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*Мухаммед Хайян Кабрет*

*Магистр машиностроения*

*Факультет машиностроения и электротехники*

*Университет Аль-Баас, Хомс, Сирия*

*Мухаммад Бакир*

*Доктор машиностроения и электротехники*

*Факультет машиностроения и электротехники*

*Университет Аль-Баас, Хомс, Сирия*

*Mohammad Hayyan Kobrit*

*\Master student of Mechanical Power Engineering*

*Faculty of Mechanical and Electrical Engineering*

*Al-Baath University, Homs, Syria*

*Mohammad Bakir*

*Doctor of Mechanical and Electrical Engineering*

*Faculty of Mechanical and Electrical Engineering*

*Al-Baath University, Homs, Syria*

# DESIGN A NEW MODEL OF INVELOX WITH A CURTAIN IN INTAKE AND A VERTICAL OUTLET

**Annotation:** *High wind velocities are required for wind projects to be economically efficient. To increase the wind speed, the concept of ducted wind turbines has been introduced in recent decades. Primary results have shown that this design can increase the overall efficiency of a wind project. In this study, the effects of the outlet area and intake area to the aerodynamic performance of the Invelox are numerically studied. By designing the new model, similar the original model, with the addition of a cylinder-shaped outlet with a diameter of (5.3 m) and a height (4.32 m) which contains inside two guides of air flow up and down to change the direction of airflow up and down. In addition, put curtain in end of intake to reduce runaway air.*

*The curtain maintains a quarter of the drawing area open to airflow, while obscuring the remaining 3/4 area. The new INVELOX model achieves prevention of reverse flow inside it. In addition, the velocity value in the Venturi region is (16.084 m/sec). The value of SR is almost constant and its average value is 2.39.*

**Key words:** *INVELOX model، economically efficient, fluid dynamics.*

## РАЗРАБОТАЙТЕ НОВУЮ МОДЕЛЬ INVELOX С ЗАНАВЕСКОЙ НА ВХОДЕ И ВЕРТИКАЛЬНЫМ ВЫПУСКО

***Аннотация:*** *Для того чтобы ветровые проекты были экономически эффективными, требуются высокие скорости ветра. Чтобы увеличить скорость ветра, в последние десятилетия была введена концепция ветряных турбин с воздуховодом. Первичные результаты показали, что такая конструкция может повысить общую эффективность проекта. В этом исследовании численно изучается влияние площади выхода и зоны входа на аэродинамические характеристики Invelox. Разработав новую модель, аналогичную исходной, с добавлением выпускного отверстия цилиндрической формы диаметром (5,3 м) и высотой (4,32 м), которое содержит внутри две направляющие воздушного потока вверх и вниз для изменения направления воздушного потока вверх и вниз. Кроме того, поставьте завесу в конце воздухозаборника, чтобы уменьшить утечку воздуха. Занавес оставляет четверть области рисования открытой для воздушного потока, закрывая оставшиеся 3/4 площади. В новой модели INVELOX достигается обратного потока внутри нее. Кроме того, значение скорости в области Вентури составляет (16,084 м / сек). Значение SR практически постоянно, и его среднее значение составляет 2,39.*

***Ключевые слова****:* *модель INVELOX ،экономически эффективная, гидродинамика.*

**Introduction.**

It is not only the aerodynamic performance of a wind turbine, which makes a wind project economically reasonable. Other factors such as the wind speed at the site of the wind project and the required initial cost of the project also affect the economics of a wind project. The power output from a wind turbine is given by the well-known expression: **P=0.5* ρ* Cp*A*V3**

- ρ is the density of air (1.25 kg/m3), Cp is the power coefficient.
- A is the rotor swept area (m2), v is the wind speed (m/sec). [1]

Clearly, Speed is the most indicator effective in wind power, because power is related to the speed cube. [2,3] if the velocity value is doubled, the energy value will increase to eight times. Allaei & Andreopoulos. [4] proposed a ducted wind turbine system, named Invelox (increased velocity), where not only the wind speed has been increased. One of the superior properties of this patented innovation [5, 6] is that it captures wind from all directions and eliminates the need for any yaw mechanism. The schematic of the Invelox initially presented by Allaei & Andreopoulos. [4] shows The five key parts of INVELOX are shown in Figure. 1. These key parts are (1) intake, (2) pipe carrying and accelerating wind, (3) boosting wind speed by a Venturi, (4) wind energy conversions system, and (5) a diffuser. The upper section is a circular cylinder, which is open to all directions and captures the wind from all directions.

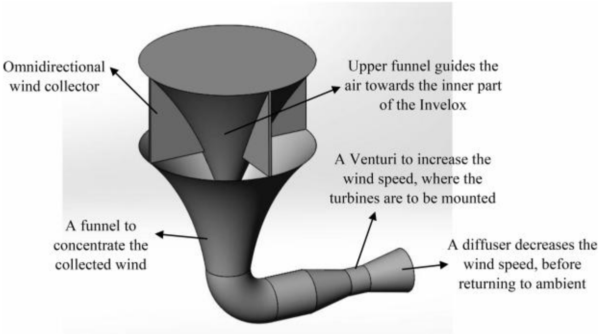


Figure. 1. Schematic of the INVELOX wind delivery system.

The field measurements performed by Allaei and Andreopoulos, [4] using a prototype revealed that Invelox can considerably improve the energy production. The original design of Invelox has been introduced by Allaei and Andreopoulos [4]. which have been used in the current study as a source for validating the numerical results.

The experimental investigations of Allaei & Andreopoulos. [7] They could considerably enhance the total harnessed wind energy by mounting three wind turbines inside the Venturi. Anbarsooz et al. [8] Their simulations also revealed that one the main problems of the original design of Invelox is that a significant portion of the inlet air escapes the opposite side of the incident wind.

## I. The new model design.

By designing the new model, similar the original model, with the addition of a cylinder-shaped outlet with a diameter of (5.3 m) and a height (4.32 m) which contains inside two guides of air flow up and down to change the direction of airflow up and down. This new model of INVELOX uses double nested cone concept and eight baffles with 360° wind intake capability. This unit is scaled to fit a (1.8 m) diameter wind turbine at the Venturi location. The speed ratio of the velocity at the Venturi $V_{(I)}$ over that of the external free wind $V_{(FREE)}$, $SR=V_{(I)}/V_{(FREE)}$, an important design factor. The outlet is cylinder-shaped which contains inside it two guides of airflow up and down.

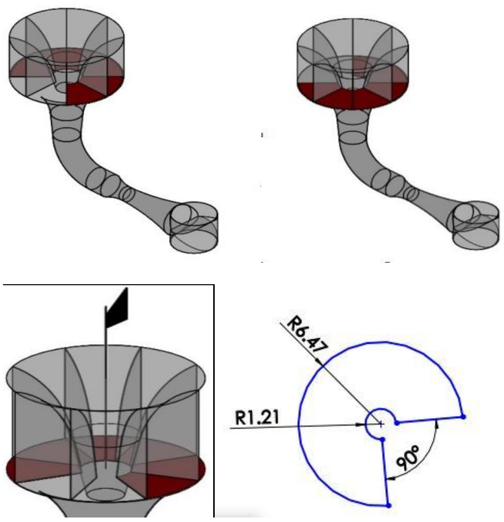


Figure. 2. shows the Physical model of new INVELOX.

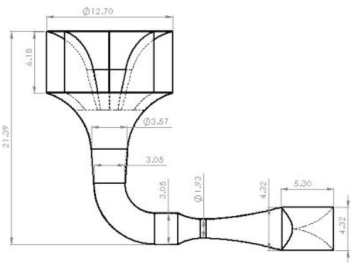

Figure. 3. shows the dimensions of new INVELOX model.

## II. CFD (computational fluid dynamics) models.

The computational domain used in the ANSYS computations had a size of 140 m length, 90 m width and 70 m height. The flow domain was discretized with a mesh of tetrahedral elements. Mesh sizes 9,800,000 elements & 0693011 nodes were used for solution convergence tests in the ANSYS computations, the three-dimensional Reynolds-Averaged NaviereStokes (RAN-S) equations were solved numerically with a second-order accuracy upwind schemes and K-omega turbulence model closures with standard wall functions. For the inlet air source, 5% turbulence intensity was used and a length scale of turbulence 1.0 m were used in the computations. Higher mesh resolution was used near the wall regions in the computations. “Extra Fine” mesh was used in the Venturi duct sections. A constant input velocity field, representing the free stream wind, was assigned to the entire frontal plane of the flow domain. The magnitude of the velocity was set at 6.7 m/s (15 mph).In the simulations, the ground was considered as wall with no-slip conditions. The reference pressure was assumed the atmospheric pressure throughout the domain. Figure. 4 shows mesh distribution on a median cross section of INVELOX.

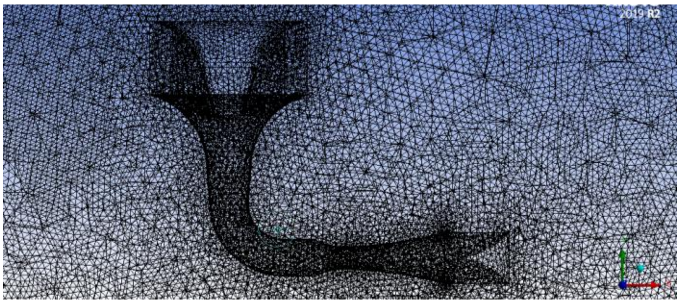

Figure. 4. mesh distribution on a median cross section of INVELOX.

## III. Results and Discussion.

We study the original and new model of the INVELOX, for seven angles of Ɵ (0 °, 30°, 60 °, 90 °, 120 °, 150 °, 180 °), so that Ɵ is the angle confined between the tunnel outlet axis and the direction of free wind. The seven angles covers three sides of the model and considers the rest of the angles similar to the studied angles. For shortcut, we will be display the Velocity contour and streamline airflow in cutaway slice on the plane of symmetry for original and new INVELOX model for three angles (0 °, 90 °, 180 °) and will display the velocity values in Venturi for all angles in Table.1.

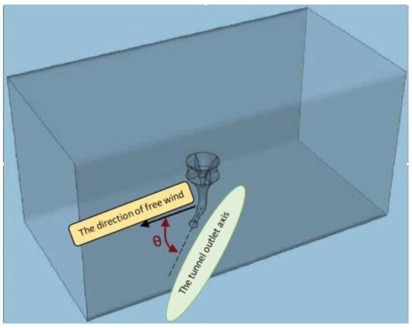


Figure. 5. the angle ϴ confined between the tunnel outlet axis and the direction of free wind.

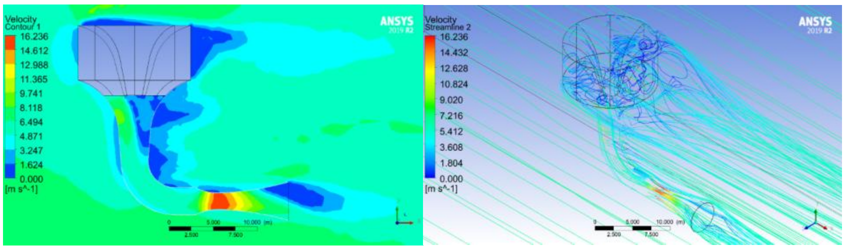


Figure. 6. Velocity contour and streamline airflow in cutaway slice on the plane of symmetry for original INVELOX model. Where (ϴ=°0).

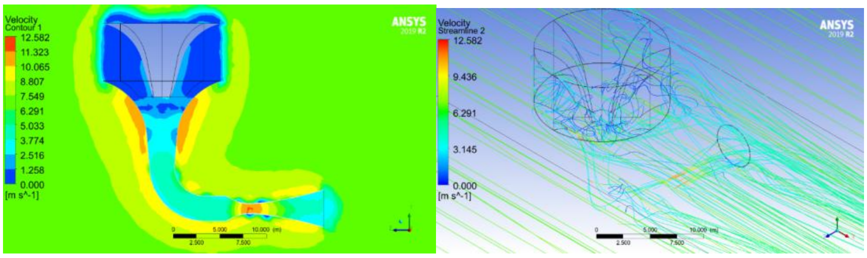


Figure. 7. Velocity contour and streamline airflow in cutaway slice on the plane of symmetry for original INVELOX model. Where (ϴ=°0).

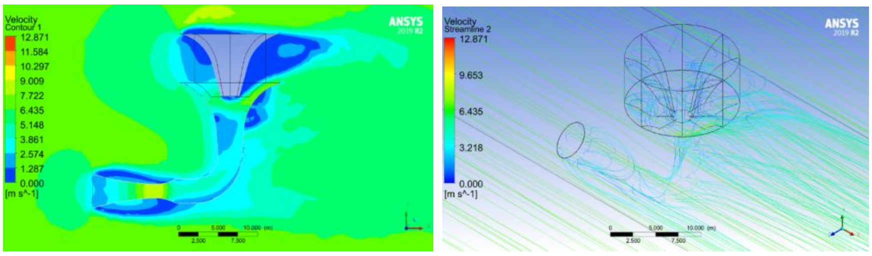


Figure. 8. Velocity contour and streamline airflow in cutaway slice on the plane of symmetry for original INVELOX model. Where (ϴ=°0).

From the previous figures of the original INVELOX model, shows a lot of the air is passes from the intake to the nozzle and the original INVELOX outlet. The airflow lines inside the original INVELOX model are passed from the intake to the outlet of the tunnel when the angle (ϴ = 0 °), and the average velocity at the neck is

(15.2 m / sec). In addition, when the angle (Ɵ = 90 °), part of the air is passes from the intake to the nozzle and outlet of the tunnel and the other part of air exits from the opposite side of the intake openings. Because of the large turbulence of pressure on both sides of the intake and influence of wind direction in the original INVELOX outlet. The airflow lines inside the original INVELOX model are passes from the intake to the outlet of the tunnel and the mean velocity in the neck is (11.2 m / sec). Moreover, when the angle (Ɵ = 180 °), the total amount of confrontation air for the intake original INVELOX model exits from the opposite side of the intake openings. The speed direction is completely opposite to the direction of the tunnel exit, and the average velocity value is at neck (-8.8 m / sec).

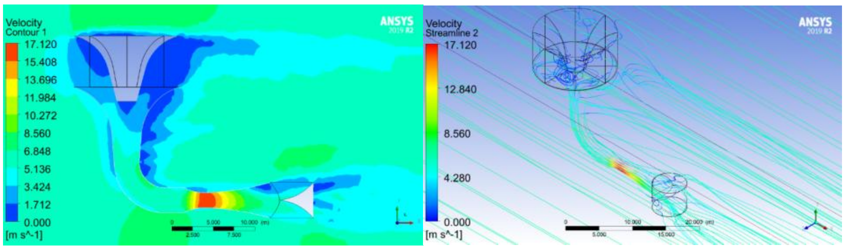


Figure. 9. Velocity contour and streamline airflow in cutaway slice on the plane of symmetry for new INVELOX model. Where (Ɵ=°0).

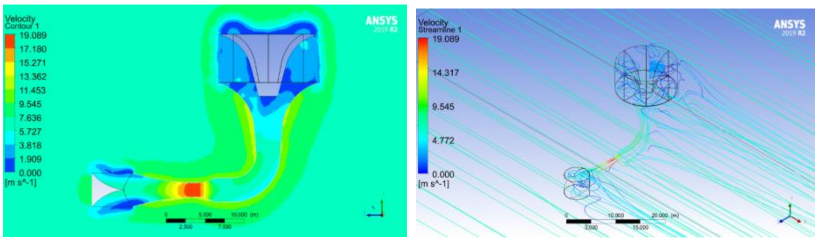


Figure. 10. Velocity contour and streamline airflow in cutaway slice on the plane of symmetry for new INVELOX model. Where (Ɵ=°0).

the plane of symmetry for new INVELOX model. Where (Ɵ=°0).

From the previous figures of the new INVELOX model, shows the total amount of confrontation air for the intake new INVELOX model. The airflow lines inside the new From the previous figures of the new INVELOX model, shows the total amount of confrontation air for the intake new INVELOX model pass inside tunnel .the airflow lines inside the new INVELOX model are passes from the intake to the outlet of the tunnel.

Simulations of airflow for original INVELOX model and new INVELOX model .were performed for angles for seven angles (0 °, 30 °, 60 °, 90 °, 120 °, 150 °, 180 °),so that it covers three sides of the model and considers the rest of the angles similar to the studied angles at inlet air velocity of 6.71 (m/s). The average velocity value in Venturi is given in Table.1

Table.1. shows velocity values at Venturi and velocity values free wind.

| Ɵ | Velocity (m/sec) | velocity at the neck the tunnel (m/sec) | |
|---|---|---|---|
| | $V_{(FREE)}$ | original INVELOX | new INVELOX |
| 0 | 6.71 | 15.2 | 16 |
| 30 | 6.71 | 14.6 | 15.1 |
| 60 | 6.71 | 14.4 | 16.8 |
| 90 | 6.71 | 11.2 | 17.6 |
| 120 | 6.71 | 7.5 | 15.7 |
| 150 | 6.71 | 6.2 | 15.2 |
| 180 | 6.71 | -8.8 | 16.3 |
| 210 | 6.71 | 6.2 | 15.2 |
| 240 | 6.71 | 7.5 | 15.7 |
| 270 | 6.71 | 11.2 | 17.6 |
| 300 | 6.71 | 14.4 | 16.8 |
| 330 | 6.71 | 14.6 | 15.1 |
| 360 | 6.71 | 15.2 | 16 |

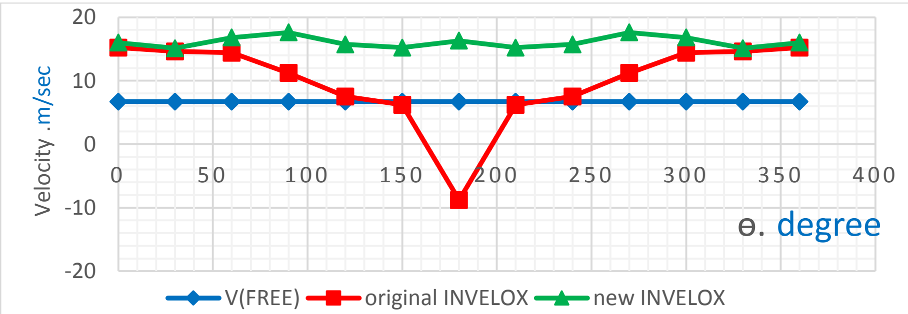


Figure.12. the relationship between velocity values

Table.2. shows speed ratio for original INVELOX and new INVELOX.

| Ө | SR | |
|---|---|---|
| | original INVELOX | new INVELOX |
| 0 | 2.265275708 | 2.384500745 |
| 30 | 2.17585693 | 2.250372578 |
| 60 | 2.146050671 | 2.503725782 |
| 90 | 1.669150522 | 2.62295082 |
| 120 | 1.117734724 | 2.339791356 |
| 150 | 0.923994039 | 2.265275708 |
| 180 | -1.31147541 | 2.429210134 |
| 210 | 0.923994039 | 2.265275708 |
| 240 | 1.117734724 | 2.339791356 |
| 270 | 1.669150522 | 2.62295082 |
| 300 | 2.146050671 | 2.503725782 |
| 330 | 2.17585693 | 2.250372578 |
| 360 | 2.265275708 | 2.384500745 |

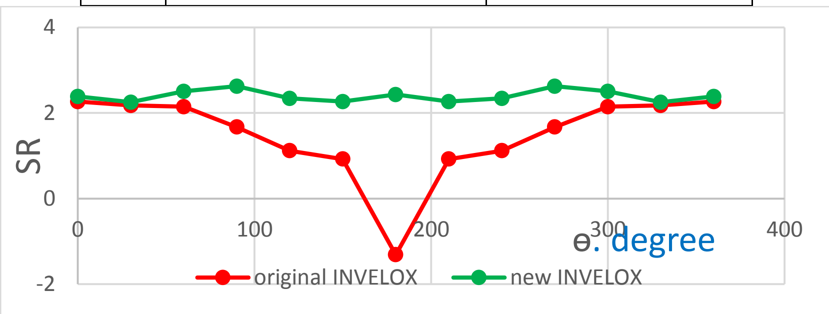


Figure. 13. The effects of wind direction on the speed ratio.

## IV. Conclusions.

The new INVELOX model achieves prevention of reverse flow inside it so that all amount of air passes intercepted by the intake of new INVELOX model passes from the intake to the outlet. In addition, the velocity value in the Venturi region is almost constant and its average value is (16.084 m/sec). The value of SR is almost constant and its average value is 2.39.

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