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The Historical Aspect of Windmills Architectural Forms Transformation

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Abstract

The modern wind-power engineering is one of the perspective directions of using ecological clean energy in the building. The article deals with the historical aspects in the transformation of the windmill's architectural forms, structures and their elements, which intend to convert wind's energy.

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1. Introduction

The modern wind-power engineering is one of the perspective directions of using ecological clean energy. Renewable energy sources used to ensure energy supply can be considered to be an upcoming trend for civil engineering [1-10]. The article deals with the historical aspects in the transformation of the windmill's architectural forms, structures and their elements, which intend to convert wind's energy. Along using of water power for the rotation of mills' water wheels, from ancient time people used to wind power for sailing. These two ideas had deep combined, forcing the wind to rotate the grindstone in the arid steppes of Asia or in the Middle and Near East (presumably in Persia) around the VII century BC. So, vertical shaft with sails based on the millstones which turned when the wind blew. Wheat or barley was milled with such simple windmills, as well as water was pumped out of

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the ground. The transformation of the windmill's architectural forms has been occur depending on social needs, the development of science and manufacturing processes and natural environment [11-22].

2. Historical Evolution

In general, there are two versions about the time of the windmill appearance (according Ph.D. Ponomarev N. A. [23]. One of them is very often expressed by many authors the windmill was invented in the Middle East, in Asia Minor, and from there entered Europe by the Crusaders. According to another version, the windmill is a European invention, appeared in the XII century or even in the XIII century.

If a post-mill had been brought to Europe by the Crusaders from Asia Minor, and about it only as we shall see, can be a question, it means that it existed in the East, at least in the IX - X c., because the Crusades campaign began in 1096. [23]

Arab geographer al-Masudi wrote about the windmills existence in Persia, who saw them in the Persian province Sistan between 915 and 943: "Sistan is primarily known as a country of wind and sand. It is known for own art using to rotate the wind mills and lifting water from wells for irrigating the gardens." The fact that the appearance in Persia in the VII century the most primitive windmill was possible, almost unquestioned. At this time, the state of the productive forces in the country was at a high level: early feudal relations formed in the VI century in Persia.

Everywhere in the states of Western Europe and Asia Minor a watermill were familiar and enjoyed. Therefore the primitive windmill could well appear in the countryside with poor water resources [23]. Arab travelers and geographers in the middle of tenth century wrote about the existence of windmills in Sistan as well as the indisputable fact. Abu Ishaq Istakri wrote: "The land around the city is deserted and sand. The air is very warm. Figs are growing here; no hills. There is no snow in the winter. Winds blew and therefore they have windmills. [24]. There are several mentions of windmills in Persia. But the most important is the description Sistan's mills and their extremely valuable drawings are in Arabic manuscripts Dimashqi Shams al-Din Abu Abd Allah Muhammad (about 1271) (Fig. 1) [23]. There is description in these manuscripts:

"Sistan has an area where frequent winds dominate and there is a lot of sand. People use the wind to rotate the mills and to move sand from one place to another, so winds subject them... They build a tall building as a minaret, or choose a high place or city tower. Here they build one building over another. There is mill in the upper building in which rotates and grinds grains. Wind wheel is built on the ground floor, rotating by wind. In this case mill on the upper floor also rotates. Whatever the wind is blowing, such mills are rotating, despite the fact that there is one millstone. ... After the construction of the two buildings, as shown in the figure, it is necessary to make four loopholes in the walls on the ground floor... The widest part of it should face outward, and the narrow part is inside; thereby a passage is obtaining for air through which it penetrates into the building with great force.

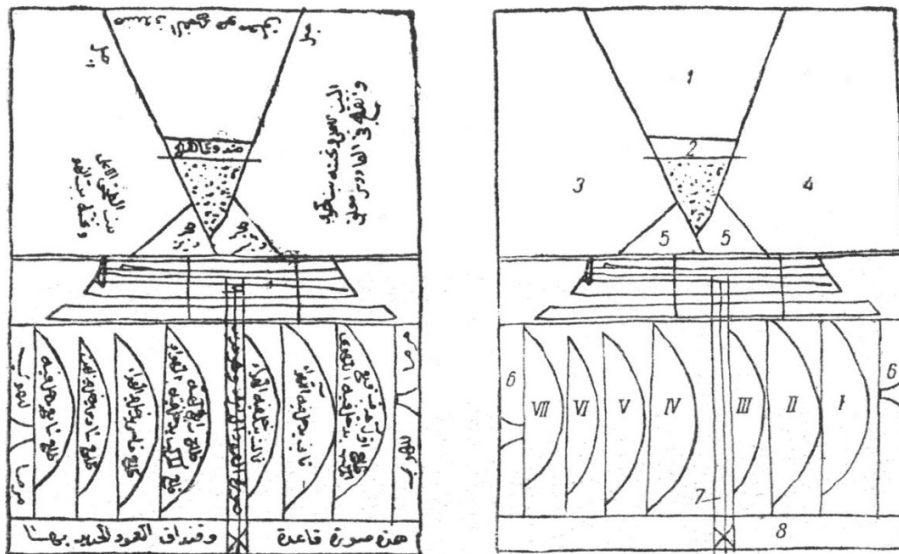


Fig.1. The Sistan mill. Drawing from Arabic manuscripts by Dimashqi Shams al-Din Abu Abd Allah Muhammad (about 1271)

1 - suspended bucket for wheat; 2 - bucket of wheat; 3 - upstairs room for grinding, there is the air chamber under it; 4 - upstairs room for mealing and wheat in the funnel; 5 - rotating grindstone; 6 - place the air inlet; 7 - the image of rotating iron rod; 8 - the image of a base: I - VII - from the seventh to the first sail, which include air

Air, entering into the building, falls on one of the concave blade wings of the rotating drum (meaning a wind wheel). The drum has 12 ribs, but their number can be reduced to six. On the edges matter is stretched, which divides the drum on the radial vane chambers with concave wings.

Air, entering into the first chamber, pushes forward and then falls into the second chamber and pushing forward and then the third and so on, so that the drum comes into rotation, and also the rotating grindstone grinding flour. These mills are suitable for highly placed castles and for areas where there is little water, but strong winds dominate. [25] It was a mill with wings on a vertical shaft, which now can be found in Sistan. They were used for wheat and barley grinding, as in the old days used to irrigation. "These mills are built from stone and sun-dried bricks. Mills stand in rows like houses. The wind enters into the hole in the wall and out through the big hole on the opposite side. [23] Early windmills with sails on a vertical shaft were not characterized by high productivity. However, it had greatly increased with the understanding that more power was produced when the blade or sail were fastened to a horizontal shaft exiting from the tower. The horizontal shaft informed through gears to vertical shaft rotational movement which turns the millstone attached to it. This modification allowed to use wind energy with a greater extent. Now mills could drive the more powerful mechanism.

But no matter what work was performed by the mill, it was required a continuous supply of energy. But the wind has a major drawback: it often changes direction. How could it ensure the sails were always arranged with the direction of the wind? The next design was the invention mill on the post. These mills were resting on a pole propped beams that allows you to rotate the entire mill barn, setting the wings against the wind. There is a huge amount of post windmill images with four wings relating to the XIII - XIV centuries in European sources. Five drawings windmill is available in the Decretals by Pope George IX, published in Italy, but illustrated in England (Fig. 2).

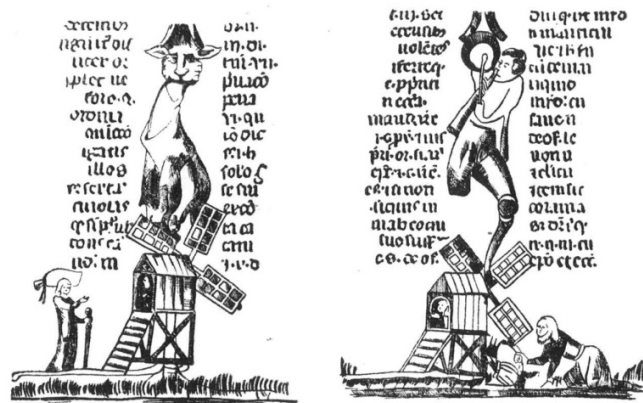


Fig.2. The post-mills images in the Decretals by Pope George IX

The Wales annals by Iolo Morganvi say that water and wind mills appeared in Wales in 340 AD. The history of the Cathedral of St. Augustine in Canterbury, written in the XVI c., argues that the windmill was used here in the 669, [23]. although this is not confirmed by other data. There are other references about windmills, but the dates of many letters are questionable.

Available reliable documents with references of the windmills dated not earlier than XII century and indicated that the windmill was not a gimmick in Western Europe, though quite possible, was not widespread. The post-mill was widely known in Italy, Flanders and Holland in the XIII century. The "Domesday Book" reflected the state of England not only in 1086 but also in the time of King Edward (up to 1066). There are mentions of the 5624 mills with an indication of their location in this book. [26] According to this census we can establish that each mill had an average of 50 families. There is no indication what the kind of mills was - water or wind, but British scientists found that they were mainly in the settlements standing on the rivers or streams. It is possible that in arid areas, already at that time windmills could be built.

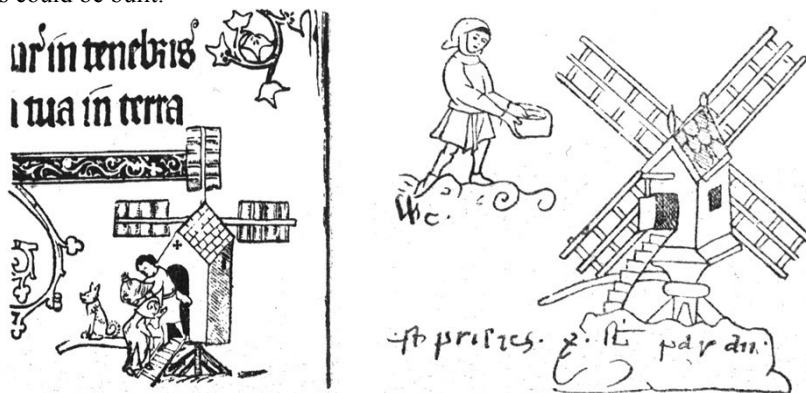


Fig.3. The post-mill's image from the manuscript Psalter XIV c.

Comparing the levels of socio-economic development of Britain and other Western European countries, Ponomarev came to the conclusion that the saturation of the mills in these countries was quite high. The main cause of windmills using in Europe, as he believed, was the maximum utilization of water resources, and therefore the use of wind power had expanded opportunities for the development of the feudal production

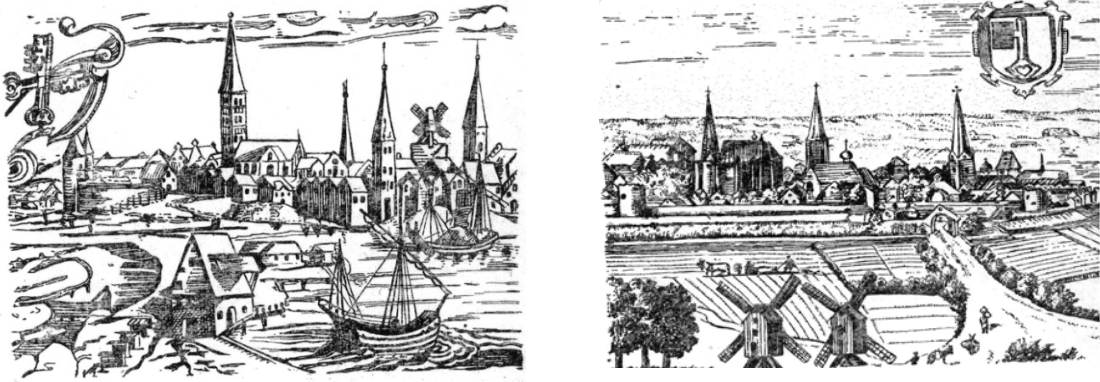


Fig.5. The post-mills images on the engravings of medieval cities: on the walls or outside the city walls.



Fig.6. The post- and tower mills images on the engraving by Dutch artist Jean van der Strat, who lived at the end of XVI - early XVII century in Italy.

A mill ban went into life in France in the IX century, much earlier than in other countries. It was seignior age prohibit the inhabitants of a certain district from grind grain on any mill other than the lord's. Already in the IX - X centuries. there were all conditions for the emergence of a windmill, contribute to the further development of the productive forces of feudal society. With high probability we can assume that firstly post windmill appeared in Normandy.

Windmill gradually had been introducing in agriculture emerged and grew cities in the XI - XIII centuries. (Fig. 5, 6). In XIV - XV centuries. windmill had been becoming an imminent membership of many European cities. Mills images that time say that everywhere stand-mills had been building. It was not possible to build water mills in the cities surrounded by castles for reasons of fortification and navigation.

There is not evidence that before the stand-mill advent in Western Europe another existed there, with the shaft of the wind wheel setting in the one position. Although such mills still exist on the west coast of Crete. They are located on the hillside and operated during certain hours by air flow rising from the sea. It is possible that such mills could be predecessors of post-mills.

The post-windmill meets the needs of feudal society everywhere, where there was no water in the course of more than four centuries since its launch. In the XV century development of the productive forces in Western Europe

had risen at a high level.

For obvious reasons the post-mills could not be very large and could not meet the requirements of the owners of large farms. The mill's size increasing was constrained by the need to keep it on the same vertical large diameter column.

The oldest known to date post-mill's design drawings of the 1430, was belong to the Italian Mariano Jacob Takkolo (Fig. 7). One of the drawings was a project which provides for increasing the revolutions number of the millstones two Lantern transmission. The idea of a two millstones drive to put from a water wheel belongs to him also. (The speed of the millstones from the time of Vitruvius to about the middle of the XVIII century did not exceed 30 revolutions per minute) [23].

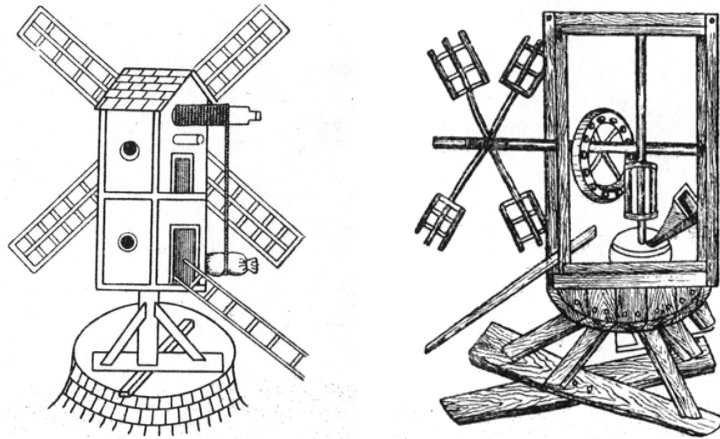


Fig.7. The oldest design drawings of the post-mills by Mariano Jacob Takkolo. 1430 [1]

The first step in the improvement of the windmill was an increase in the number of the post-mill's wings of the wind wheel to six, and then to eight. These mills were to be found in Russia, for example, in the Moscow province (Fig. 8). But the increasing of the number of wings or lengthening it only weigh the structure.

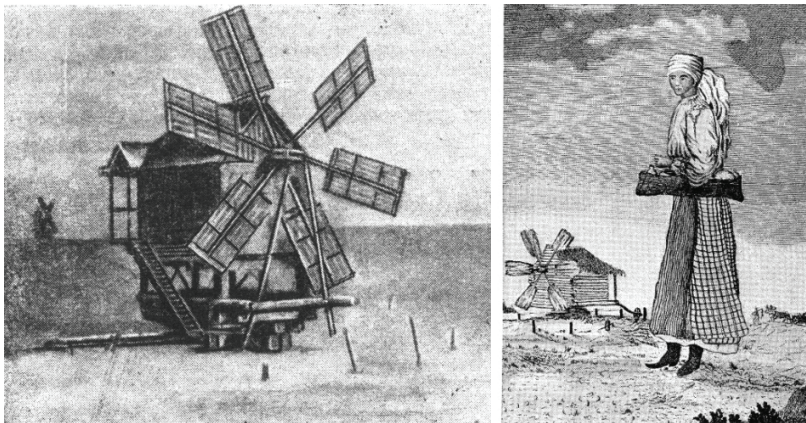


Fig.8. The six-winged post-mill in Moscow province on Russian types lithographs. Little Russian peasant woman from the book by Goun [5]

And then there was a new design - a fixed tower with a revolving roof. In this type of mill main shaft coming out of the roof, so that wherever the wind blew it with the wings- sails can be deployed against the wind with a lever or "gates", mounted on the other side of the roof and reaching up almost to the ground



Fig. 9. The tower-mill's image in the manuscript collection of poems by french poet Guillaume Machaut, XIV c (Paris National Library)

The oldest image of the tower-mill with rotating top is available in one of the drawings in the manuscript collection of poems by French poet Guillaume Machaut which stored in the Paris National Library. The manuscript belongs to the XIV century (Fig. 9) [23] The second image of the tower windmill is available in Hebrew manuscript about baking, dated near 1400 and stored in the Nuremberg Museum (Fig. 110). Another ancient image of several tower-mills can be seen in the book Gryunemberga Knight, in which he described his journey to the Holy Land. (Fig. 11)

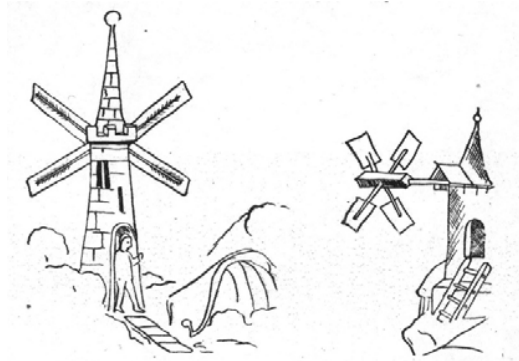


Fig.10. From Jewish manuscripts of baking, dated approx. 1400 (Nuremberg Museum)

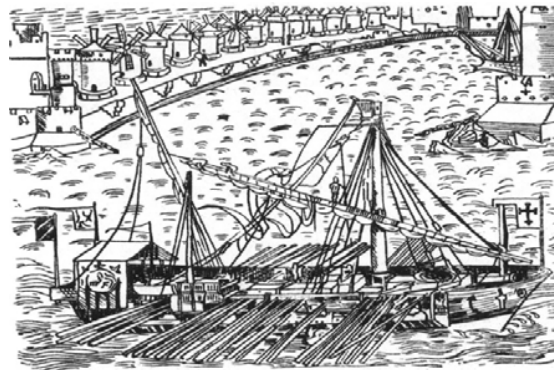


Fig.11. Panorama of Rhodes harbor port with 13 six-winged tower-mills from the book by knight Gryunemberg, in which he described his journey to the Holy Land

The unfinished sketch of the tower windmill without comment 1500 and sketch the rolling circle of a mill roof belongs hand of Leonardo da Vinci (Fig. 12). With this construction of the rolling circle for the roof there is no need to turned beam. Such roof can be rotated inside too.

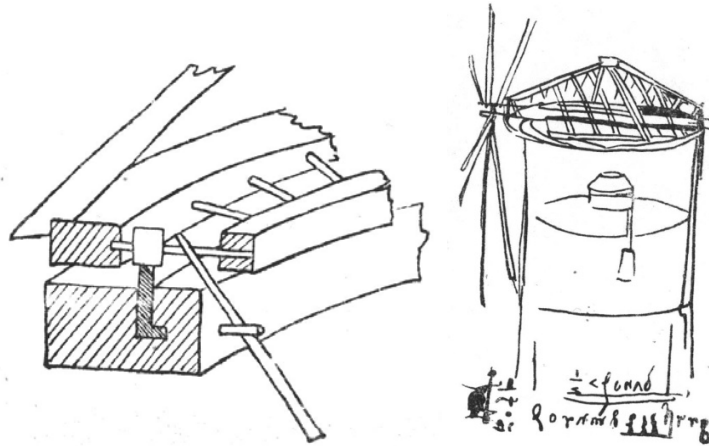


Fig.12. The tower-mill by Leonardo da Vinci and the sketch of a rolling circle in a tower-windmill roof by Leonardo da Vinci

So, based on the comparison of different data, it can be argued that the tower windmill was invented by no later than I half of XIV century.

The stone building of a smock-mill, cylindrical, resembling a tower not only provides greater stability facilities, but also allowed to use greater length wings and, consequently, the larger diameter of millstones through the increasing power of the wind turbine (Fig. 16).

The oldest body of such mills are still used on a number of islands in the Mediterranean, in Portugal, Spain and Normandy. Mills with wings-sails are probably one of the earliest in the series of mills with a horizontal shaft, by analogy with the sails of ships, as the use of wind energy in the sailing fleet was, of course, initially.

Understanding of the internal structure of the tower-mill is given by information from the encyclopedia I. Kryunitsa (Fig. 13). A single stone grinder is emplaced on the second floor. A winch is visible for lifting bags to the second floor. The mill has no vertical shaft with a toothed wheel for rotation grindstones below. The grindstone is rotated directly from the top by the gear which is fixed to the wind shaft. An internal location and mechanisms system are similar to the post-mill. [28].

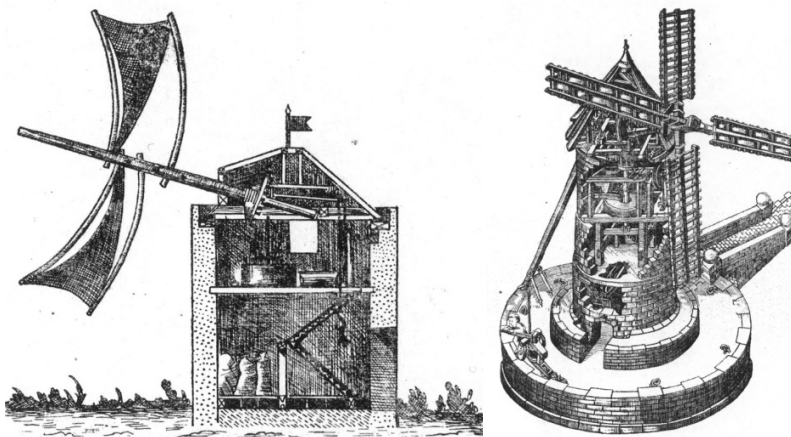


Fig.13. The tower-mill's section from the Encyclopedia by I. Kryunits [28] and the engraving of the smock windmill in stone body from the book of the XVI century by famous engineer Agostino Ramelli. 1588.

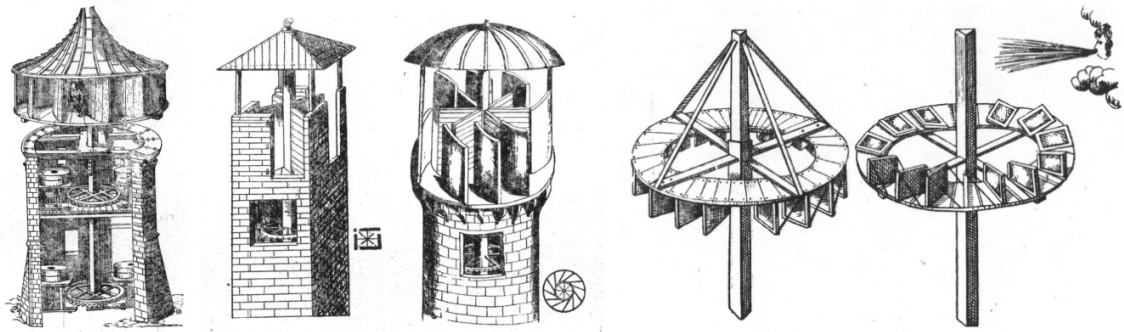


Fig. 14. Drawings of construction variants tower-mills carousel tipe by F. Veranti XVI century

In the XVI century search for improvements mills was continued. Hungarian bishop Faust Veranty who enjoys technique followed the path of development wings on a vertical shaft, on the basis of Sistan, the most ancient, which is used mainly in one direction of the wind (Fig. 12 - 14). Despite the long history of existence these mills had not become widespread because of the fact that the utilization of wind energy have been lower than the post and smock-mills.

But this type of mill had existed before the XIX century. They were to be found in Russia too (Fig. 15): “7 sails are arranged inside the buildings, like the sails of a boat, and the building is equipped with a large and close outside doors and windows. When a favorable wind blows two or three windows are opened on the side from which it is blowing, and through these windows or doors wind blew up the sail and drives the rapid treatment the entire machine”[29].

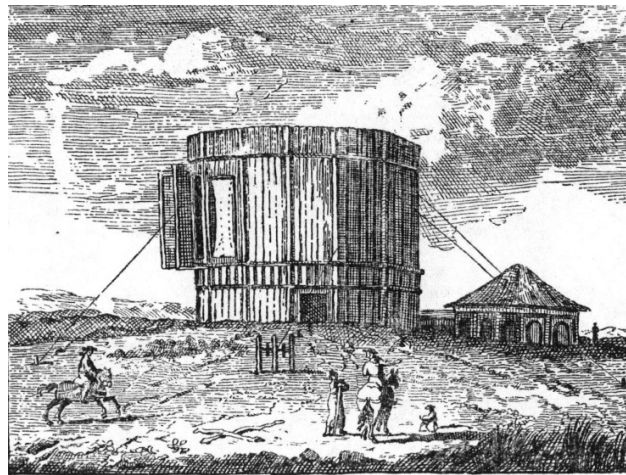


Fig.15. The tower windmill of a carousel tipe near Voronezh, arranged by Cherkassy master (1703) (From de Bruin).

In 1804 the appearance of a windmill with a vertical shaft and wings in the form of triangular sails were published by F. Kryunits in his encyclopedia. Besides wind power such mill used to a power of animals. There was the carrier for horse traction on the ground floor of the mill (Fig. 16). On the ground floor of the mill carrier for horse traction is shown. This kind of mill called horse-wind.

The problem of constantly changing wind strength control was solved in 1772 by the Scottish inventor who replaced sails on the automatically opening and closing shields, similar to the blinds. With rotating roofs and self-adjusting wings windmills reached its peak at the end of the XIX century.

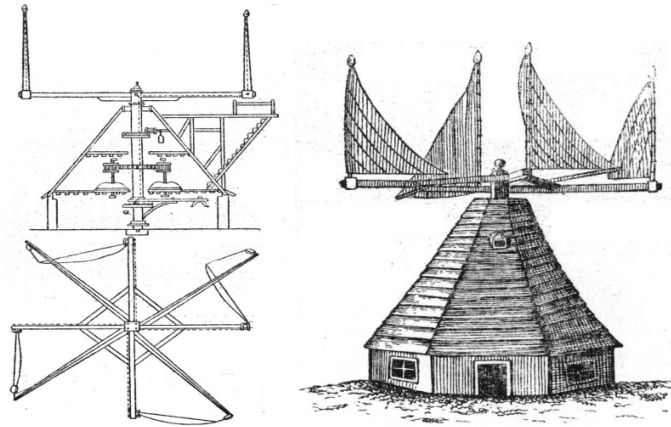


Fig. 16. The exterior of the windmill with a vertical shaft and wings in the triangular sails (encyclopedia by F. Kryunits. 1804) and the mill's longitudinal section and the the wind wheel's plan from the encyclopedia by F. Kryushits.

3. Conclusions

Windmills construction and types had been developing during almost 10 centuries. The problem with wind generated power is that it is subject to the whimsies of the wind. The transformation of windmills forms had been occurring depending on social needs, the development of science and manufacturing processes and natural environment. Achievements of scientists, engineers and builders influenced the spread of more efficient mill structures in other countries. Model projects had been published in the scientific literature. Windmills reached their own peak in the XIX c. But handy for running direct current appliances, when electrification by connection to the main power grid came to many rural areas, the windmill lost its popularity at the early XX c.

With the increasing interest in clean energy and advances in technology, windmills have come back into vogue.

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