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FLOW TYPE TURBINES EFFICIENCY ANALYSIS

Sargis G. Gabayan
Institute of Water Problems and Hydro-Engineering
Named After I.V. Yeghiazarov
125 A.Armenakyan St., Yerevan, Armenia, 0047
s_gabayan@mail.ru
ORCID iD: 0000-0002-8407-1097
Republic of Armenia

Abstract

Over the last years European-made flow type turbines have become widespread in small hydropower engineering. A distinctive feature turbines of this type is that at high heads (40m and more) the turbine works as an active one, and at low heads (3-40m) as a reaction one. In the operational zone, as an active, flow turbine and all its elements have constant efficiency equal to 81.85 per cent, independent of the design pressure head value. In the zone where the turbine functions as a reaction one, efficiency of the turbine and the gearbox depends on the design head. This paper presents dependences determining the efficiency of the aggregate and its elements, based on the systematically conducted statistical analyses. .

Key words: water, hydropower engineering, turbine, gearbox, generator, operational head, turbine efficiency, aggregate efficiency.

Introduction

In recent years, European-made flow turbines have become widespread in small hydropower engineering. The main manufacturers of flow type turbines are Ossberger (Germany) and Cink Hydroenergy (Czech Republic). Flow turbines produced by these companies operate in a pressure range from 3 to 200m and at a water flow rate per turbine from 10 l/s to 12 m3/s [1, 2].

The operating range of the flow turbine practically coincides with the operating range of the Francis (10-200m) and Kaplan (3-20m) turbines.

A distinctive feature of a this turbine is that at high heads (40m and more) the turbine operates as an action one, and at low heads (3-40m) as a reaction one, and a discharge pipe is installed under the turbine at that.

Having a number of advantages, such as stability at pressure and flow rates drops, clog-free impeller, high reliability and ease of operation, it is somewhat inferior to its competitors in efficiency at the design flow rate (by 3-4%), which is quite successfully compensated by the high stability of the efficiency. in a wide range of flows [3].

Conflict setting

The flow turbine is very often confused with the widespread in the 1930-1960s Banki turbine. The modern flow type turbines have been significantly modernized and have very high performance characteristics, which is confirmed by their high sales over the past 30-40 years. During this period, more than 500 units of this type have been installed in more than 50 countries around the world. They are especially popular in Europe, North America and the CIS countries.

The nature of a flow turbine operation at different heads and flow rates is less studied than other types of turbines operating in the same range.

The task is to analyze the flow type turbine efficiency in the entire operating range of its heads, based on the passport data of more than 50 units installed in neighboring countries.

Research results

Final efficiency of a unit equipped with a flow turbine is determined by multiplying the efficiency of its three components: the turbine, gearbox and generator. There are known cases when a flow turbine is directly connected to the axis of the generator, without a gearbox, however, such cases are very few and therefore are not considered here.

Modern units manufactured by the above mentioned companies are equipped with generators from leading European manufacturers, of which efficiency ranges from 95 to 97 per cent, and its value practically does not depend on the design head and power of the station. Nominal efficiency of flow type turbines depends on the design head of the station. The analysis of the passport data of units with a different range of design heads is shown in Fig. 1. As seen from Fig.1 nominal efficiency flow turbine, in the pressure range from 40 to 200m, the pressure is very stable and equal to 87 per cent. Considering that the 40m head is the threshold for the execution of flow turbines as action ones, it can be argued that the calculated efficiency of a flow turbine, when it is active, does not depend on the design head of the station, is stable and equal to 87 per cent.

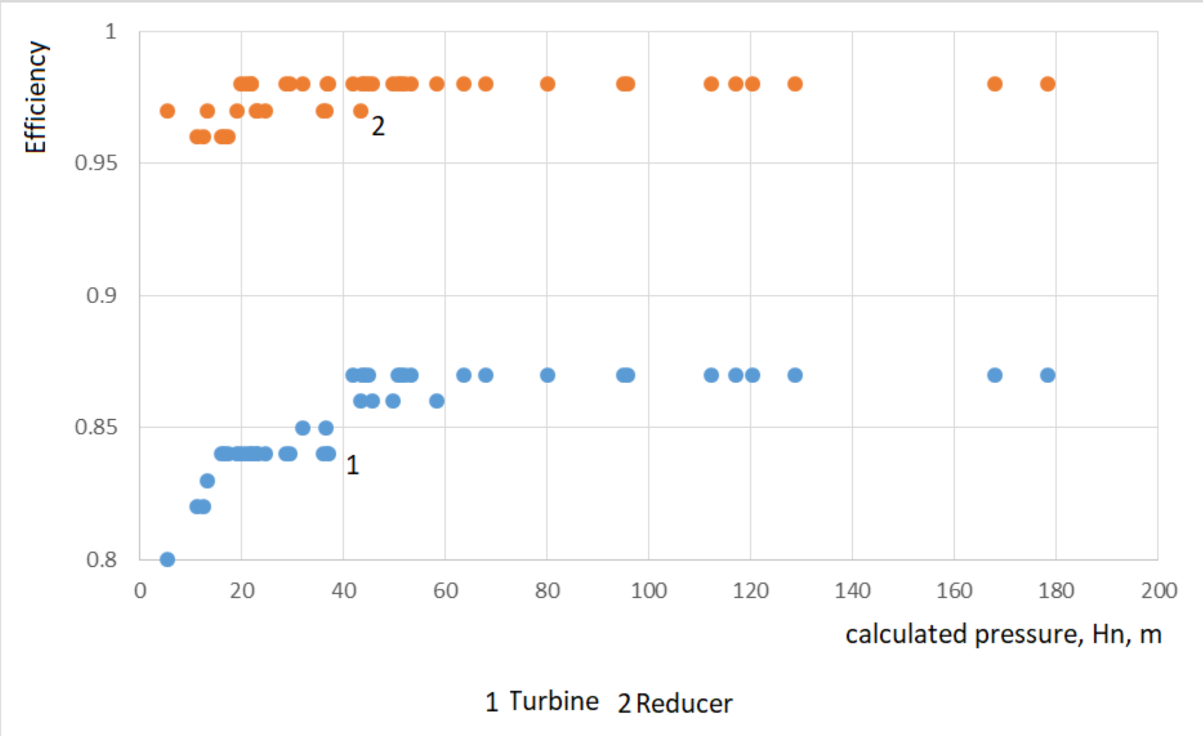

Fig. 1. Efficiency of the flow turbine and the gearbox operating at heads from 4 up to 200m

Fig.1 shows that at heads of more than 40m we also have a gearbox constant efficiency equal to 98 per cent.

At design heads less than 40m, a slight drop in efficiency is observed. a flow turbine and at a head of 4-5m, it reaches up to 80 per cent (Fig. 2).

At low design heads, for a preliminary assessment, efficiency of ha flow turbine can be estimated by the power dependence:

$$\eta_T = 0.777 H_p^{\,0.0243} \tag{1}$$

where η_T is the turbine efficiency at the design flow, H_p is the design head of the station.

The considered flow turbines are usually equipped with gearboxes manufactured by Siemens (Germany) or Wikov (Czech Republic). Analysis of the efficiency data for such gearboxes has shown that there is a stable 98 per cent efficiency within the design head of stations in the range of 40-200m.

At lower heads, a slight decrease in efficiency is observed. reducer, which at its maximum value is 2%.

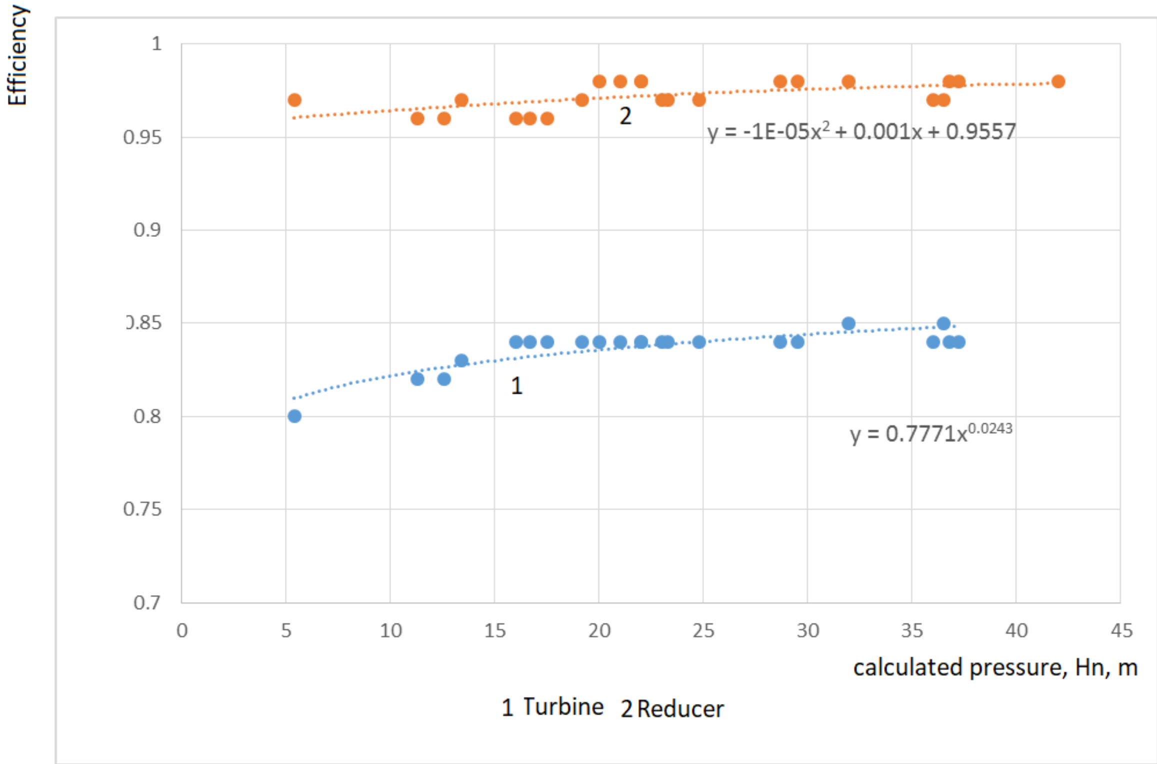

Fig. 2. Efficiency of the flow turbine and the gearbox operating at heads from 4 up to 40m

Drop in efficiency reducer in the range of design heads of 4-40m, is most accurately described by a below polynomial of the 3rd degree

$$\eta_{\mathrm{p}} = -9.85 * 10^{-0.5} H_{\mathrm{p}}^{2} + 0.001 H_{\mathrm{p}} + 0{,}9557 \quad (2)$$

where η_{T} is the turbine efficiency at the design flow, H_{p} is the design head of the station.

Thus, the overall efficiency of the aggregate η_a, assuming efficiency of the generator η_g equal to 96 per cent and taking into account its constancy in the entire range of design heads of the flow turbine, in the zone of the action flow turbine (40-200 m) can be considered constant and equal

$$\eta_{\mathrm{a}} = \eta_{\mathrm{T}} * \eta_{\mathrm{p}} * \eta_{\mathrm{r}} = 0.87 * 0.98 * 0.96 = 0.8185 \quad (3)$$

In the area of a flow type turbine operation as a reactive (4-40m), efficiency of the aggregate depends on the design head of the station (Fig. 3) and is described by the Eq.(4)

$$\eta_{\mathrm{a}} = 0.6893 H_{\mathrm{p}}^{0.0384} \quad (4)$$

Thus, when performing preliminary calculations to assess the project, the efficiency of the aggregate equipped with a flow turbine with a gearbox can be selected with sufficient accuracy from the data given in Table 1. At the stage of detailed calculations, the characteristics of the aggregate should be requested from the equipment of the manufacturer.

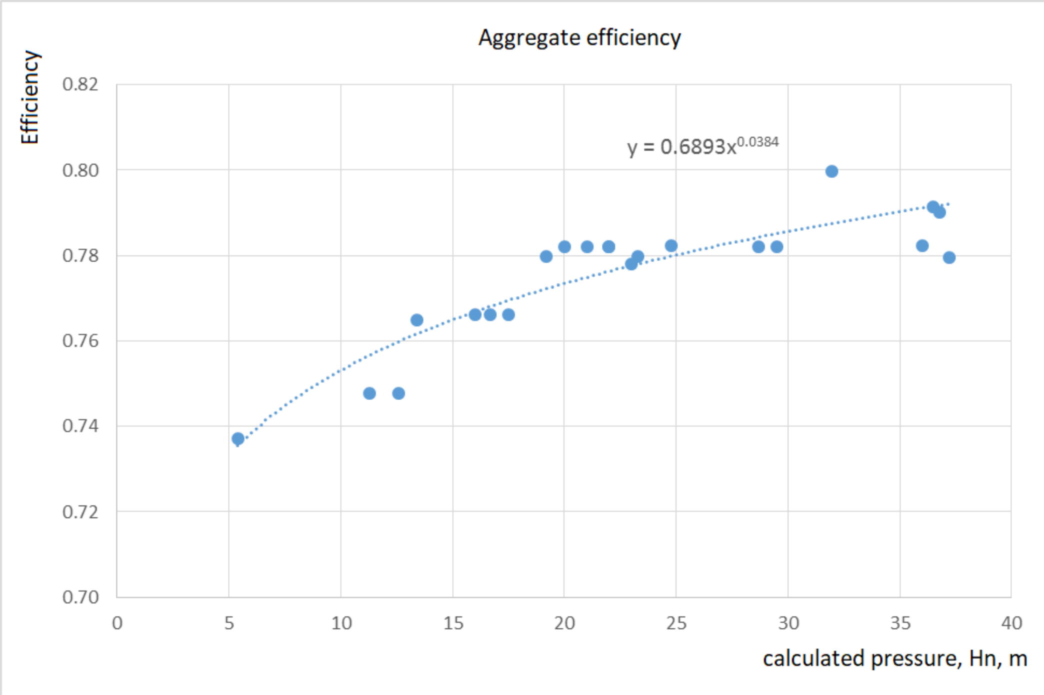

Fig. 3. Dependency of efficiency of the aggregate equipped with a flow turbine on the design head in the range from 4 up to 200m

Table 1

Efficiency of the aggregate and its elements at various design heads

	Reaction turbine zone	Action turbine zone
Design head, m	4 – 40 m	40 – 200 m
Efficiency of the turbine	$\eta_T = 0.777H_p{}^{0.0243}$	0.87
Efficiency of the gearbox	$\eta_p = -9.85 * 10^{-0.5}H_p^2 + 0.001H_p + 0{,}9557$	0.97
Efficiency of the generator	0.96	0.96
Efficiency of the aggregate	$\eta_a = 0.6893H_p^{0.0384}$	0.819

Conclusion

Based on the analysis performed, the following conclusions can be drawn:

1. Flow turbines by the nature of their operation are divided into reaction (design head from 4 to 40m) and action (design head from 40 to 200m).
2. Units equipped with active flow turbines have constant efficiency, independent of the design head.
3. Efficiency. units equipped with reaction flow turbines depend on the value of the design head of the small hydroelectric power station, and tend to decrease with a decrease in the design head.
4. Based on the more than 50 aggregates obtained as a result of the analysis of the passport data, the dependences have been derived for determining the efficiency of this type aggregates and their individual elements.
5. The above dependencies can be used in preliminary calculations to assess the performance of small hydroelectric power plants and the choice of the type of

turbines. With more detailed calculations the efficiency of the aggregate should be requested from the manufacturer.

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ՀՈՍՔԱՅԻՆ ՏՈՒՐԲԻՆՆԵՐԻ ՕԳՏԱԿԱՐ ԳՈՐԾՈՂՈՒԹՅԱՆ ԳՈՐԾԱԿՑԻ ՎԵՐԼՈՒԾՈՒԹՅՈՒՆԸ

Գաբայան Ս.Գ.
Ակադեմիկոս Ի.Վ.Եղիազարովի անվան ջրային հիմնահարցերի և հիդրոտեխնիկայի ինստիտուտ

Վերջին տարիներին փոքր հիդրոէներգետիկայում լայն կիրառում են ստացել եվրոպական արտադրության հոսքային տուրբինները: Քառասուն և ավելի մետր էջքի դեպքում հոսքային տուրբիններն աշխատում են ակտիվ, իսկ երեքից՝ քառասուն մետրի դեպքում՝ ռեակտիվ աշխատակարգով:

Ակտիվ աշխատակարգի պայմաններում հոսքային տուրբինի օգտակար գործողության գործակիցը կախված չէ էջքի չափից և հավասար է 81,85%:

Ռեակտիվ աշխատակարգի պայմաններում հոսքային տուրբինի օգտակար գործողության գործակիցը կախվա է էջքի չափից: Ստատիստիկ վերլուծության արդյունքում ստացվել են հիդրոագրեգատի և դրա տարրերի օգտակար գործողության գործակցի որոշման առնչությունները:

Բանալի բառեր. ջուր, հիդրոէներգետիկա, տուրբին, գեներատոր, աշխատանքային էջք, տուրբինի օ.գ.գ., ագրեգատի օ.գ.գ.:

АНАЛИЗ КОЭФФИЦИЕНТА ПОЛЕЗНОГО ДЕЙСТВИЯ ПРОТОЧНЫХ ТУРБИН

Габаян С.Г.
Институт водных проблем и гидротехники им. академика И.В.Егиазарова

В последние годы в малой гидроэнергетике получили широкое распространение проточные турбины Европейского производства. Отличительной особенностью этой турбины является то, что при высоких напорах (40м и более) турбина работает как активная, а при низких (3-40м), как реактивная.

В зоне работы как активная, проточная турбина и все его элементы имеют постоянное к.п.д. равное 81,85%, не зависящее от величины расчетного напора. В зоне работы турбины как реактивная, к.п.д. турбины и редуктора зависят от расчетного напора. На основании статистического анализа приведены зависимости определяющие к.п.д. агрегата и его элементов.

Ключевые слова: вода, гидроэнергетика, турбина, редуктор, генератор, рабочий напор, к.п.д. турбины, к.п.д агрегата.

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