

PEDAGOGY

Training model to demonstrate the conversion of thermal energy into mechanical energy

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Abstract. The article discusses the problem of familiarization of the students with physical basics of energy saving. Given the technical description (design and operation of the proposed device for demonstrating the conversion of thermal energy into mechanical energy, determined by its position in the school demonstration experiment in physics and the peculiarities of its approbation. The proposed device for demonstrating the conversion of thermal energy into mechanical energy can be used in the educational process in physics as a visual demonstration tool in the study of selected topics in mechanics and molecular physics and thermodynamics. In this article the device in collaboration with the experimental group students obtained the patent of Ukraine for useful model "Device for demonstrating the conversion of thermal energy into mechanical energy". The object of the invention was made by the use of previously known product (a child's toy "Protective boat") for a new purpose – as a demonstration device for physical experiment. In contrast to known devices of similar purpose of use of the device in question allows you to demonstrate a closed cycle with a working medium that experiences a phase transformation liquid-vapor-liquid; to demonstrate the use of converting thermal energy into mechanical energy for practical purposes; to be used as a source of energy for various fuels; to promote the safety demonstration of the transformation of thermal energy of the working fluid into kinetic energy of the model. A device and passed peer review on the national and international contests of physics and technical direction, where he received approval. The use of the model protective engine expands the horizons of students in the field of energy saving (in particular, deepens their knowledge of the devices and methods of converting one form of energy into another), and also contributes to their interest in the study of physics as a whole.

Keywords: physical basis of energy saving, device for demonstrating the conversion of thermal energy into mechanical energy, a demonstration experiment in physics.

Statement of the problem. The importance of learning in the physics course of the processes of conversion of thermal energy into mechanical energy is determined, among other things, their value to solve the problem of energy saving. So, at the present stage of technological development is important problem of creation of installations that would be energy efficient and would not pollute the environment.

However, our experience shows that students (and students) there are certain difficulties in studying such an important issue for school and University physics courses. Among the reasons for this do not last role is played by weak experimental support (or lack thereof) of educational process in studying these issues. Therefore, the development of appropriate demonstration devices, which should contribute to the absorption of this material is an urgent task.

the most widely used the following two procedures demonstrate the conversion of thermal energy into mechanical energy.

So, in [1, p. 115] described a device to illustrate the water vapor, which expands. It consists (Fig. 1, a) with a metal bullet, a working cylinder with piston, the heater, a steam pipe connected with a pressure gauge and spirometer, and the upper end of the steam pipe is a metal tube with a vertical hole. This device works in this way: in a metal bowl pour the water hole of the steam pipe is closed, lit the spirit lamp to heat the metal bullet, proving her steam pressure to $2.02 \cdot 10^5$ PA, open the steam line – steam is supplied to the working cylinder, lifts the piston, doing work.

Another known device for demonstrating the conversion of thermal energy into mechanical energy model is given in [2, p. 56]. It contains (Fig. 1, b) a working cylinder, a combustion chamber, a heater, a steam pipe, nozzle, turbine. The model works in the following way: the water that is in the working cylinder is heated to the boiling temperature, which changes its aggregate state from liquid to gaseous (vapor). Steam exits through the nozzle and spins the turbine.

Among the main disadvantages of both of the devices we mention the following:

- the inability to demonstrate a closed cycle with a working medium that experiences a phase transformation;
- low sample properties, consisting mainly in a weak naochan the possibility of using conversion of thermal energy into mechanical energy in practical objectives;
- danger during operation (applies mainly to the first of these devices in the pressure of water vapor at a temperature of approximately 100°C reaches 2 ATM);
- the limited duration of the devices the evaporation of

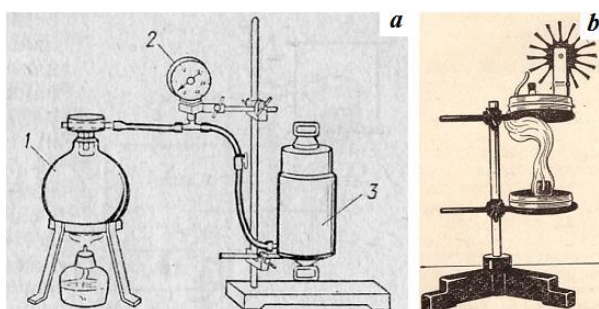


Fig. 1. The known device for demonstrating the conversion of thermal energy into mechanical energy:

a) model with spirometra: 1 metal bowl; 2 – manometer; 3 – spirometer; b) the model with the turbine.

Analysis of recent research. In the analysis of the educational literature revealed that today in school practice,

water;

- design complexity and relatively high consumption of the devices as a whole (together with tripods and stands).

Together with the students of the experimental group we developed a device to demonstrate the conversion of thermal energy into mechanical energy, is devoid of these drawbacks.

The purpose of the article. In this article we aim to review the technical description (design and operation of the proposed device to determine its place in the school demonstration experiment in physics and illuminate the features of his approbation.

The main material of the article. The idea of this device is based on a long-forgotten child's toy that had the name "self-Propelled boat" [3]. He was quite popular in 30-e years of the XX century (by the way of its existence, the author learned from his grandfather – the experienced inventor S. M. Moshkova).

Despite the fact that the design protective mover is a well-known (see e.g. [4] and [5]), its function in the educational-methodical literature almost nothing is said. In addition, remains virtually unexplored question regarding the use of the device in the educational process in physics. Thus, it is known from various literary sources model protectivna courts are not seen as educational, but only as a pure toy.

Technical description of the device for demonstrating the conversion of thermal energy into mechanical energy. The design of the device in question is characterized by its simplicity (Fig. 2). This device contains: cylinder – 1; water-jet nozzle – 2, pipe – 3; heater 4; a floating body of the device – 5.

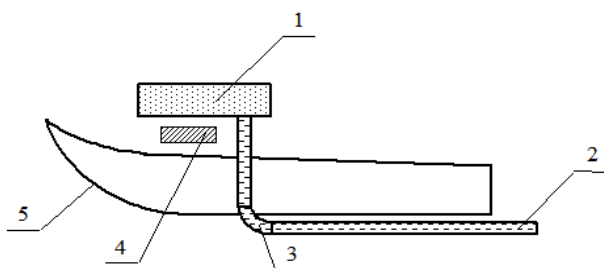


Fig. 2. Design scheme of the device for demonstration conversion of thermal energy into mechanical energy.

The principle of operation of this device is as follows. Before starting, the slave cylinder must be filled with water. To do this in one of the jet nozzles to pour water to completely fill the working cylinder and the pipeline. To ensure the closed cycle of the working fluid, the floating body of the device is placed in the water while its nozzle is under water. As the heater can be used, for example, dry fuel. In this device the working body changes its aggregative state in a closed cycle. The principle of operation of the device is illustrated by a schedule of the thermodynamic cycle (Fig. 3).

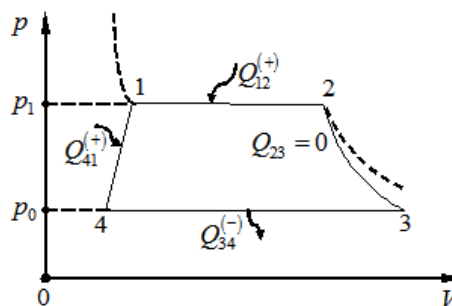


Fig. 3. An idealized cycle of the considered device.

During the first phase (phase 1 - 2) working fluid received from the heater the amount of heat $Q_{12}^{(+)}$ (the "+" sign means that the working fluid receives heat). Thus there is a phase transition liquid - vapor (which ends at point 2 of the cycle), which is accompanied by expansion of the working fluid at constant temperature T_1 and pressure p_1 ($p_1 > p_0$, where p_0 – atmospheric pressure). The expansion of the working fluid results in the release of water from the jet nozzle creates a jet thrust.

During the second phase of the cycle (phase 2-3) working fluid (steam) has continued to expand up until the pressure is equal to atmospheric pressure (hydrostatic pressure of the water layer at the level of the nozzles can be neglected). At the end of the second phase of the cycle (point 3) the pressure of the working fluid becomes equal to the atmospheric pressure. The velocity of water in nozzle (against the vessel) becomes zero. During the second phase the temperature of the working fluid decreases from the maximum value in the cycle value T_1 (point 2) to a minimum – T_2 (point 3).

In connection with corotative the second phase can be approximately regarded that flows adiabatic ($Q_{23} = 0$). With this approach it is possible not to take into account the processes of heat transfer in the environment from working medium in the working cylinder and the pipeline. Further cooling by heat transfer working fluid leads to compression of the working fluid by the force of atmospheric pressure (third phase). This compression is accompanied by the phase transition vapor - liquid, while there is the return of warmth $Q_{34}^{(-)}$, which is released when steam condensation, characterizing the change of the aggregate state of the working fluid.

In the beginning of the fourth phase of the cycle (point 4) the working fluid is in a liquid state at a temperature T_2 and at atmospheric pressure p_0 . During the fourth phase working medium expands and is heated to a temperature T_1 to pressure p_1 . During this phase, the working fluid received from the heater the amount of heat $Q_{41}^{(+)}$. Thus, the loop terminates and all processes again.

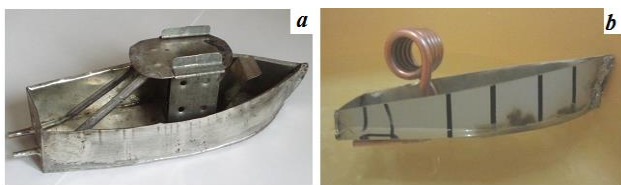


Fig. 4. Photos of existing models to demonstrate conversion of thermal energy into mechanical energy:
a.) the first version of the model; b) improved model.

The current model of the device. Together with the students of the experimental group, we have manufactured various variants of the existing models consider the device to demonstrate the conversion of thermal energy into mechanical energy. The first was the model shown in Fig. 4, and. The analysis of literary sources, which describe the design of such devices (in the first place, this [4] and foreign electronic resources, in particular, [5]), has allowed to improve the existing model (Fig. 4, b). It can be used in a demonstration experiment in physics.

The current model consists of a floating hull, made in the form of the vessel, the heat engine (protective engine) and heater. Heat engine in turn consists of a working cylinder, tubing and nozzles. Structurally, all of these elements of the heat engine made of copper tube with an inner diameter of about 3 mm (one specific implementation, the heat engine shown in Fig. 5, a). In the heater heat energy in the combustion of fuel (solid fuel, or ethanol (Fig. 5, b)). During engine operation the nozzle shall be immersed in water. Cooler in the current model is water in the pond.

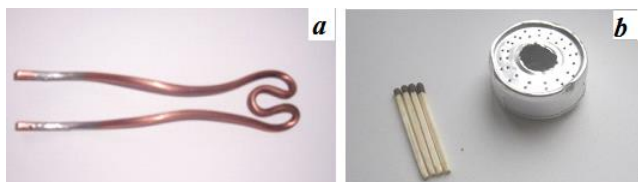


Fig. 5. One of the options the design of the working cylinder and pipeline model (a) and the possible design of the heater, which uses ethyl alcohol (b).

Place the model in the educational process in physics. Consider some methodological suggestions for using the device to demonstrate the conversion of thermal energy into mechanical energy in the physics lessons. Experience shows that the greatest training effect from the use of this device can achieve on the lessons of generalization of the material. This is because in the process of learning with the students of this device fails to reproduce the basic semantic elements of the educational material of a specific section, as well as to demonstrate their practical value. First and foremost, we are talking about the sections:

- “*Mechanics*” (in particular, units: the momentum of the body and systems of bodies; the law of conservation of momentum; jet propulsion (jet engines); mechanical energy, work, power; efficiency mechanisms);
- “*Molecular physics and thermodynamics*” (in particular, an ideal gas; ideal gas equation of state; sobriety; real gases, isotherms of real gases; vaporization and condensation; a saturated vapor and nienasycenie; boiling; the dependence of the pressure and density of saturated steam temperature; changing States of aggregation of matter; a critical state).

Considerable teaching value is the model to organize the cognitive activity of students in extracurricular component of teaching physics. So, based on this device you can:

- in-depth to explore with students the processes of conversion of thermal energy into mechanical energy;
- to implement a number of interesting physical demonstrations;
- to carry out theoretical and experimental studies of model protective of the vessel (about the experience of using the device for teaching physics will be discussed in our next article).

Testing of the device. In this article, the device us in collaboration with the experimental group students received the patent for useful model “Device for demonstrating the conversion of thermal energy into mechanical energy” (patent of Ukraine No. 78031 [6]). We give the formula of the solution.

The formula of the utility model. Device for demonstrating the conversion of thermal energy into mechanical energy using the working fluid, which experiences a phase transformation liquid-vapor and contains a working cylinder, heater, duct, nozzle, characterized in that the floating body and at least two jet nozzles, which are below the line of draught of the device body, and the working fluid (water) is subjected to two-phase transformation liquid – vapor – liquid in a closed loop.

Using the terminology of the legislation in the field of intellectual property (in particular, the classification of the objects of the invention [7, p. 137]), we can say that the object of the invention in our case made use of a known product for a new purpose. Indeed, the novelty of the proposed technical solution lies primarily in the use of already known devices – a child’s toy “Protective boat” – for a new purpose – as a demonstration device for physical experiment.

In contrast to known devices of similar purpose (two of them are described in the beginning of the article) use of the device allows you to:

- restrict the duration of operation of the device evaporation of water in the cylinder;
- demonstrate a closed cycle with a working medium that experiences a phase transformation liquid-vapor-liquid;
- demonstrate the use of the conversion of thermal energy into mechanical energy for practical purposes;
- to use as a source of energy for various fuels;
- to increase the safety demonstration of the transformation of thermal energy of the working fluid into kinetic energy models (floating body unit).

Note that the considered device has passed the expert evaluation on the national and international contests of physics and technical direction, where he received approval. In particular, the development was represented by students (co-authors of the patent) on these contests:

- International competition and the Olympics projects on the theme “sustainable world” International Sustainable World (Energy, Engineering, Environment) Project Olympiad (abbreviated I-SWEEEP) (2010 g. m. Houston, Texas, USA);
- International competition of research works of pupils of 9-11 classes “Scientists of the future” (“future Scientists”) (2010, Moscow, Russia organizers: Moscow state

University and Intel);

• All-Ukrainian contest-defense of research works of pupils- members of Small Academy of Sciences (MAS) of Ukraine (state stage MAN 2012, Kyiv).

Conclusions. The proposed device for demonstrating the conversion of thermal energy into mechanical energy can be used in the educational process in physics as a visual demonstration tool in the study of selected topics in mechanics and molecular physics and thermodynamics. The use of the model protective engine expands the hori-

zons of students in the field of energy saving (in particular, deepens their knowledge of the devices and methods of converting one form of energy into another), and also contributes to their interest in the study of physics as a whole.

Further research we associate with the development of a series of theoretical and experimental tasks and interesting physical demonstrations that can be implemented using the considered device.

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Учебная модель устройства для демонстрации преобразования тепловой энергии в механическую

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Аннотация. В статье рассматривается проблема ознакомления учащихся с физическими основами энергосбережения. Приведено техническое описание (конструкция и принцип действия) предлагаемого авторами устройства для демонстрации преобразования тепловой энергии в механическую, определено его место в школьном демонстрационном эксперименте по физике и освещены особенности его апробации. Предлагаемое устройство для демонстрации преобразования тепловой энергии в механическую может быть использовано в учебном процессе по физике в качестве наглядного демонстрационного средства при изучении отдельных тем по механике и термодинамике. На рассмотренное в данной статье устройство в соавторстве с учениками экспериментальной группы был получен патент Украины на полезную модель «Устройство для демонстрации преобразования тепловой энергии в механическую». Объектом изобретения выступило применение ранее известного продукта (детской игрушки «Парореактивная лодка») по новому назначению – в качестве демонстрационного устройства для физического эксперимента. В отличие от известных устройств аналогичного назначения рассматриваемое устройство позволяет: продемонстрировать замкнутый цикл с рабочим телом, испытывающим двухфазное превращение жидкость-пар-жидкость; показать возможность использования преобразования тепловой энергии в механическую в практических целях; использовать в качестве источника энергии разные виды топлива; повысить безопасность демонстрации преобразования тепловой энергии. Рассмотренное устройство прошло экспертную оценку на всеукраинских и международных конкурсах физико-технического направления, где получило одобрение. Использование рассматриваемой модели парореактивного двигателя расширяет кругозор учащихся в области энергосбережения (в частности, углубляет их знания в области преобразования одного вида энергии в другой), а также способствует повышению их интереса к изучению физики в целом.

Ключевые слова: физические основы энергосбережения, устройство для демонстрации преобразования тепловой энергии в механическую, демонстрационный эксперимент по физике.