THE DEVELOPMENT OF A REACTION TYPE TOTAL FLOW TURBINE

YOSHIKAWA, S., OHNO, Y., SHIMODA, K., Fuji Electric Co., Ltd.,
1-1 Tanabe-Shinden, Kawasaki, Japan

Total Flow Turbine

At present, most of geothermal wells in the world produce hot water from pits, rather than steam, for generating electric power.

The total flow turbine is an ideal power generating system for practical applications, since a high power generating efficiency can be obtained utilizing such geothermal resources.

In conventional systems, hot water from geothermal wells is separated into steam and hot water by means of a separator so that only the steam is fed to a geothermal turbine for generating electric power.

The total flow turbine for power generation is driven by expanding hot water directly, thus improving the working efficiency of hot water.

However, the total flow turbine has not been used for practical applications as yet because of technical problems

(The diagrams are shown in Figure 1.)

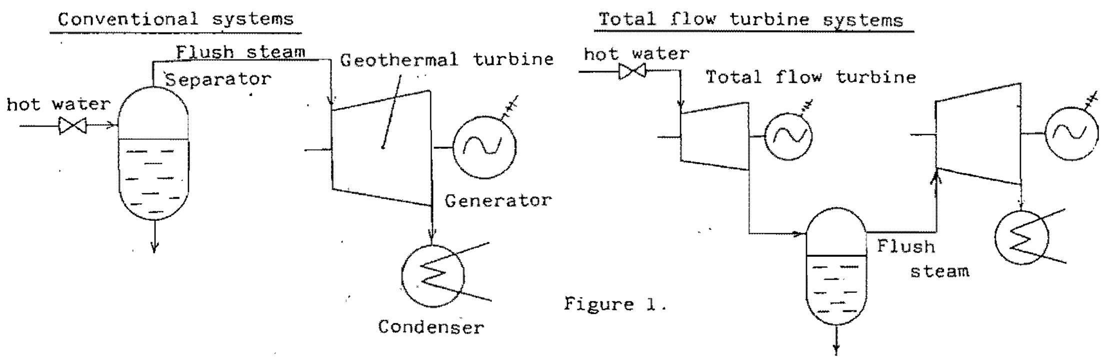

Figure 1.

Impulse Type Total Flow Turbine

The cross section of blades of impulse type total flow turbine is shown in Figure 2. The total flow turbine is quite different from conventional steam turbine because in that hot water occupies 90% of mass of two-phase flow flowing to the moving blade, while steam occupies more than 90% of volume flow, and because the density of hot water is about 1000 times larger than that of steam.

Therefore, when two-phase flow is largely changed in the flow direction while being applied to the impulse blade, water drops having a large density cannot change its flow direction along the flow of steam, but they come into collision directly with the side of profile, whereby a large difference in speed takes places between the steam and water drops flowing from the moving blades.

The water drops which have collided with the side of the profile turn to a water film that flows over the surface of the profile. The flow speed at the outlet of the moving blades is accelerated approximately to the peripheral speed "U".

The energy required to accelerate the flow speed of water drops is given by the turning energy of the impeller, and the collision of water drops contributes to the generation of an impulse force but the adhesion of water drops and water film cannot easily be removed from the rear edge of profile, which is a major reason why the expected performance cannot be obtained from the impulse type total flow turbine.

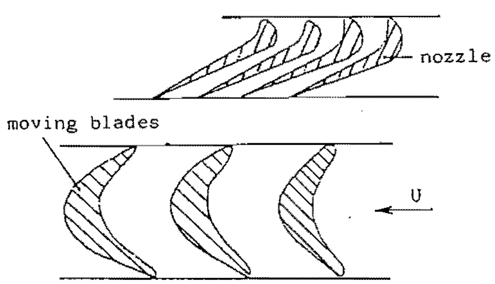

Figure 2.

Fuji Reaction Type Total Flow Turbine

Profile of tapered total flow nozzle is shown in Figure 3.

Hot water from the 0-0 section passes through the throat for continuous flushing and expansion, then it flows out from the II-II section at a low pressure.

When the nozzle profile between the I-I section and the II-II section is changed symmetrically with the surface in respect to the Z-Z axis as shown by broken lines, a profile of moving blades can be formed which rotates at the peripheral speed "U".

On the speed triangle of hot water in the I-I section, choose the peripheral speed "U" that realizes the following relations.

$$C_1 = W_1$$

$$\alpha_1 = 180° - \beta_1$$

Then, hot water from the nozzle is expanded through the moving blades as if it flowed through one total flow nozzle and flows out from the moving blades at the speed "W_2" and the angle "β_2". Therefore, the total flow turbine forms a stage to prevent hot water from changing the flow direction in the flow channel of the moving blades.

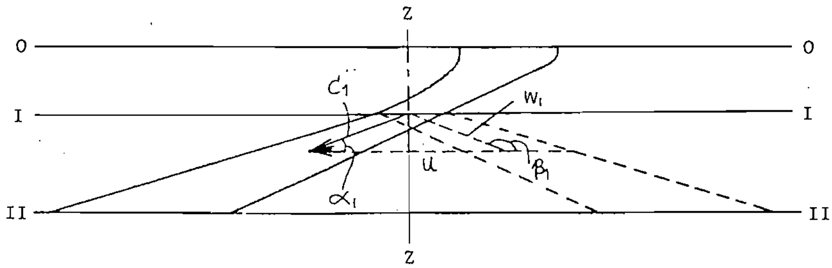

Figure 3.

Example of structure and Features of Fuji Reaction Type Total Flow turbine

Structure of reaction type total flow turbine based on the principle mentioned above is shown in Figure 4. The moving blades are composed of an array of simple flat plates. The flow channel in the moving blades is broadened by increasing the blade length in the axial direction.

The array of flat blades has no curvatures and does not change the flow direction in the flow channel, so it is used indeed at the tip of low pressure moving blade at the final stage of a steam turbine.

As explained above, Fuji total flow turbine has such features that hot water from the nozzle flows straight through the moving blades and hence the turbine rotor can rotate by the reaction force of hot water flowing out of the moving blades, thus realizing excellent peripheral efficiencies. Also, this total flow turbine is simple in structure and allows a highly reliable design.

Because of reaction type, the speed of flow in the blade flow channel is on the increase at all time, eliminating the possibility of deposits of impurities dissolved in hot water. The reaction type is ideally suited for total flow turbines using geothermal hot water containing a large quantity of impurities.

Also, this turbine is of a full admission structure, there is no mass-unbalance due to hot water which stays in the blade flow channel by partial admission.

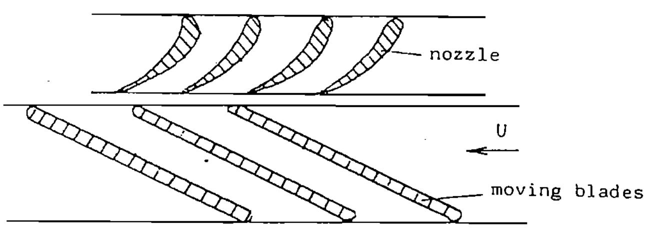

Figure 4.

Test Result

In order to evaluate the high efficiency of the Fuji reaction type total flow turbine, a model turbine of actual scale was manufactured and tested with hot water. The turbine power was about 21kW with 1.7 atg of hot water.
The specification is as follows.

Hot water	:	2.7 ata saturation
Exhaust	:	1.033 ata (atmospheric pressure)
Hot water flow	:	About 50 ton/H
Turbine rated speed	:	1800 rpm
Moving blade average diameter	:	ϕ530 mm
Turbine dimensions (approximation)	:	1500(L) x 1500(W) x 1650(H) mm
Turbine weight (approximation)	:	2500 kg
Load-measuring	:	Hydro-power meter

Fig. 5 shows the section of the model turbine.

The result of the field test conducted during the period of May 9,1987 to Jul. 0,1987 is as follows.

Purpose of test is as follows.

1) Confirmation of no deposits of scale in turbine and no presence of erosion/corrosion during long period of operation
2) Confirmation of aged deterioration (blade gap, wear of cabon packing, etc.)
3) Confirmation of characteristics of the operation (example, start/stop characteristics)
4) Confirmation of bearing temperature characteristic and vibration characteristic

Load-measuring was used with Hydro-power meter,and the model turbine speed was about 1000-1200 rpm(continuous operation). The model turbine was operated for a total of 1000 hours for the field test.

Operating condition is as follows.

The model turbine was operated for a total of 1000 hours for the evaluation test.

Test result is as follows.

(1) The turbine operated without causing trouble throughout the total operating period.
(2) The turbine start/stop operating was smooth without difficulty.
(3) Noise and vibration (less than 5 μm) were low in level and did not affect the proper operation of the turbine.
(4) The inside of the turbine was almost free from deposits of scale and from erosion/corrosion.

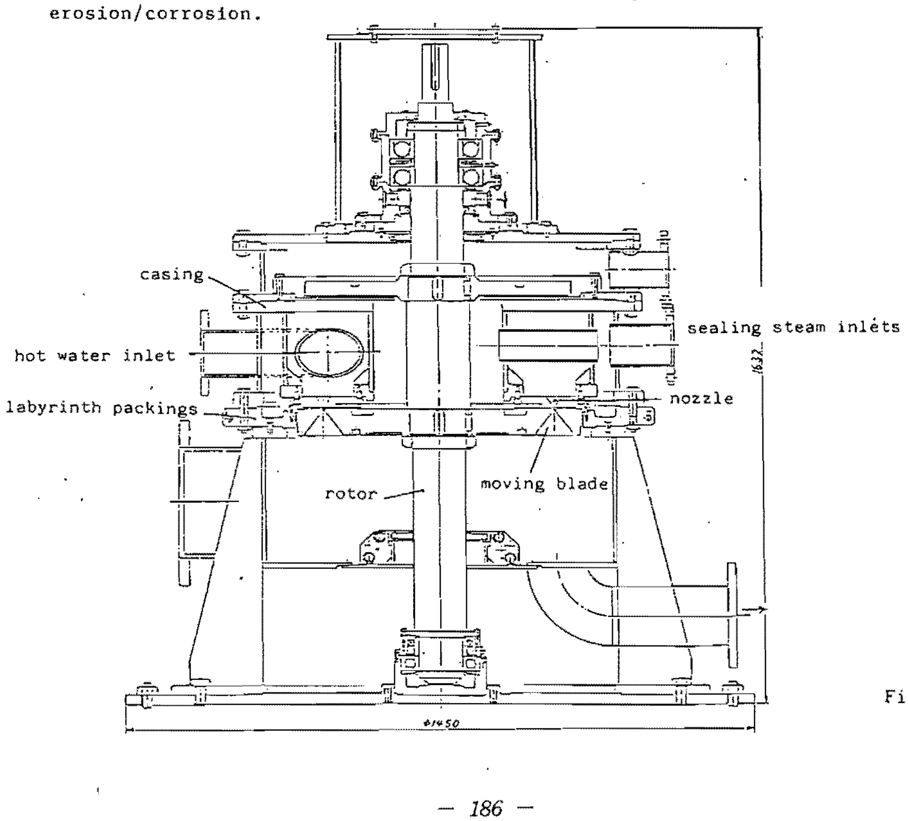

Figure 5.