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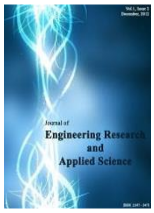

Designing and Modelling of Vertical Axis Wind Turbine with a New Wing Structure and Investigation of Electricity Production

Mahmut Gur[1,a], Ethem Toklu[1]

[1] Duzce University, Faculty of Engineering, Mechanical Engineering, Duzce, Turkey.

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Abstract
As a result of increasing needs and increasing production capacities, the need for energy has increased, and energy supply has become difficult due to demand intensity. The use of limited energy stored in the ground layers causes many environmental problems and the negative effects on the cycle of nature increase day by day, increasing the interest of the authorities in renewable energy sources. The direction of this interest is in the direction of energy sources that are easy to use, mature in technology, and developing the fastest. Countries direct their investments to their own energy resources that can be found continuously and that do not have the cost of raw materials. Countries prefer wind energy for reasons such as reducing imports in energy, being environmentally friendly, and easy and fast facility installation. In this study, wind energy, which is one of the alternative energy sources, and wind turbines that will enable us to use wind energy like electricity or mechanical energy are examined. The blade model of the vertical axis wind turbines, whose prototype production is planned, was designed and modeled and the turbine electricity generation was examined.

Keywords: Wind turbine, vertical axis, wing, electricity production.

1. Introduction

Energy, which is generally a difficult concept to understand, is tried to be explained by giving examples from time to time. Sometimes it can simply be defined as the safe use of power in nature. In law, it may be specified separately. E.g; In the "Energy Efficiency Draft Law (EVYT)", energy; is defined as the ability of a system to produce activity outside of itself. In the Japanese Law for the Rational Use of Energy (JERKY), energy is defined as fuel forms such as liquid fuel, combustible natural gas, and coal, as well as the heat and electricity obtained from them. In addition to these, Naoto Shinkawa has received three awards for energy saving in Japan. According to this definition, energy is expressed as "money needed to (purchase) a comfortable and comfortable (appropriate) livelihood" and is also emphasized as "cash " by the UK Energy Efficiency Office. These definitions mean "energy = money”[1].

Energy resources are grouped in two classes in terms of the sources from which the needed energy can be obtained. The first is as it is obtained from nature, and the second is the energy sources created by processing after the source obtained [2-4].

Substances that cannot be replaced once used and cannot be used a second time are non-renewable energy sources. Nuclear energy source atoms, natural gas, hard coal, lignite, oil are non-renewable energy sources. These resources are not evenly distributed on the earth. There is a lot of it in one place, but there is no or very little in another place. Humans live all over the world and can stay away from non-renewable energy sources [4-6].

In order to avoid environmental pollution caused by the use of fossil fuels as well as the possibility of exhaustion of existing resources; People have turned to the search for a clean and inexhaustible source of energy. The Sun, which is the starting point of all kinds of energy, the Earth, which provides the living conditions for living things, and the Moon, the satellite of the Earth, can be examined in three groups as renewable energy sources as seen in Figure 1 [7].

[a] Corresponding author;
Phone: +90532 316 31 46, Email: mgur@entmakina.com

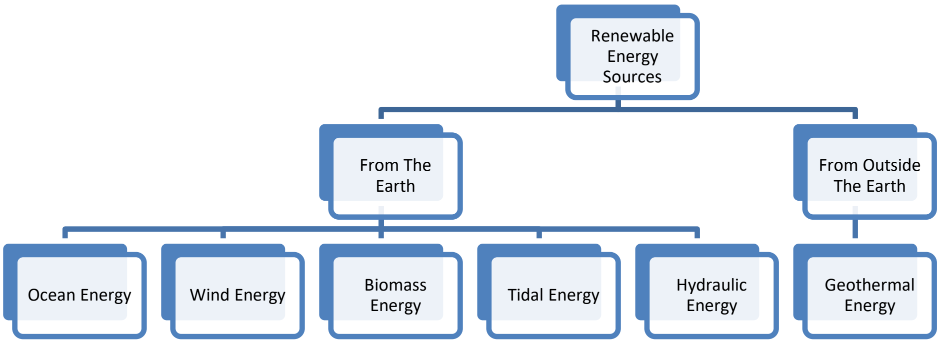

Figure 1. Classification of Renewable Energy Sources

Renewable energy sources, which are planned to be used as an alternative to fossil fuels, have not yet been brought to the desired level, except for hydroelectric energy, at the stage of competing with fossil fuels, which are traditional energy sources, due to both the innovation of technological developments and the high cost of installation and operation. However, geothermal, solar, wind and biomass technologies have just begun to appear in the world energy market. Recently, there has been a lot of research on the use of hydrogen as an energy source.

The use of wind energy in electricity generation dates back to earlier times, and electricity generation from wind started 100 years ago. Although it was mostly worked on relatively small diameter machines of 20-100 kW before the 1950s, the construction of 1250 kW turbines is based on these dates. In the 1980s, it was tried to be developed again with new technology and materials. In this context, new blade designs have been made and wind turbines with reduced costs have opened an era for wind electricity [6,7].

2. Wind Energy

Density of air changes with temperature. The heated air expands and its density per unit volume decreases. The air with decreasing density begins to rise through the denser air masses. The rising air mass stops rising when thermal equilibrium is achieved with its surroundings in certain layers of the atmosphere, and moves horizontally due to the movement of the earth. Heating and mass displacement of the air causes the pressure distribution to change. In this way, the pressure exerted by the atmosphere varies in every part of the world. Pressure differences vary depending on gravity, temperature and altitude. In this way, high and low pressure centers are formed. The air, which tends to be evenly distributed in its location, moves from high pressure areas to low pressure areas and causes the natural phenomenon we call wind to occur. When the winds reach the low pressure area, they tend to move tangentially to the hose wall formed by the rising air and move circularly around a center. The air flow, which starts a circular motion, is exposed to a force that tries to throw it outward from the center in each molecule. This force is called the force of inertia in Newtonian mechanics. The magnitude of this force varies in direct proportion to the speed of the air flow. The force that is not effective in creating the wind and resists the wind is called the friction force. This force, carried up by the turbulences, reaches its maximum value near the ground. This force, which is created by the wind being caught in natural or natural obstacles, can be effective up to 450-600 m from the ground. Some of the energy contained in air masses can be converted into usable mechanical or electrical energy. With the increase in the needs of this idea, the effort to use it since ancient times continues to increase today.

The wind, which exists naturally and is a type of energy that always renews itself, has been used by people even in ancient times. There is a need for new research on its industrial use.

Research has revealed that the use of wind energy began in the Middle East around 2800 BC. There are findings that wind energy was used for irrigation purposes in Mesopotamia in the 17th century BC and that wind energy was used in China in the same period. The first windmills were established near Alexandria, located at the mouth of the Nile delta. M.S. Although Turks and Iranians started to use the first windmills in the 7th century, Europeans also met windmills after the crusades. It was only in the 12th century that windmills began to be used in France and England.

Windmills, which were designed for purposes such as running sawmills, pumping water, grinding agricultural products in the field of forestry, continued their rapid development in many areas until the Industrial Revolution in Europe. The Dutch alone had built 10,000 windmills by the end of the 18th century. The dependence of the wind on the weather conditions and the construction of the steam engine; With the start of uninterrupted energy production from fuels such as wood and coal, wind energy has begun to lose its importance. However, the ease of access to wind energy, albeit irregularly, and the lack of supply costs have kept the construction of machines called wind turbines, which are used in electricity production, attractive. The first machine was established in Denmark in 1891 by Paul la Cour, one of the pioneers of modern aerodynamics.[8] In the recent period, important studies have also been carried out in Germany on the development of these machines. While wind power machines were replaced by fuel powered power machines, the development of new technologies for the continuation of the use of wind energy continued. However, it has been recorded that the efficiency of the first wind turbines developed in the 19th century was quite low.

In Denmark, in 1918, investments began to be made to deliver the electricity obtained by using wind energy to rural areas. Electricity generation in more than a hundred rural areas determined within the framework of this purpose is provided by the use of 20-30 kW wind turbines. In Russia, in 1931, a 100 kW wind turbine was installed and electricity was tried to be produced. In the USA in 1941, the largest wind turbine of the period with a power of 1250 kW was the Putnam wind turbine, which was installed in Granpa's Knop near Vermont. Its two-bladed rotor (wheel) had a diameter of 53 m. The Putnam turbine is considered the forerunner of modern wind machines. The total weight of the power plant, which was produced with a very high investment cost (approximately 1 million USD), was around 250 tons [6-9].

As a result of the experimental studies started in England in 1945 after the war, and in Denmark in 1947, three-wing Andreu machine with a power of 10 kW and a diameter of 15 meters in England in Enfeld, and in Denmark in 1959 with a diameter of 200 kW, with a diameter of 24 meters. A three-bladed Gedser turbine was installed. The wind turbine in Noeget Le Roi, one of the machines built in the same period in France, has a power of 300 kW. Evaluation of the turbines according to the number and form of blades is given in Table 1.

Table 1. Evaluation of the turbines according to the number and form of blades.

	1 Wing	2 Wings	3 Wings	More than 3 Wings	Savonious	Darrieus
Cost	High	High	Low	Low	Low	Low
Aesthetic look	Bad	Bad	Good	Good	Good	Good
Noise	High	High	Low	Little	Little	Little
Working Speed	High	Low	High	Low	Low	Low
Tower Need	Yes	Yes	yes	yes	no	no
Purpose of usage	electricity	electr.	electr.	Less Electric. and	Less Electric. and	Less Electric. and

				Water pumping	Water Pumping	Water Pumping
use today	no	no	yes	yes	Little	Little

3. Energy Production

3.1. Generator Design

Due to the inability to reach a ready-made generator suitable for the turbine design, the need for new manufacturing arose. The generator is permanent magnet and has 28 coils. The magnets are 40x20x5 mm in size and a coil is made of insulated aluminum wire suitable for these dimensions. Coils are fixed on a 600 mm diameter circle at 360/28 degree intervals by bolts and nuts as seen in Figure 2.

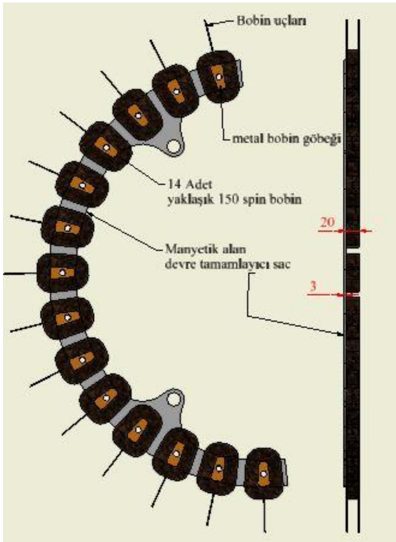

Figure 2. Designed Coil Placement.

Coil and magnetic circles were completed and assembled in a position to generate energy, and the generator to be used was revealed. The necessary infrastructure has been manufactured for the assembly of the generator to the turbine, the coil ring is fixed to the carrier legs and the magnet ring is attached to the lower surface of the gear, which is placed at the base of the turbine and rotated by the blades, as seen in Figure 3.

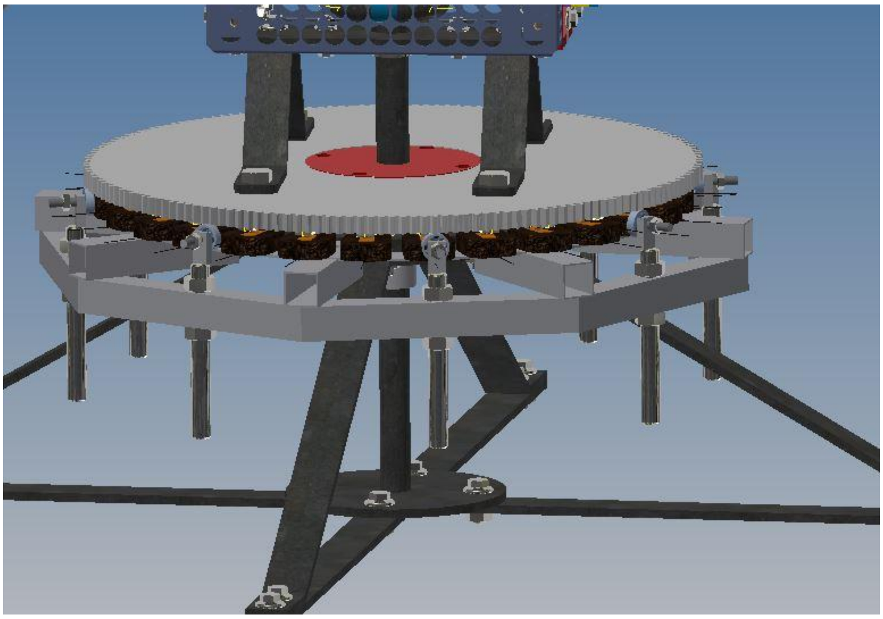

Figure 3. Assembled Magnetic Ring And Coil Ring.

3.2. Wınd Turbıne Maın Desıgn

The final state of the wind turbine, which has been designed and prototyped, is as seen in Figure 4 and Figure 5.

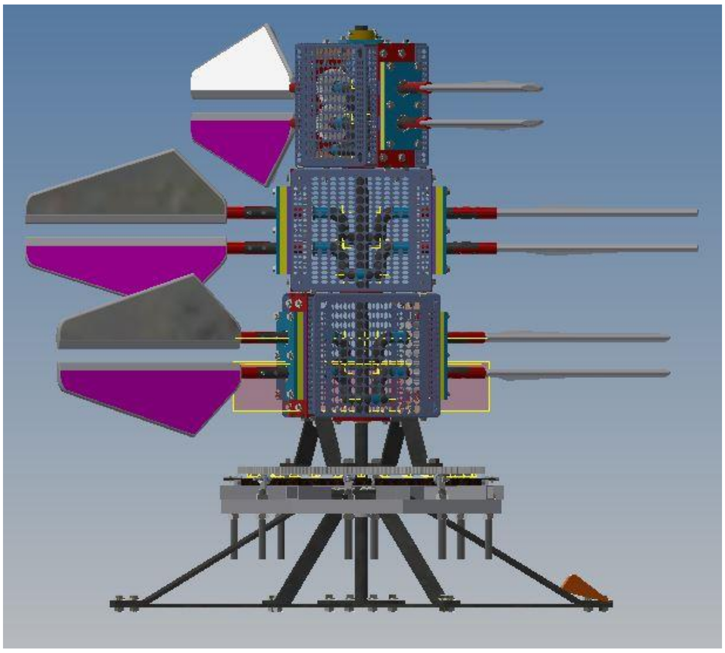

Figure 4. The Final Version of the DERT Design.

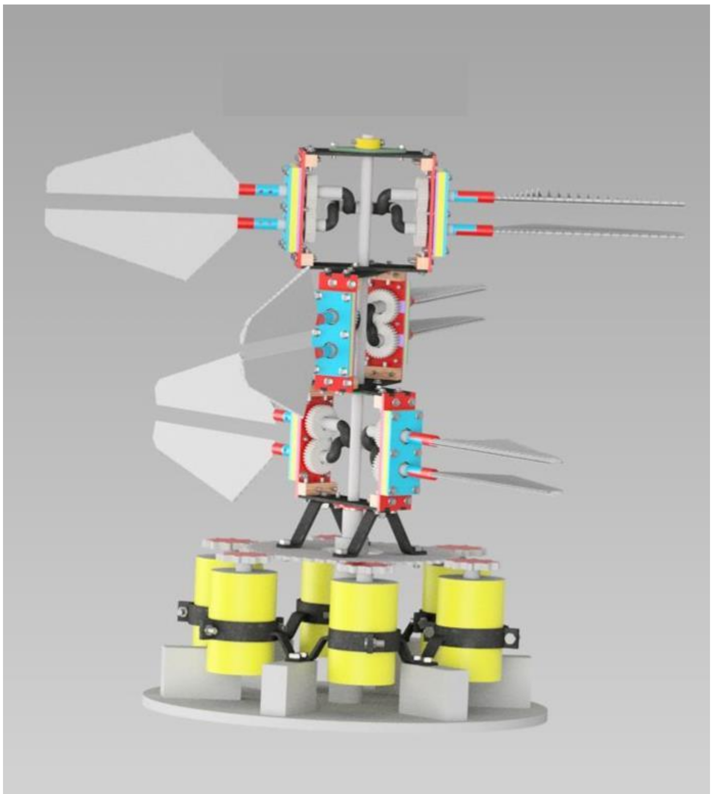

Figure 5. Multi-Generator Prototype DERT.

3.3. Wing Manufacturing

For blade manufacturing, the casting mold of the blade whose form was determined was produced. Molds are prepared for polyester material casting. In The wings were cast in two separate molds, right and left. After the molds were cast, they were painted and made ready for use. Wing fittings are placed together order to ensure the rigidity of the wing, the wing was strengthened by placing metal rods inside before casting.

with in-mold iron parts before casting. The wings are shown in Figure 6.

Figure 6. Wings

3.4. Turbine Manufacturing

After all the parts required for prototype production were prepared and put together, the prototype was assembled. After the main body was assembled, it was ensured that the wings work by performing a function test. Afterwards, the generator was manufactured and mounted on the prototype as seen in Figure 7.

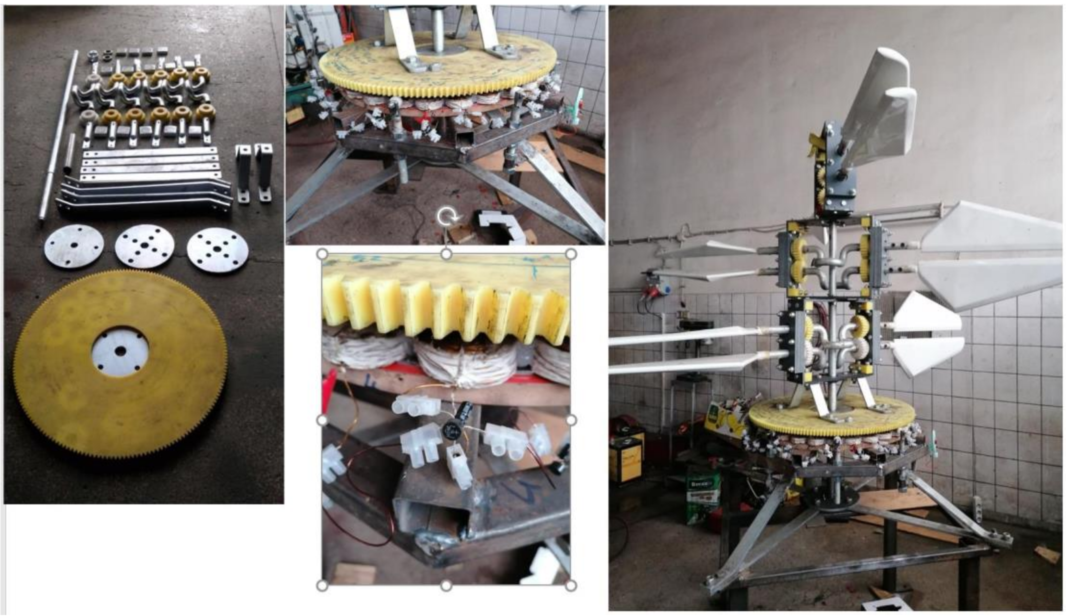

Figure 7. Completion of Turbine Prototype.

4. DERT Prototype Trials

Since the turbine must be operated at certain speeds for a certain period of time in order to determine the operability of the system, it is expected that the wind will blow by placing it in a suitable position. Assuming that the wind blows, it is desired to blow at a constant speed for a certain period of time. The behavior of the turbine at the determined constant speed should be examined. The turbine should be tested at different speeds, even in a storm.

As there was no Wind tunnel in the immediate vicinity, a different solution had to be found. In line with these considerations, the prototype turbine was mounted on a car to provide the necessary conditions as seen in Figure 8. Routes that can drive for a reasonable amount of time and at different speeds have been identified. Tests were carried out during periods of almost no traffic.

Figure 8. Test Setup of the Wind Turbine.

In these drives, the turbine performed its function at different speeds and accelerations between 0-120 km/h. The turbine has passed the function test. It has been observed that the turbine starts to rotate at wind speeds of 3-4 m/s (10-14 km/h vehicle speed). It has been determined that the divergence angle of the symmetrical blades decreases below 90 degrees at wind speeds of 15 m/s and above (55 km/h and above). The turbine has always rotated in the same direction at all times and speeds. It has been determined that the inertia of the blades, which negatively contributes to the smooth operation of the turbine and the start of movement at low wind speeds, is high. It will be sufficient to play with the parameters of the design in order to improve the negativities revealed in the tests.

The turbine was also tested under load. While the turbine is connected to the generator, the initial wind speed has increased to the order of 4-5 m/s depending on the weather. It was observed that the angle between the symmetrical blades decreased below 90 degrees at 15-20 m/s (65-70 km/h) wind speeds. However, the turbine continued to rotate without slowing down. This feature shows that the prototype turbine has a peak speed limitation depending on the energy drawn from the Generator. This speed reaches Vb while the turbine is rotating under load and at Va speed while it is idling (Vb speed > Va speed), and even if the wind speed increases, the turbine speed remains limited.

If the wind speed is between 40 and 60 km per hour, it is defined as a strong wind, and if it exceeds 60 km, it is called a wind storm. This means that the prototype manufactured in the light of this information continues to produce energy even in the storm.

It is essential to keep energy efficiency high in the generator type designed for the system. By connecting the generator coil outputs in series, a total alternating voltage is obtained. While it is possible to store this energy by converting it to direct current, the rectified current can also be used directly to heat the appropriate material. Or it can also use rectified current to produce hydrogen by electrolysis method. During the tests, it has been determined that more energy is produced if the coils are connected in series after converting the voltage to direct current. It has been determined that there are some irregularities in generator manufacturing as the reason for this.

In case the coil and magnetic match is not fully realized in series connection before voltage correction, the voltage generation in other coils undergoes shifts during the transition of the magnetic field from one coil to the other, and they neutralize each other in certain phases. As a result, there is a negative difference between the actual production and the accumulating in the battery. If the voltage of each coil is rectified before connecting it in series and then connected, the voltage produced in each coil is transmitted to the battery by adding one on top of the other, since the voltage is disconnected from the voltage produced in the next coil. The total amount of charged energy is higher.

5. Finding and Discussion

The fact that the systems that will produce in MW dimensions are being made in a few countries in the world and again by a limited number of companies, have turned to alternative energy sources in our time when the impact of environmental problems is felt. If the technical specifications in this field are fulfilled, there will be no problem in finding customers and marketing the systems produced. The system we are working on is expected to be 30-50% less costly than the three blade turbine system.

A maximum of 59% of the energy capacity of the captured wind can theoretically be utilized in horizontal axis three-bladed turbines. Although the efficiency in three-wing systems, which is currently the most efficient in the world, differs from manufacturer to company, it is around 30% to a maximum of 40-45%.
The operating times of the existing systems are limited by the upper and lower wind speeds. The system studied does not have an upper wind speed limit, and it has the capacity to produce even at 4-5 m/s wind speeds at the lower limit.

One of the factors that increase the cost of installation in existing systems is the concern of raising all energy generation units 50-100-120 m above the ground and keeping them operational in order to reach regular wind and to realize high-capacity systems. These weights can vary between 10 and 50 tons. In order to keep these weights at these heights and storms, an expensive infrastructure construction is required. The system produced is vertical axis and all weighting units are accessible on the ground and at all times. Since the wing system resists the wind with its rotational movement, it brings the tilting power of the wind to near zero level, and the system can stand and continue its production with its own weight, even without being connected to almost anywhere. If desired, the system can be built in a portable state very easily when desired, without being tied to a place.

6. Conclusions and Recommendations

In this study, a new vertical axis wind turbine has been developed with a new design from a new idea. It has a structure that minimizes the wind resistance with its self-opening wing structure according to the wind speed and the situation of meeting the wind. In this way, the conversion of kinetic energy to mechanical energy increases. The idea of a wind turbine has been turned into a prototype product. Mechanical tests, wind tests were carried out and the operability of the turbine was measured. Electricity production studies have been carried out and successful results have been obtained. The power coefficient (cp) was found to be equivalent to the most efficient turbines when compared to the wind turbines currently available in the literature and applications.

While the turbine uses the wind as an energy source, streams can also be used for energy production. When the turbine blades are submerged, the electrical components of the turbine stay out of the water and are easy to maintain.

This prototype confirms the working principle of vertical axis wind turbine which is the subject of the study. Improvements can and should always be made. The system can produce at low wind speeds and maintains this feature in storms as well. The center of gravity of the electricity generation section is on the ground and does not require costly foundation construction if desired. It is possible to take it from one place and transport it to another place as assembled.

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