Numerical Study of Flow Patterns in the Windcatchers in Herat, Afghanistan By using Computational Fluid Dynamic

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***Abstract*—To use the renewable energies such as solar and wind energy efficiently for cooling, heating and air-conditioning of building, we should consider the Energy Professionals' experiences. So by taking advantages of these valuable experiences, we can use indigenous materials properly and combine them with the new situation. One of these methods is the use of windcatchers. In this study, we will survey the background and function of windcatchers. Then we will survey the airflow behavior, belonging to one of this kind of common windcatchers in Heart, Afghanistan. Because of its special form of architecture, these kinds of windcatchers can be used in Iran, especially in the regions with less wind attitude. To make similar of the wind flow of this kind of windcatchers, the software naming FLUENT is used. It is based on Finite Volume Method. According to the results, we will consider the desirable function of this kind of windward for the purpose of improving the refreshment of house inside environment.**

Keywords— The windcatchers of Afghanistan; Computational Fluid Dynamic; Flow pattern; FLUENT.

I. INTRODUCTION

The landscape of fossilized stores shows that these stores are coming to an end after passing a few decades and this finishing along with the globalization resulted to competition increase among the countries in the world. [7]
These cause a better consumption of energy as a strategic policy noted by economists and governmental men throughout the world. So it's necessary to take into consideration the issue replacing new energy by fossilized fuels. Every year, the new methods for improving energy consumption are set forth for discussion. In recent years, the discussion of using new energy for heating and cooling of buildings had attracted the engineers and architects' attention toward itself. By considering the great parts of Iran are located have hot climate, we should find suitable ways for decreasing of cooling expenses.
Therefore, we should attempt to decrease energy consumption for the purpose of better building temperature efficiency. Then this attempt will be resulted to great saving of natural limited resources.
Today, we can use windcatchers as complete systems of air conditioning and cooling of buildings.
We can provide comfort situations with natural refreshing in the certain time of year.
And just at the time of year that wind could not afford the desired temperature of building, we should use mechanical instruments. [1]
Windcatcher is a symbol of engineering masterpiece of Iran and no designer or inventor is determined for it. Architects and builders of this engineering masterpiece have completely been aware of the aerodynamic, Thermodynamic, temperature transferring, material resistance and human comfort temperature principles and use them in their designs very well. We don't have the complete and exact information about background and history of windcatchers.
But it is clear and certain that ancient Iranians knew about the airflow conditions and usage of windcatchers.

According to their knowledge, we can bravely attribute this invention to Iranian. In figure 1 a few of common plans of Iranian windcatchers is seen. [2]

Fig. 1. *A few of common plans of Iranian windcatchers*

In Iranian dictionary, another name such as Bad Ahanj, Bad Ahang, Bad khan, Badkhaneh, Bad Khor, Bad Ras, Bad Qard, Badang, etc have been used. In the poems of Iranian poets such as Abu Abdolla, Ja'farebn Mohammad Rudaky Samarqandi, the mellifluous poet of Iranian works and books windcatcher is not directly mentioned with its different names, but it is considered as the symbol of creating comfort and relief. Zoroaster, Iranian prophet (660 B.C) said that "Mazda created the Earth and the sky

and also Alborz Mountain, soil and we appreciate all good things."

Mohammad karim Pirnia, one of the greatest and the most famous contemporary architects, had talked about the old history of windcatchers, "wincatcher is used since ancient times in Iran and we can conclude from its old and different names like watqar, Badkhan, khisud and khishkhan some reports about the structure and efficiently of windcatchers can be seen in European and American tourists' travel accounts. For example, Marco polo stated in his travel a account, "In that place there are big and small cities and Hormoz is one of them, with its Arabic spoken people. Because of too much heat in Hormoz, air conditioning instruments are built for keeping wind. These instruments are located in the direction of airflow which brings it from outside toward inside of house for making cool. In Figure 2 we can see a picture of Bushehr harbor by Ojen Flanden.

Fig. 2. *Bushehr harbor by Ojen Flanden[2]*

In other countries, the windcatchers with various patterns were designed. In figure 3 and 4, the picture of an Egyptian and Pakistan an windcatchers.

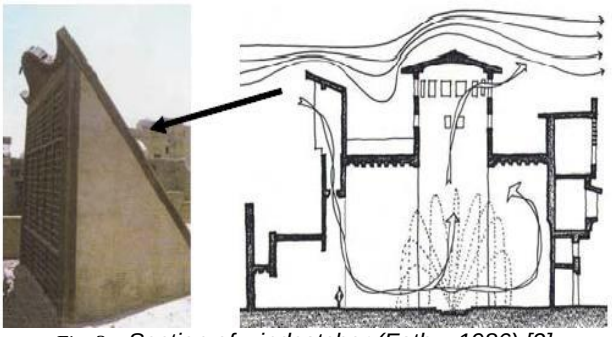

Fig. 3. *Section of windcatcher (Fathy, 1986) [2]*

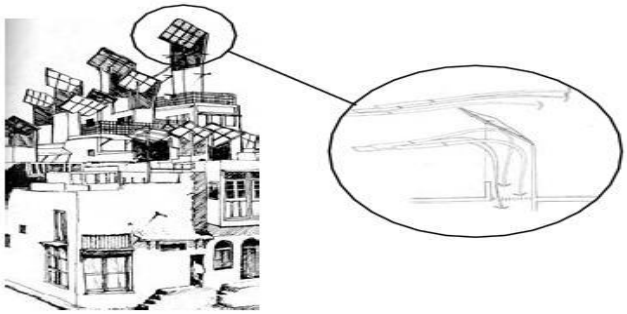

Fig. 4. *Windcatcher of Heydar abad, Pakistan*

The windcatcher of Heart in Afghanistan is a simple thing that is commonly situated on the domical roof of all rooms; its most height is 1.5 meters. These are built in the direction of dominant wind that blows form north. Their plan forms are square with 1*1 meter and steep roofs with angles of nearly 30˚ (Figure 5).

Windcatchers of Afghanistan are much similar to the short and one-sided ones in east, northern east and southern east of Iran.

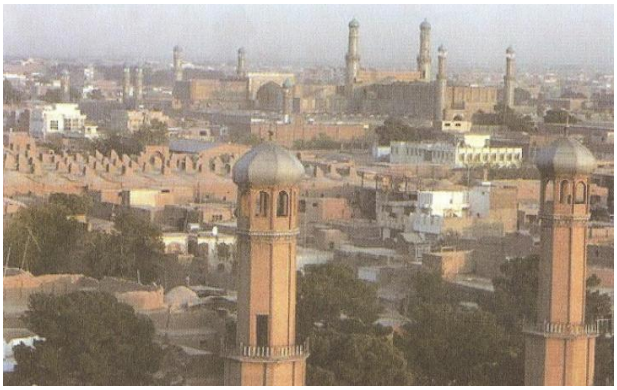

Fig. 5. *Short and one-sided wincatchers in Heart*

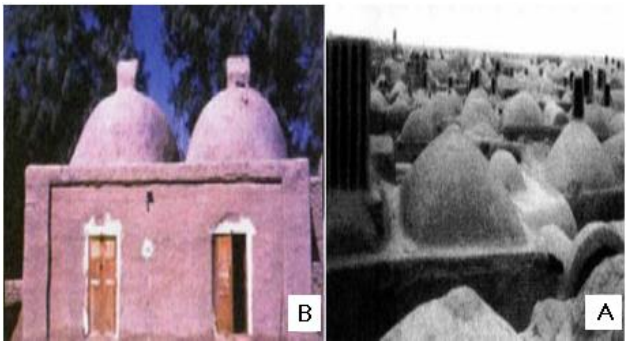

Fig. 6. *A- Short and one-sided windcatchers in Mahand village. B-Two short and one-sided windcatchers in Zabol*

II. NUMERICAL MODELING

There are 3 ways for solving the problems related to fluid mechanical that are as followers: Empirical, Analytic and Numerical methods.

The progress of numerical methods in few recent decades has been noticeable. Because of high expenses of empirical methods and weaknesses of analytic method in solving engineering problems, most of researchers pay attention to the numerical one. [8]

For the purpose of gaining access to passing airflow behavior from Herat windcatchers, geometry of windcatcher by available plans in made in the Gambit software (Figure 7). According to figure 7, we've used two boundary conditions (inlet velocity and outlet pressure) for solution. Then we transfer this geometry to FLUENT software. Fluent software is the peak of art of programming for modeling fluid flow and temperature transfer in complicated geometries.

This software is based on the Finite volume method which is a strong (powerful) way in computational fluid dynamic. [3]

In this article k-ε is chosen as a turbulence model. k-ε Model is a rather complete and common but very expensive which is used for describing turbulence and to express the transferring of turbulence properties by medium flow and also it is useful to produce and amortization of turbulence.

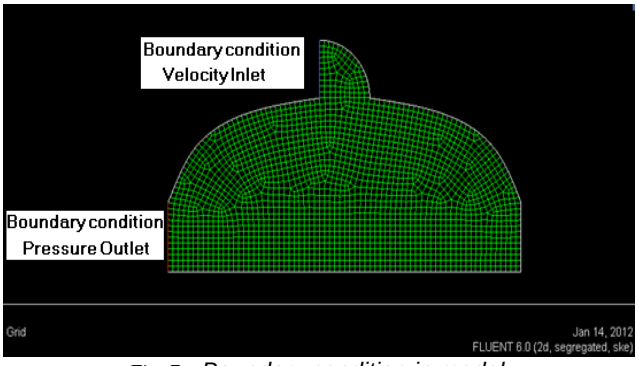

Fig. 7. *Boundary condition in model*

Standard k-ε model uses transition equations (1) and (2) in FLUENT software: [8]

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho\varepsilon u_i)=\frac{\partial}{\partial x_i}((\alpha+\frac{\alpha_t}{\sigma_k})\frac{\partial \varepsilon}{\partial x_i})+G_k+G_b \quad (1)$$

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho\varepsilon u_i)+C_{2s}\rho\frac{\varepsilon^2}{k}=\frac{\partial}{\partial x_i}((\alpha+\frac{\alpha_t}{\sigma_k})\frac{\partial \varepsilon}{\partial x_j}) \quad (2)$$

$$+C_{1s}\frac{\varepsilon}{k}(G_k+C_{3s}G_b)(2)$$

$$k=\frac{1}{2}(\overline{u'^2}+\overline{v'^2}+\overline{w'^2}) \quad (3)$$

K= Kinetic Energy related to turbulence
αt=Viscosity of turbulence
The equations include that is amounts are as follows:

$$\sigma_k=1.0 \quad C_\alpha=0.09 \quad C_{1\varepsilon}=1.44 \quad C_{2\varepsilon}=1.92 \quad \sigma_\varepsilon=1.30$$

GK= Term of producing turbulence motion energy
GB= Term of producing turbulence motion energy
For the purpose of flow pattern survey in Herat windcatchers, it is supposed that a wind with the speed of 5 meters per second enters into the windcatcher. By solving it, the results are gained in pictures 8 to 11. In Table 1 are also seen the amounts of at least and at most velocity in the direction of X and Y and the amount of velocity.

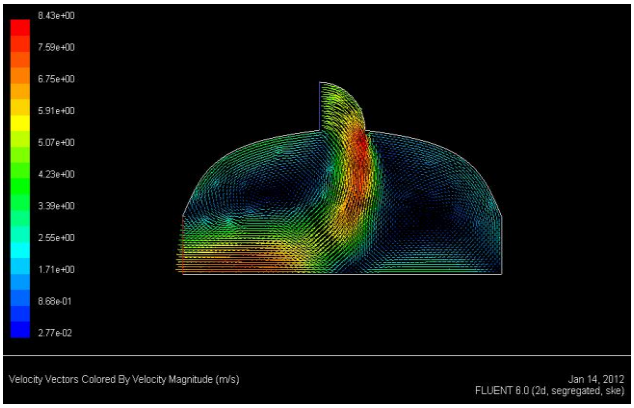

Fig. 8. *Velocity vector colored by Velocity Magnitude*

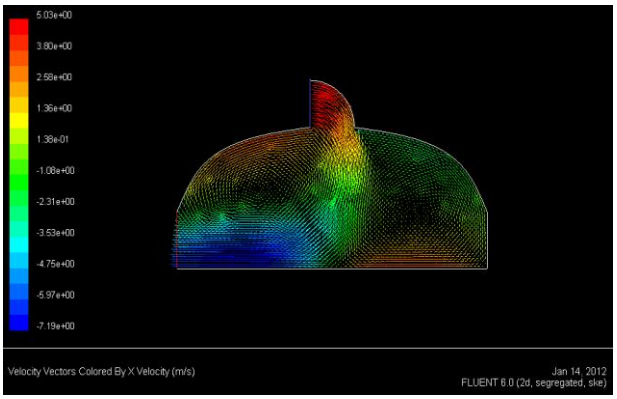

Fig. 9. *Velocity vector colored by X Velocity*

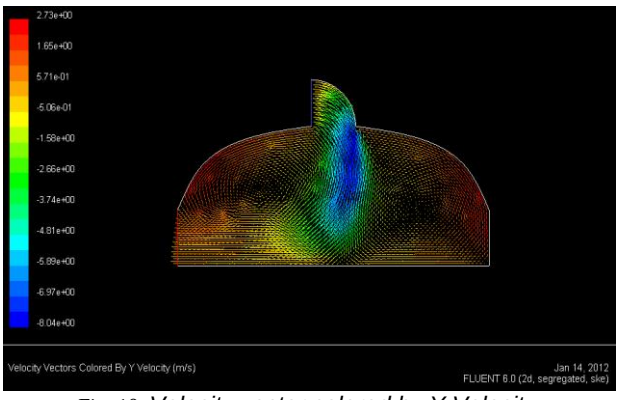

Fig. 10. *Velocity vector colored by Y Velocity*

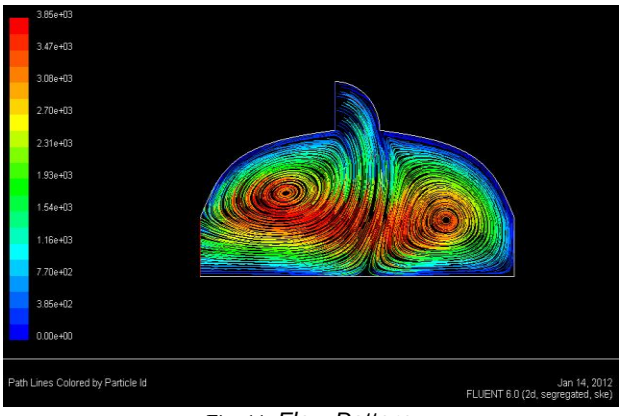

Fig. 11. *Flow Pattern*

TABLE I. MAXIMUM AND MINIMUM AMOUNT OF VELOCITY

	Velocity Magnitude	*Velocity in X direction*	*Velocity in Y direction*
Min	*0.0277*	*-7.1948*	*-8.0441*
Max	*8.4348*	*5.02688*	*2.7252*

III. CONCLUSION

According to the result and the acquired forms in this research, we can get these results from this numerical study:

1) The most of vectors of speed in the direction of +X, in the entrance windcatcher and the room floor has occurred (Figure9).
2) The most of speed vectors in the direction o +X are acquired in the room floor (Figure9).
3) The most of speed vectors in the direction of +Y are occurred in the room walls (Figure10).
4) The most of speed vectors are occurred in the direction of –Y in the center of the room, exactly beneath the windcatcher (Figure10).
5) According to this fact that in the parts of structure the amount of velocity in v=5 m/s as a result of wind blow, speed in the direction of X and speed in the direction of Y are in this order: -8.0441, -7.1948, -8.4348 (Table1) and also according to acquired flow pattern in the structure (Figure11), we can understand the proper operation of this system for refreshing of the inner environment of house.
6) According to the acquired amounts and forms, we can conclude that FLUENT software has a high ability for modeling of flowing into Herat windcatchers and by this software; it is possible to acquire parameters related to wind flow favorably.

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