

INVOLVING FLUID POWER IN ART – A POSSIBILITY TO MATERIALIZE THE ARTISTIC VISION

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Abstract: The article presents the materialization of an artistic vision with the help of mechanical engineering, involving the fields of fluid power, mechanics, electricity, and others. In order to create a component of the Ivan Patzaichin Memorial Ensemble from Tulcea, a collaboration was established between an artistic team (artists, architects, etc.) and a design team; the object of the collaboration was the creation of a feasible project for the physical realization of a 'water wheel', inspired by Asian technical achievements in the field of irrigation, but with a symbolism adapted to the purpose of the artistic creation. The final physical realization was very close to the artistic vision.

Keywords: Fluid Power, artwork, Ivan Patzaichin Memorial Ensemble, water wheel, hydraulic drive system

1. Introduction

Most works of art in history or today are static creations; very few add movement to the images or shapes, mainly because this would imply some technical knowledge of the artist or association of the artist with people in the field of exact sciences, such as engineering, mathematics, physics, etc. However, the impact of an artwork with moving elements is much greater, compared to a static one [1]; and when nature is associated with the artistic vision and contributes to the realization of an object in motion, the result is a superior one [2].



Fig. 1. Kinetic Sculpture by Anthony Howe

Waterwheels belong to the category of human achievements that have gone from useful objects to artistic achievements; while in the past they harnessed the energy of running water for the production of energy used for multiple purposes (grain mills, sawmills, pumps for irrigating fields, various small factories, etc.), today they retain their utility only in less developed countries, and in many cases their maintenance is done for tourist purposes.

One such example is the water wheels for irrigation in Vietnam [3]; in some regions, water wheels were adapted for "pumping" water due to the artificially created level difference; the water is raised by means of vessels into a trough at a height, whence it is distributed to the fields to be irrigated by means of bamboo pipes. In addition to their practical utility, they are an attraction for visitors.



a.



b.

Fig. 2. Irrigation water wheel in Vietnam. a. – overview; b. – water collection reservoir

In Romania, at the initiative of the Ivan Patzaichin – Mila 23 Association, a water wheel was created, which is part of the Ivan Patzaichin Memorial Ensemble located on the Ivan Patzaichin seafront in Tulcea. As is well known, Ivan Patzaichin was a famous Romanian sportsman, with a competitive activity of 43 years, of which 18 years as a canoeist and 25 years as a canoe racing coach. Ivan Patzaichin was born in the village of Mila 23 in the commune of Crişan, Tulcea county, and spent his entire career at the Dinamo club in Bucharest. In 2010, together with the architect Teodor Frolu, he founded the Ivan Patzaichin - Mila 23 Association, which aims to promote the nature and traditions of the Danube Delta and the development of this region, but also of other areas in Romania. After the disappearance of Ivan Patzaichin, the association made efforts to create a memorial to remember his activity; this memorial comprises 6 works that highlight his native area and sports activity. Among these works, the one titled "Water Collector" (or "Water Wheel") is the only dynamic work, and the one with the deepest meanings.

2. The objective of the work. Requirements and possibilities of achievement

2.1 Artistic requirements

Being a work carried out with public funding, the proposal participated in a selection contest; the author of the work, the artist Dan Vezentan, describes it as follows in his proposal:

Kinetic floating installation, attached to a floating pontoon, which will collect and transform water from the Danube into drinking water. Its shape starts from the mill wheel (+ inspirations from Asia – Vietnam) and consists of **24 radially arranged arms** (the 24 hours of the day), which have **enamelled metal buckets** at the end, **paddles** for movement/rotation and on the outside **480 of decorative "wings"**. Inside we will have a **stainless steel double-walled collection basin** to keep the water at a decent temperature + discharge through the inside. It will take the water collected through pipes inside the axle and filter it through an approved system. The principle of operation of the wheel is similar to that of the bicycle fork: the wheel rotates, the fork and the axle are fixed.

To this fixed axis we attached the basin, which will take the water between the movements of the buckets in the interval 10...14 - if we visualize the wheel as a clock.

The author of the proposal has also made various simulations of the object, both in electronic format (artistic drawings or simulations), as well as a 1:5 scale model.



a. b.
Fig. 3. The water collector in artistic vision. a. – artistic sketch; b. – numerical simulation

The biggest challenge for this work was the materialization of the artist's vision in a dynamic object, but which also has utility (provides drinking water), in a structure as close as possible to the artistic one.

In order to obtain the best results, the promoters of the project turned to the Hydraulics and Pneumatics Research Institute from Bucharest, for the development of the layout, and for the actual embodiment a company specialized in metal works was chosen. Since in the artist's vision, the wheel had to be driven in rotation by the Danube, the first stage of the project was to make a dimensioning calculation, to see to what extent it is possible to implement this solution.

2.2 Checking the working condition of the water wheel when driven by the Danube

The water wheel proposed in the project is of the type with lower intake, suitable for floating constructive solutions, with simple construction but which have the lowest efficiency compared to the other types of water wheels [4, 5, 6]. Figure 4 shows a simplified diagram of the water wheel, for which the dimensions necessary for the operation verification calculation are highlighted, and figure 5 shows the proposed site, for which the functional parameters - depth and water speed - have been determined.

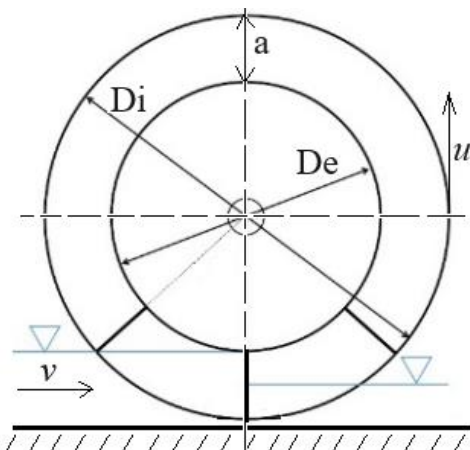


Fig. 4. The dimensions of the water wheel



Fig. 5. Location of Ivan Patzaichin Seafront

The calculation scheme for the water wheel consists in checking the power that it can supply to the shaft so that two conditions are met: that of starting at a low level of water, respectively of the speed of the water current, and the water supply of a water tank coupled to a filter device for providing drinking water.

The water wheel has 24 straight vanes at the end of the arms and works through the effect of hydraulic shock, thus neglecting the relative flow between the blades and therefore the connection

between the absolute velocity "v" of water flow, the peripheral velocity "u" and the relative velocity "w". Under these conditions, the efficiency of the wheel has values between 0.3 – 0.4. The impulse force will be:

$$F = \frac{\gamma Q}{g}(v - u) \quad (1)$$

where the flow rate Q is calculated taking into account the width B of the wheel and the data according to figure 4.

$$Q = B \cdot a \cdot v \quad (2)$$

The wheel power under the above conditions is:

$$P = \frac{Fu}{75} = \frac{\gamma Q}{75g}(vu - u^2) \quad (3)$$

By deriving relation (3) in relation to the peripheral speed u, the optimal peripheral speed of the wheel is obtained which is: $u = 0.5 v$, or for practical reasons $u = 0.45 v$. Under these conditions, the maximum hydraulic power will be:

$$P_h = \frac{\gamma Q}{75g}(0.45v^2 - 0.45^2v^2) = 0.336 Qv^2 \text{ (CP)} \quad (4)$$

If the theoretical power of the river is:

$$P_t = \frac{\gamma Q}{75g} \cdot \frac{\gamma Q v^2}{2g} = 0.68 Qv^2 \quad (5)$$

it follows that the theoretical hydraulic efficiency of the water wheel will be:

$$\eta_h = \frac{P_h}{P_t} = 0.495 \quad (6)$$

If it is considered that the mechanical efficiency of the rotating assembly would be $\eta_m = 0.8$, the effective power at the turbine shaft can be calculated:

$$P = 0.336 Qv^2 \eta_m = 0.27 Bav^2 = 0.27 Sv^2 \quad (7)$$

where S is the surface of the blade immersed in water, having the shape of a rectangle with sides B and a.

The geometric data imposed by the proposed water wheel and the hydraulic parameters of the site are: maximum speed of the water current $v = 1$ m/s; blade width $B = 0.6$ m; blade length $a = D_e - D_i = 0.55$ m. For these data, the power at the turbine shaft will be $P = 66$ W, resulting in a rotation speed $n = 3$ rev/min. Considering that the actual speed of the water in the site will be lower for the period of the warm season, when the demonstration water wheel will be in the public's attention, the average speed of the current was evaluated at the value of 0.4 m/s. Under these conditions the total power available at the shaft will be $P = 11$ W, which shows that, in fact, **the water wheel will not be able to be turned by the Danube.**

After placement, it was found that a number of 3...4 blades are simultaneously in the water, which recommends doubling the power obtained above for a single blade; however, even in the situation of doubling the power, there is not enough energy for the Danube to turn the wheel.

2.3 Presentation of the implemented solution

Because of the insufficient energy that flowing water can provide, the wheel will have to be driven into rotational motion by an external source; the solution to this requirement was to drive the wheel with a hydraulic system (whose diagram is shown in figure 6), hidden inside the support subassembly. It ensures a rotation speed of 1 rpm, as well as safe operation, taking into account that it is located on the Danube.

The power source is a compact pumping unit (1), which generates a flow transmitted through the directional control valve (3) to the low speed orbital motor (4). This motor offers high torque and low rpm, but still too high for the application; for this reason, a planetary reducer was placed after the motor which reduces the revolution in a ratio of 21.6:1, so that the final revolution of the wheel is 1 rpm. In order for the water wheel not to increase its speed due to the increase in water speed, a double overcenter valve (2) was installed in the system. For the maintenance of the wheel - free rotation - a valve (6) was mounted that can link the two connections of the hydraulic motor together, allowing it to rotate freely.

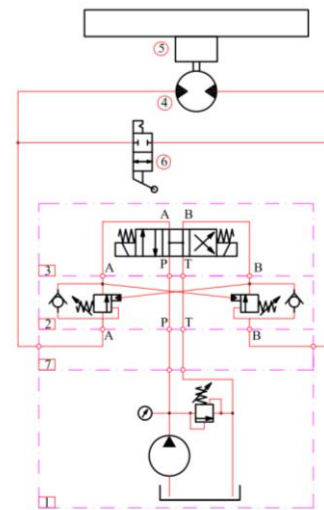


Fig. 6. Hydraulic diagram of the drive system

2.4 Realization of the components

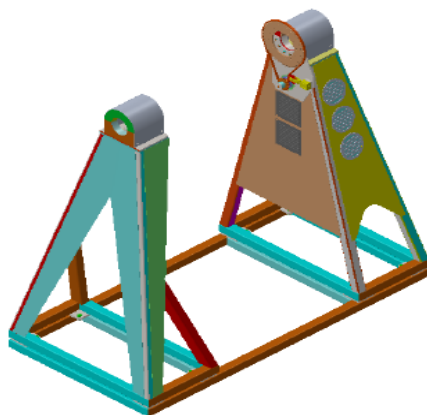
For the mechanical and water circulation parts, solutions were found in time that meet the following requirements:

- to have the artist's consent
- can be manufactured by a company specialized in metal constructions (TEHNOMET SA Buzau)
- to allow the obtaining of drinking water, which can be safely consumed by tourists; this task was assumed and completed by the company Toma Treatment Group SRL [7].

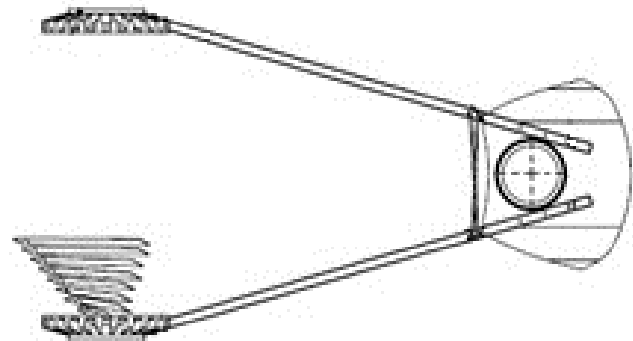
Constructive particularities, taking into account that the artistic work is located on the Danube:

- the spokes of the wheel were galvanized; removable assemblies were made with screws protected against oxidation
- the decorative fins were made of stainless steel
- the tank was made of stainless steel
- the buckets are enamelled and painted in a colour representative of the Danube Delta area (Lipovan blue)
- in the cold season, the assembly is taken out of the water and stored in a special place, so as not to be damaged by ice.

Below are some images (figure 7 and figure 8) of the designed and built components.



a.



b.

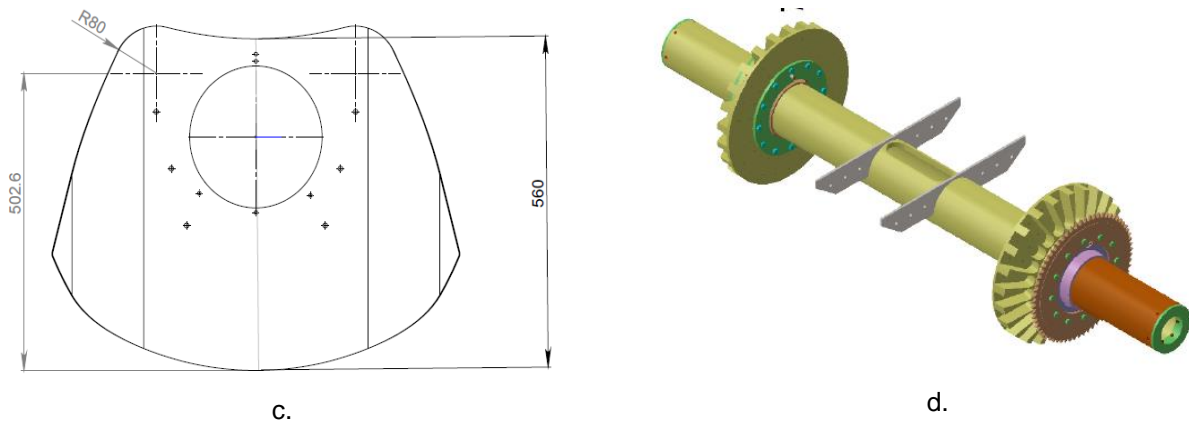


Fig. 7. Components designed and built
a. supporting structure; b. arm plus wheel blade; c. blade; d. wheel shaft

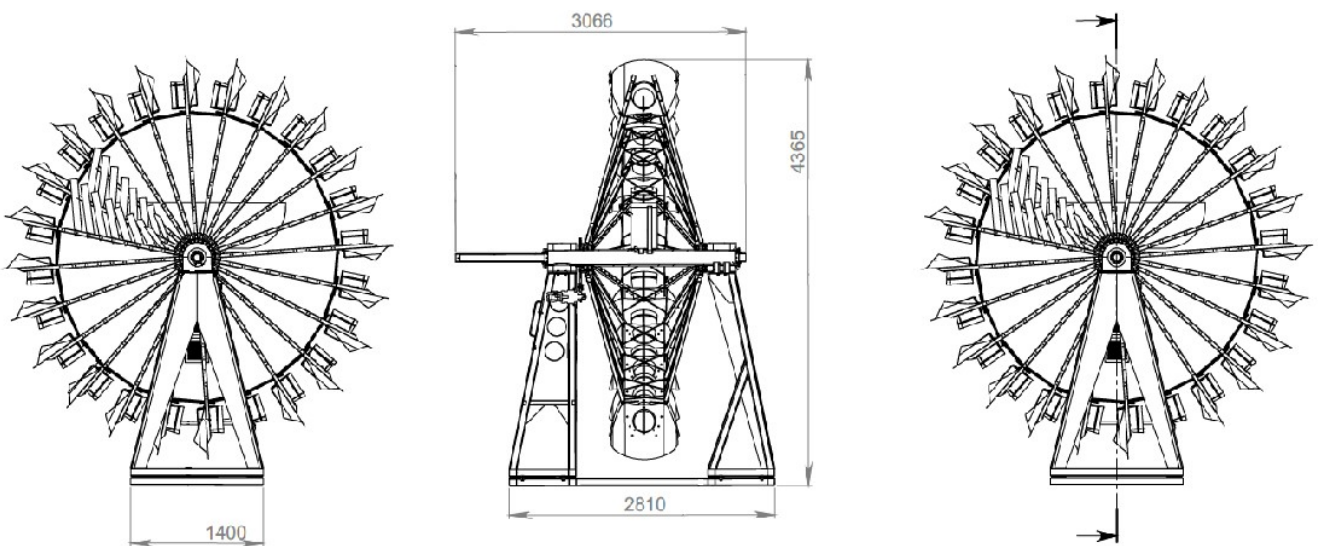


Fig. 8. Overview of the water wheel

The whole assembly is placed on a floating pontoon, so that the blades and buckets enter the water partially. The water collector was made in a form very close to the one proposed by the artist, as one can see in figure 9 below.



Fig. 9. Waterwheel located on site

3. Conclusions

Starting from the artistic vision, the work was carried out in such a way as to meet all the requirements of design, functionality and security in operation. The chosen solutions took into account the operation in the specific environment of the location area, the Tulcea seafront. For turning the wheel, it was determined in the design phase that the energy provided by the Danube is insufficient; therefore, a solution was implemented for the drive with a rotary hydraulic motor and a speed reducer, which are located in the area of the wheel support structure and are not visible to the public. The rotation speed is 1 rotation/min. The filtration system has also been made to the expected parameters and can provide high quality drinking water.

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References

- [1] Chen, Guang-Dah, Chih-Wei Lin, and Hsi-Wen Fan. "The History and Evolution of Kinetic Art." *International Journal of Social Science and Humanity* 5, no. 11 (November 2015): 922-930.
- [2] ***. "Anthony Howe. Available works." *Howe Art*. Accessed October 5, 2023. <https://www.howeart.net/>.
- [3] Thien-Viet Cuong, Thong. "Water Wheels in Na Khuong." *Vietnam Pictorial*, September 19, 2017. Accessed October 16, 2023. <https://vietnam.vnanet.vn/english/tin-tuc/water-wheels-in-na-khuong-157792.html>.
- [4] Pavel, Dorin. *Hydraulic machines / Maşini hidraulice*. Vol. I. Bucharest, State Energy Publishing House / Editura Energetică de Stat, 1954.
- [5] Budiarmo, Budiarmo, Dendy Adanta, Warjito, Ahmad Indra Siswantara, Pradhana Saputra, and Reza Dianofitra. "Optimization of the Water Volume in the Buckets of Pico Hydro Overshot Waterwheel by Analytical Method." *IOP Conf. Series: Materials Science and Engineering* 316 (2018): 012056.
- [6] Nuernbergk, Dirk M. *Water wheels with goiter channels. Calculation bases and new findings / Wasserräder mit Kropfgerinne. Berechnungsgrundlagen und neue Erkenntnisse*. Verlag Moritz Schäfer GmbH & Co., Detmold, 2013.
- [7] Borş, Adriana Mariana, Ştefan Toma, Liliana Dumitrescu, Ştefan-Mihai Şefu, and Gabriel Nae. "Advanced water purification system - contribution to the development and promotion of Romanian cultural and natural heritage." Paper presented at ISB-INMA TEH' 2023 International Symposium, Bucharest, Romania, October 5-6, 2023.