ISSN 2076-2429 (print)
ISSN 2223-3814 (on line)

UDC 621.039.534.25

O.V. Korolyov, Dr.Eng., Assoc.Prof.,
O.V. Derevyanko, specialist,
O.Yu. Pogosov, Dr.Eng., Professor,
Odessa National Polytechnic University

TWIN-ROTOR COMBINED TURBINE DRIVE WITH A TRANSMISSION FOR THE NUCLEAR POWER PLANT EQUIPMENT EMERGENCY WATER SUPPLY SYSTEM

Introduction. The existing systems of NPP water environment feeding are oriented onto electrical pumps use, but such technical solution is completely inacceptable under circumstances of emergency power blackout.

Analysis of recent research and publications. An alternative option of feeding pump driven for water supply equipment may be provided with a specially purposed steam-turbine plant. But to mention is that in this case the applicability of blade turbine as such facility part is limited with the steam quality which humidity should never exceed the permissible value. At that the water-charged non-separated vapor in the emergency power units operation that is especially realistic for nuclear power plants, represents an available energy carrier and can be effectively used if operating at appropriately developed improved-design turbine drive [1].

The Aim of Research is to analyze the possibilities for creating device model that can be used as turbine drive operating with wet non-separated steam as the working fluid.

Main Body. Analyzing the known scientific and technological solutions we have found that instead of a blade turbine conceptually convenient for using as a drive is another turbine type; this one well-known since N. Tesla developments time, a friction turbine. This turbine consists of a rotor - shaft with friction elements attached, disposed in a housing with inlet and outlet nozzles (e.g., in some cases a disk turbine represents the functional analogue of such turbine). However, the disadvantage of this, although quite simple device relates to its low efficiency, that forbids its extensive use as a NPP power units' feed pumps drive. Alternatively, we can consider another technical solution embodied into a device [2] of friction turbine designed for converting the kinetic energy of the liquid, gas or wet steam into mechanical work; sometimes such turbine is highly convenient to use as the pump unit drive. This device embodies a technologically sound solution for nuclear power plants using wet steam as the working fluid, as it provides a non-impact steam action onto the rotor. The apparatus comprises a cylindrical body, a tangential inlet disposed around its periphery, and an outlet located at the axial zone center, also it includes an impeller mounted on the shaft. The tangential inlet usually arranged in a way providing the tangential nozzle feeding the working fluid to the cylindrical body wall; and the axial outlet branch is positioned so that its inlet enters the rotor cavity. This design disadvantage is that such devices' operation is still not efficient enough, especially when used as a pump drive for feeding the power units' aquatic environments, what is important from the safety standpoint. As our research shows, the described device needs to be modified, i.e. required is to install supplementary a bladed turbine, structurally included behind the friction turbine.

Known is a combined turbine drive, which engineering design unites two different types of turbines in a common housing: the friction turbine and the axial blade turbine arranged on the same shaft [3]. This solution due to a combination of two structurally dissimilar turbines does guarantee the reliable turbine assembly's start without blade turbine damaging, that is possible when wet steam repre-

DOI 10.15276/opu.2.44.2014.17

sents the working fluid. Despite the positive effect achieved by combining the blade turbine and the friction one, the assembly effectiveness is insufficient under transient modes. The problem issue is due to that the main structural elements (friction turbine and blade turbine) are attached to the same shaft as it creates the interference between the shaft's mechanical action and the steam action in rotational motion energy transfer to the ending shaft end thus reducing the device efficiency.

Actually, the friction turbine being the first of combined structure component also is first that put in motion, being initially the leading one at these two turbines' tandem. But there exist several transient modes associated with a further change in the device components' relative speed, when the first stage (friction turbine) can gear down the rotor's motion (for example, full or partial cut of working medium supply to the turbine). In this case, the second stage rotor is a leading one by angular velocity due to the inertial rundown. Consequently, the blade turbine should be able to rotate independently, without braking the first rotor (friction turbine rotor) that can never be guaranteed at the two rotors on one shaft positioning. At the same time, when due to working body respective effect, the angular velocity of the friction turbine (first rotor) allows engaging to rotation the blade turbine (second rotor), therefore the first rotor shaft should maintain the rigid coupling to the second rotor shaft.

The above mentioned imperfections allowed formulating the problem, subordinate to this research's objectives, stated and resolved using a new technical solution. This problem relates to the combined device efficiency increase with respect to the constructive variance allowing to arrange independent rotary movement of two turbines' rotors in the same housing when the second turbine angular speed is greater than the first turbine angular speed, ensuring the same angular velocity of two turbines rotors, if the first turbine operates as the driving one.

Results. The stated problem solution can be achieved by placing turbine rotors at different shafts, interconnected with the blade turbine rotor slow pace mechanism. This device always has the driving friction turbine (first rotor) shaft and the blade turbine (second rotor) shaft is respectively driven. The proposed construction's slow-down mechanism installed between the turbine assembly stages should act as the combined turbine rotor speed matching element, thereby solving the problem and serving to achieve the study and design objectives.

The designed device structure, as shown at Fig. 1, consists of: housing 1, representing the turbine drive stator, including the friction turbine 2 and the blade turbine 3, which form the rotors (with wheelspaces shaped) together with two rotary shafts — shaft 4 and shaft 5. The shaft 5 rotation energy is consumed by a pump rotor 6, the rotational kinetic energy being input with the working fluid 7. The pump, shown at Fig.1, has a rotor connected to the second turbine's rotor, and supplies from a separate tank the feeding liquid medium 8, to satisfy the corresponding equipment needs.

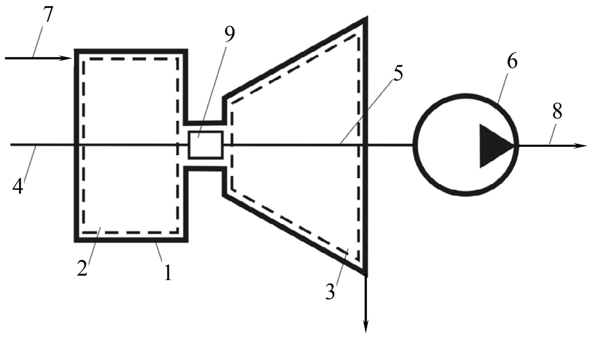

Fig. 1. Scheme of two-rotors combined turbine drive with transmission for the NPP water supply emergency system pumping unit

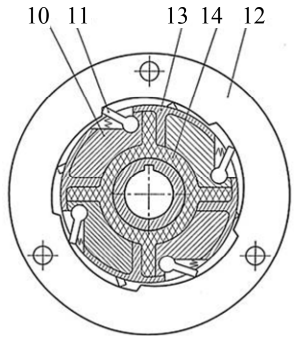

Fig. 2. Structural scheme of blade turbine freewheel variance as an example of transmission implemented at the combined turbine drive assembly

The slow pace mechanism 9 is an important design feature of the device, eliminating the collision between the rotation of blade turbine's 3 shaft 5 and the shaft rotation due to the friction turbine 2 from the working body movement or the blade turbine rotor inertia. Freewheel blade turbine rotor (transmission) provides engagement of shafts 4 and 5 when the angular velocity of shaft 5 rotation

ISSN 2076-2429 (print)
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doesn't exceed this one of the shaft 4. Freewheel bladed turbine rotor (transmission) is assigned to transmit the torque from the driving shaft to the driven.

The peculiarity of the proposed transmission mechanism for use at turbine unit is that the torque according to the embodiment example shown at Fig. 2 is transmitted from one shaft 10 by pawls 11 to the second haft 12 with the sealing inserts 13 and 14 only in a predetermined direction and exceptionally when the angular rotation speeds of the driving and driven shafts are identical. Once the angular velocity of the driven impeller for whatever reason exceeds the speed of the driving shaft the freewheel automatically (without external control actions) separates the parts of two linked turbine rotors.

To implement this technical solution structure we can apply standard industrial equipment, elements, components and materials which are widely used in industry. Thus, all parts of the device may be made of steel. The friction turbine being, for example, a disk-type (to reduce cost), its impeller may be formed at industrial production using methods of turning, of such materials as corrosion and stainless steel or aluminum. At freewheel manufacturing we can choose between a number of different engineering options. A particular embodiment of the device may represent a ratchet, but there are many other options from among well-known mechanisms that can provide the desired effect [4].

The described combined turbine drive (Fig. 1) operates as follows. Through the inlet pipe of the turbine drive housing and the nozzle, the working body 7 enters the cylindrical chamber 1 tangentially to its side surface (when considering the chamber profile). Further movement of the working fluid is due to its interaction with the lateral surface of the cylinder chamber 1 and represents a rotational movement (tangential when considering the cylinder profile). Rotation of the body as a result of its contact with the impeller surface causes rotation of the rotor 2. At that, the frictional force captures rotor 2 to rotate and transfers the kinetic energy from the rotational flow in the rotor, mounted on the shaft 4, and provides its rotation. Due to mechanism 9 presence, the shaft 4 rotates the shaft 5 of the blade turbine behind the friction turbine, if the working fluid after the friction turbine does not engage shaft's 5 rotation, with an angular velocity greater than the angular velocity of the shaft 4.The effect of "tweaking" by shaft 4 the first turbine's stage at the combined structure of the second turbine's shaft 5 is particularly significant in the starting conditions, when the working fluid has not yet reached the flow section of the turbine blade, but it does work on the friction turbine. Freewheeling turbine blade through the mechanism 9 can be observed when the second wheel of turbines tandem (blade turbine wheel) rotates faster than the first one; that becomes possible, for example, in the event of a working body feeding ceased. In this case, the friction turbine, incorporated before the blade turbine, slowing rotation, does not preclude the "rundown" (inertial motion with early speed) of the blade turbine. When the blade turbine rotating speed reaches the rotational speed of the friction turbine rollers 4 and 5 are blocked thus no freewheel motion. After working fluid displacement in the friction turbine to the rotor shaft 4 the fluid is displaced in the output channels and fed to the inlet nozzle of the blade turbine 3 then expanding and performing a work in its flow passage. Thus an effect of the rotor shaft rotation is reached, after that the shaft can efficiently transmit its motion to the pump unit 6 whichever (including transient) mode would be operated.

The elaborated combined design of turbine with respect to its effective operation can be implemented, being efficiently applied in various domains of mechanical and power engineering, especially when there is a possibility and necessity to use wet steam as the working fluid. Particularly useful this structure will be in those cases when under electric power failure the equipment needs an alternative (extra, optional) water feeding for technological heat exchange using turbine-driven pumps.

Conclusions. At research issue we conclude that wet steam can be actually used as the proposed design as an energy carrier, at least at the nuclear power plant, where this environment represents a working fluid for the emergency heat exchange equipment feedwater specialized pump turbine drive. In this case, the turbine drive should be combined containing from the structural point of view both friction turbine and blade turbine, the impellers being mounted on different shafts, connected by a transmission mechanism, that provides blade turbine's freewheeling respectively to friction turbine if the relative angular velocity of the two turbines differs from zero.

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АНОТАЦІЯ / АННОТАЦИЯ / ABSTRACT

О.В. Корольов, О.В. Дерев'янко, О.Ю. Погосов. **Двороторний комбінований турбопривід з трансмісією для системи аварійного водопостачання обладнання АЕС.** Розглядається оригінальний конструктивний варіант комбінованого турбоприводу насосного агрегату, в якому пропонується закріплення робочих коліс на різних валах, з'єднаних між собою трансмісійним механізмом. Метою є проведення аналізу можливостей розробки моделі пристрою, який можна застосувати як турбопривід, з використанням несепарованої пари в якості робочого тіла вологої. Розглянута конструкція відноситься до енергетики і може бути використана як привід живильного насоса, що подає водне середовище (теплоносій, робоче тіло) в циркуляційні петлі ядерних енергетичних установок в передаварійних та аварійних режимах функціонування.

Ключові слова: ядерні енергетичні установки, надійне підживлення водних середовищ, попередження аварій.

А.В. Королёв, О.В. Деревянко, А.Ю. Погосов. **Двухроторный комбинированный турбопривод с трансмиссией для системы аварийного водоснабжения оборудования АЭС.** Рассмотрен оригинальный конструктивный вариант комбинированного турбопривода насосного агрегата, в котором предлагается закрепление рабочих колес на разных валах, соединенных между собой трансмиссионным механизмом. Была поставлена цель провести анализ возможностей разработки модели устройства, который можно применить в качестве турбопривода, с использованием в качестве рабочего тела влажного несепарированного пара. Рассмотренная конструкция относится к энергетике и может быть использована как привод питательного насоса, подающего водную среду (теплоноситель, рабочее тело) в циркуляционные петли ядерных энергетических установок в предаварийных и аварийных режимах функционирования.

Ключевые слова: ядерные энергетические установки, надежная подпитка водных сред, предвосхищение аварий.

O.V. Korolyov, O.V. Derevyanko, O.Yu. Pogosov. **Twin-rotor combined turbine drive with a transmission for the nuclear power plant equipment emergency water supply system.** Considered is the original constructive version of pump unit's combined turbine drive, the suggested solution being to fix impellers at different shafts interconnected with a transmission mechanism. The study goal was to analyze the possibilities of developing a device model, which can be applied as a turbine drive, with the use of wet non-separated steam as a working body. The considered design relates to power engineering industry and can be used as a feeding pump drive supplying the aquatic environment (heat carrier, working fluid) in the circulating loop of nuclear power plants at pre-emergency and emergency operation modes.

Keywords: nuclear power plants, reliable feeding of water environments, accidents anticipating

Reviewer Dr. techn. sciences, Prof. Odesa nat. polytechnic univ. Dubkovsky V.O.

Received June 16, 2014