets to flip over to one side and makes lots of vibration and makes it unstable (Fig.11) [2].

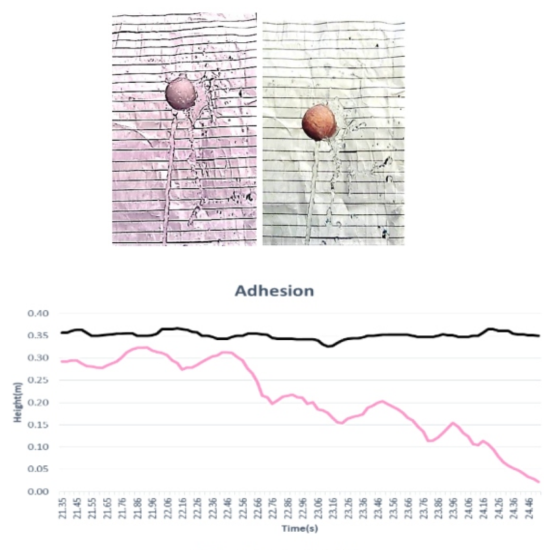


Fig. 11: Two balls with different surfaces

The next experiment was with a disc and a ball were covered by oil which both of them weren't stable at all because oil prevents the water from sticking to the objects' surface to make them spin (Fig.12).

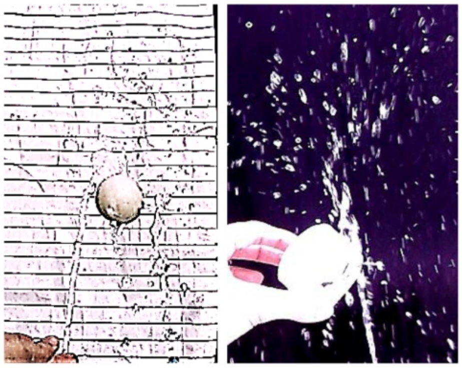


Fig.12: An oily ball and disc

4 Results and discussions

According to the experiments and the results obtained, let's talk about the best position for this phenomenon:

1. **Flow rate:** The important thing about this parameter is that the used water jet should be so powerful to handle any kind of object (Fig.13).

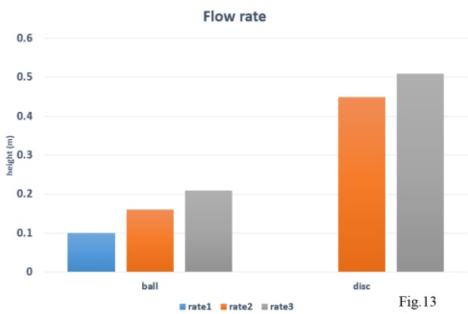


Fig.13: The effect of flow rate on ball and disc

2. **Weight:** It is too important to use an object that is as light as possible (Fig.14) .

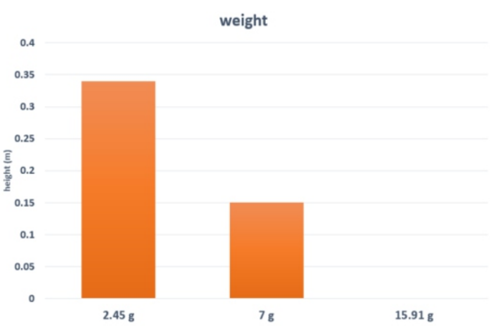


Fig.14: The effect of different masses

3. **Water jet nozzle:** This parameter relates to the object which if the used nozzle is small is better to use disc and if the nozzle is bigger, it's better to use ball (Fig.15).

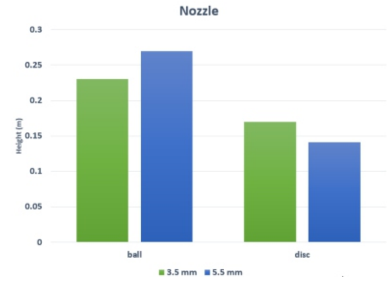


Fig.15: The effect of different size of water jet nozzles

4. **Surface properties:** this parameter has the main effect on this phenomenon. The object should be so clean, without any external covers on its surface in order to see the best results (Fig.16).

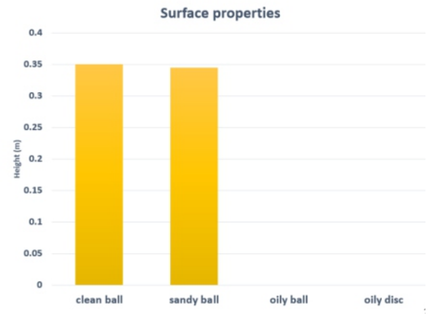


Fig.16: The effect of surface properties

5 Conclusions

The suspended water wheel express the manner of a light object that placed near the edge of water stream. We could analyze this phenomenon by Reynolds transport equation to find the force that is applied to a part of the object surface. Flow rate, weight of the objects, water jet nozzles and surface properties were investigated in this phenomenon. In use of the ball and disc in all experiments the stability of objects was examined which the ball is more stable than the disc.

References

[1] Fornberg B, (1988), " Steady viscous flow past a sphere at high Reynolds numbers". J. Fluid Mech. 190, 471-489

[2] Srinivas ,VL, (2018), "Can you explain Veritasium's Hydrodynamic levitation or Fluid Juggling ? researchgate.net, https://www.researchgate.net/post/