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A new bladeless hydraulic turbine

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HIGHLIGHTS

- The rotating motion without using any turbine blades.
- The theoretical explanation of hydraulic principle is first and unique.
- Low manufacturing turbine costs, especially rotor.
- The turbine is capable of utilizing small water sources, low water gradient.

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ABSTRACT

A water turbine constructed on the water turbulence or whirlpool principle is capable of utilizing very small sources even for untapped water, and it is highly suitable for the closed circuit production of electrical energy. The non-monotonic distribution of the radial velocity component is important for the onset of the driving force of the angular instability. This instability and the existence of the radial fluid motion give rise to the angular volume force. The strong gradient of entropy in the boundary layer of the inner rotating conical cylinder is a dominant source of vorticity. The solution presented as a result of the theoretical analysis includes discussion and comparison with rough preliminary experimental data. The rotating fluid action is obviously of interest for further research. An improvement in efficiency is the genuine motive for further research.

1. Introduction

The process of hydrokinetic energy conversion implies utilization of kinetic energy contained in river streams, tidal currents, or other man-made waterways for generation of electricity [1]. In recent years we have tended to encounter some new approach towards energy production, and this is usually found in an effort to use smaller amounts of renewable resources, in various marginal sources of water potential (waste-water treatment plant, small streams and creeks). From this viewpoint we focused on a very small rolling liquid turbine, which could bring about a certain benefit from these non-traditional potentials. It has already been verified in practice that it is technically feasible to sufficiently convert very small water potentials (read low flow capacity and hydraulic gradient) to an effective output. It can deal with both the case of renewable energy, for example of a mountain stream, and the case of hydropower, and which has been until now thwarted as a non-utilized potential in various systems of the production process or within the framework of the operation of higher buildings, etc. One of the biggest energy consumers in modern society are the so called statistically average households. A particular effort towards lowering the energy dependence of member states of the European Community can already be recorded in connection with Directive No. 93/76/EEC. It has been recently replaced by Directive 2006/32/EC of the European Parliament and of the European Council of 5th April 2006 on energy end-use efficiency and energy services. The resulting instrument involves two basic interpretations leading to the certification or categorization of buildings, but also to a change of attitude towards energy consumption and usable renewable resources in their entirety. Energy dependence of the countries of EU-27, however, continues to grow. EU-27 energy imports grew within the year 2006 by 2.4% and total energy dependence has grown by 54% that is around 1% per year.

The year 2007 shows a decrease of −0.7% but with the further years 2008 and 2009 we are witnessing growth of dependency by +1.7% and in 2009 a small decrease −0.8%. In the long-term

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Nomenclature

r	radial coordinate (m)	$\dot{Q}$	flow rate (kg s^{-1})
φ, ϕ	angular coordinates (rad)	h_t	total enthalpy (J kg^{-1})
z	axial coordinate (m)	s	entropy (J K^{-1} kg^{-1})
t	time variable (s)	u	internal energy (J kg^{-1})
x	new radial variable (–)	b	non-dimensional channel width
v	spatial velocity (m s^{-1})		
w	vorticity (s^{-1})	*Special characters*	
p	pressure (Pa)	ν	kinematic viscosity (m^2 s^{-1})
f	volume force (N kg^{-1})	ρ	fluid density (kg m^{-3})
L	length of the turbine (m)	γ	gradient of the channel's divergence (–)
R_1	inner cylinder radius (rotor) (m)	ω	phase frequency (s^{-1})
R_2	outer cylinder radius (stator) (m)	Ω	angular velocity of the rotor's precessions (rad s^{-1})
Re	Reynolds number (–)	Ω_1	angular velocity of a rotor around its axis (rad s^{-1})

developing trends of energy needs there can be found historical parallels with current development [2]. One is the continuity in the use of hydropower itself.

The concepts of the water wheel and nowadays the water turbine have been with humankind for centuries. In Fig. 1 there is given a time series of the frequency of occurrence of the mentioned concepts. It became of topical relevance in the last two centuries. (Source: Gogole.com, Eurostat.eu, and Scopus.eu).

It can be stated that interest in the traditional renewable resource of water is permanent, long-term and not liable to surges of short term interest. A modest growth trend is objectively noteworthy; see Figs. 1 and 2 and energy structure in Fig. 3 and Ref. [2]. It is interesting that the basic principles of hydro engines admit of a relatively small degree of fundamental or principal innovation.

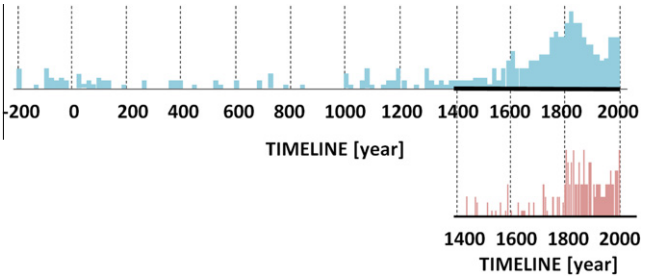

Fig. 1. Relative frequency of the concepts of water wheel (upper graph) and water turbine (lower graph). (Source: Authors processing of the data: Scopus, Web of Knowledge, and Google)

When searching for sources of energy it is obvious that hydraulic engines fulfill the limits and hydro energy fulfills requirements for the renewable nature of an energy source [4].

Requirements of emission The EU includes among renewable resources energies that are (a) solar, (b) geothermal, (c) wind, (d) hydropower see Ref. [25], (e) biomass. The structure of consumption is given in Fig. 3. Hydro-energy is currently the second biggest commodity of renewable energy. At the same time, however, the hydro-energy of water flows in Europe is considered to be exhausted, at least in respect of the potential of the bigger energy resources. Energy resources with a low energy potential were in the last century part of a depleting commodity, see islanding detection, distributed generators in Ref. [3]. The accessibility of power energy at relatively low prices pushed to the background its actual externalities.

2. Description of the machine

The rotor and the stator create in a quiescent state a symmetrical coaxial diffuser as shown in Figs. 4 and 5. However, this state is unstable and as a consequence of the instability of the flow through the gap between the rotor and the stator it changes to an asymmetrical one. The shape of the rotor and stator can be variable (i.e., it might be improved or optimized). In practice the most common rotors are hemispheres as in Fig. 4, but what really matters is the diffusion angle of the gap between the rotor and the stator. One tip of the rotor's shaft is fixed, so that the rotor can roll along the inner side of the confuser. When the fluid flows along the rotor, then due to the flow field instability, the fluid starts to

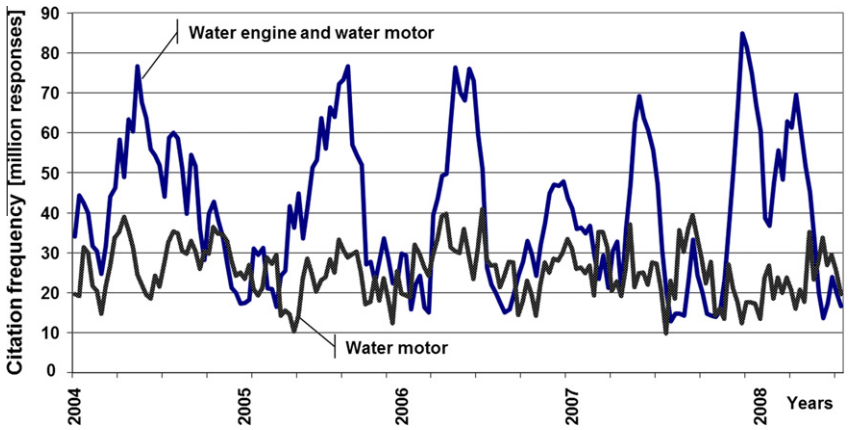

Fig. 2. Average frequency of the terms water energy and water engine and water motor.