Hydropower Stem Pressure Machine

A new concept for highly efficient waterpower exploitation

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Fig.1: Stem Pressure Machine, downstream view of pilot plant

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Abstract.

In the past, water wheels were built exclusively as either overshot or undershot machines. The main disadvantage of such water wheel types was their low intake capacity and consequently their poor efficiency.

The recently developed **Stem Pressure Machine (SPM),** represents a hydraulic power plant with the ability to compete the performance of low-pressure turbines. In addition, it reduces significantly the production costs and eliminates the need for expensive process monitoring. The patented SPM not only utilizes the potential energy (head), but also – for the first time (breakthrough product) – the kinetic energy (flow energy) of large amounts of water.

1.Lay-out, working method and economic aspects

The Stem Pressure Machine (SPM) can be built with one or several paddle wheels side by side (fig.1 and 2 cross section). Each wheel confines and utilizes the water flow channel by its hub and the lower paddle. In idle motion, all of the water passes through the wheel unimpeded. While drawing power (slowing down of the wheels), a water column emerges in front of the machine which corresponds both to the desired performance and the given head (fig.2, axial section). A by-pass overflow enables the discharge of the excess water.

Because of this characteristic feature, while having large water quantities and a relatively low head, the SPM is capable of substituting a low-pressure turbine.

Economical point of view: As a result of its unique design and control system, the SPM benefitsis considerable in cost savings during construction. The costs of building a complete power station are being lower as those necessary for a conventional plant. The SPM will work efficiently and profitably even if the turbines cannot operate due to a significant low head, for instance <1m.

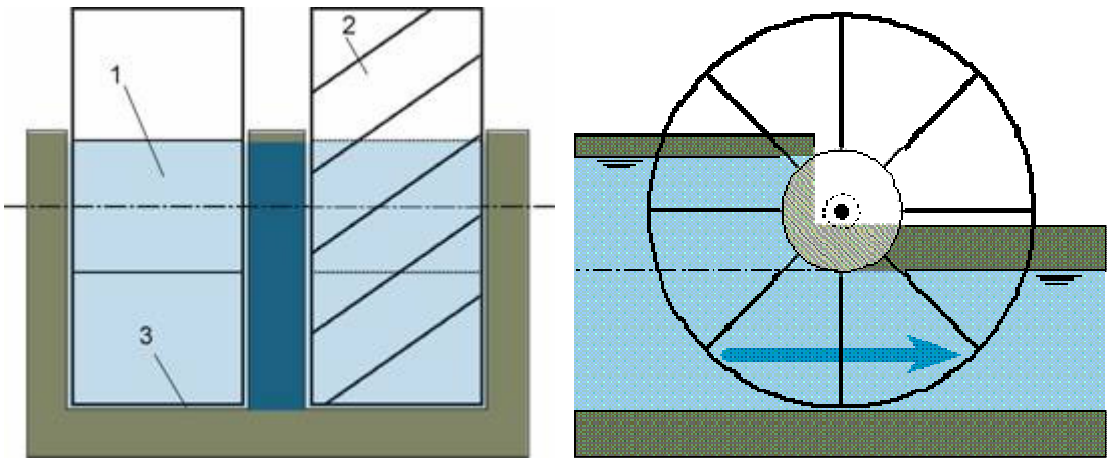


Fig.2: Schematic view, cross section and axial section

1= hub 2= blade 3= air gap

One of the most important innovations in connection with the SPM is the newly developed and ingeniously simple control technique which is able to stabilize the upstream water level within a range of only 5 cetimeters. It thereby guarantees the utilization of all different

water quantities in the range of the plants design nearly without anyenergy loss. Problems with varying water levels are technically excluded.

Because this new type of hydropower machine does not cause any change of flow direction, no losses will occur during the operation, which is unavoidable with turbines. It will only be negligible small capacity losses, caused by the SPM, because of water loss due to mechanically determined air gap. (fig.2, cross section and chart 2)

The construction method of the SPM wheels is highly flexible by allowing a wide field of applications.The technical layout varies according to the given amount of water and head. Depending on individual need an arbitrary number of SPM wheels may operate side by side. Head of up to several meters can be used and exploited.

For a proper operation, only a coarse bar rack is required upstream in order to keep away rubbish or large pieces of driftwood. The machine can easily cope with approximately 95% of any drifting material. For all living beings in the water, the SPM is completely passable in the downstream direction and therefore harmless to fauna and flora.

The paddle ends are screw-mounted. They can be repaired or replaced easily in case of distortion. The wheel bearings are practically maintenance-free due to lifetime lubrication. They are easily accessible in any mode of operation and not submerged into the water at any time.

2. Exploitation of kinetic energy

The SPM wheels processing large water quantities do not only exploit head (potential energy) but, for the first time, flow energy (kinetic energy) too.

In the past, the so-called ship mills utilized flow energy. However, such ship mills had only a very limited draught tolerance and consequently a low performance.

The new, special construction of the SPM wheels allows an operation in deep water with only minor losses due to mechanical friction. While a turbine would need approx. 10% of its capacity to compensate for self-induced losses, the SPM needs only fractions of its additionally available kinetic energy for compensation.

Chart 1a/1b show very clearly the connection between flow velocity and comparable head.

flow velocity	head
2,00 m/s	0,20 m
2,50 m/s	0,32 m
3,00 m/s	0,46 m
3,50 m/s	0,62 m
4,00 m/s	0,82 m
etc	etc

Chart 1a: Flow velocity (m/s) and corresponding head (m)

Geschwindigkeiten und zugehörige Fallhöhen (Fortsetzung).

Geschwindigkeit.	Fallhöhe.	Geschwindigkeit.	Fallhöhe.	Geschwindigkeit.	Fallhöhe.	Geschwindigkeit.	Fallhöhe.
m	m	m	m	m	m	m	m
2·01	0·2059	2·51	0·3211	3·01	0·4618	3·51	0·6280
2·02	0·2080	2·52	0·3237	3·02	0·4649	3·52	0·6316
2·03	0·2100	2·53	0·3263	3·03	0·4680	3·53	0·6352
2·04	0·2121	2·54	0·3289	3·04	0·4711	3·54	0·6388
2·05	0·2142	2·55	0·3315	3·05	0·4742	3·55	0·6424
2·06	0·2163	2·56	0·3341	3·06	0·4773	3·56	0·6460
2·07	0·2184	2·57	0·3367	3·07	0·4804	3·57	0·6497
2·08	0·2205	2·58	0·3393	3·08	0·4835	3·58	0·6533
2·09	0·2226	2·59	0·3419	3·09	0·4866	3·59	0·6569
2·10	0·2248	2·60	0·3446	3·10	0·4899	3·60	0·6606

Redtenbacher, Theorie u. Bau d. Wasserräder. 2te Auflage.

Chart 1b: Extract from „Redtenbacher, Theorie und Bau d. Wasserräder, 2nd ed.“

3. Diagram of forces

Fig.3 represents the SPM in a channel of 1m width and 1m head. The represented situation is static. The water levels are equally high on the two sides of the blade of the SPM wheel. In this state there is no torque effective on the blade. In case of water flowing, kinetic energy would be effective on the lower blade

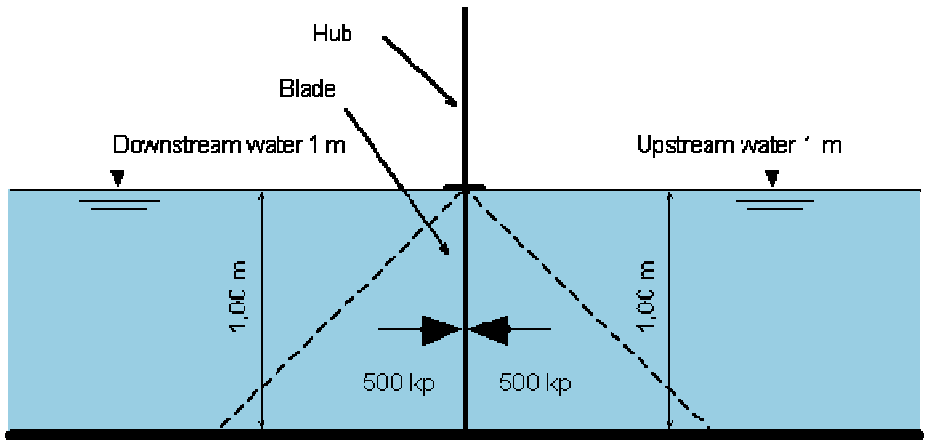


Fig.3: Hydrostatic pressure at the same water level upstream and downstream

Pressure difference = 0

Fig.4 represents the static pressure ratio on both sides of the lower blade. Because the SPM wheel in a blocked state seals the channel tightly (except for the mechanical air-gap), the channel becomes a sealed tank. The pressure resp. the torque, however, permanently remains at the same high value.

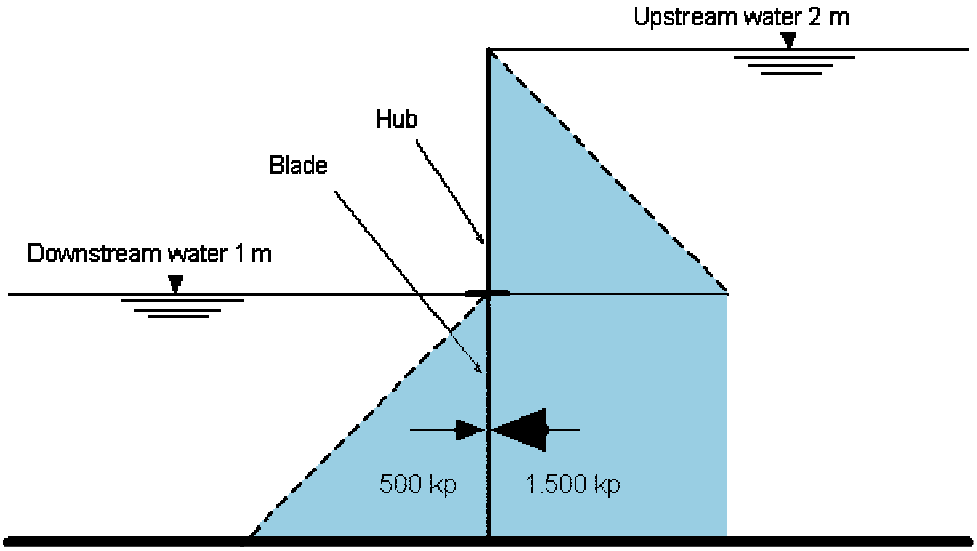


Fig.4: Hydrostatic pressure distribution at different water levels upstream and downstream

Pressure difference = 1,000 kp

4. The SPM in comparison

In order to assess the SPM correctly, a basic comparison with other water power machines is necessary. However, water wheels and high-pressure turbines have to be eliminated as comparable machines for the following reasons: Water wheels have only a very small absorption capacity and low performances.

High-pressure turbines require large head. Therefore, only the low-pressure turbines remain as comparable machines to the SPM.

These two water motors have two remarkable features in common: Namely the large absorbtion capacity and the ability to exploit a relatively small head.

The turbine is a pure flow machine. That means, the turbine needs ideal flow- and speed conditions for the energy transformation at a high degree of efficiency. In case the turbine blades are running at a speed too slow for the water flow, water will be lost without passing its energy to the blades. Ultimately in the case of a turbine being blocked, the complete amount of water that passes the blades is wasted.

This specific mechanism is the main weakness of such type of water motor. The question must be asked: What is the reason for this? At first it has to be mentioned that the energy transmission doesn‘t take place inevitably but will be effected by a deflection momentum (fig.5).

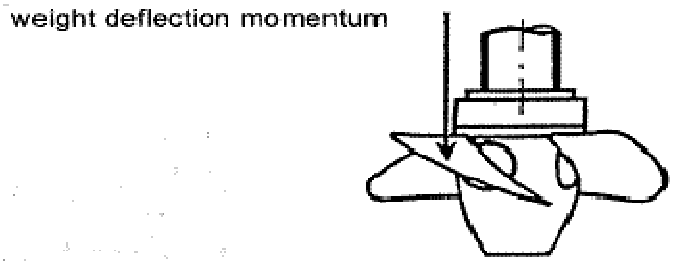


Fig.5: Schematic diagram of deflection momentum on turbine blade

An obstacle is set against the water pressure, the blade, which is in turn pushed to the side under an angle relative to the flow direction, causing the turbine to turn. To ensure these sequence of operations at a high degree of efficiency, extensive efforts have to be made in respect to mechanical and electrical controls (adjustable blades etc.) as well as to the construction, inlet structure and rake system.

The SPM is different from the normal turbine by the fact that the energy transformation isn‘t achieved by a free deflection momentum but by inevitable and permanent pressure on the lower wheel blade (fig.4). Here too, a deflection momentum is active, however, the forces have a vertical direction and are causing a horizontal power acting on the lower blade.

It is a critical construction characteristic of the SPM that the wheel does not allow a free passage of water at any position. If the wheel is turning, the following water pressure will shove through the water, which is located in the blade chambers under the hub.

The outstanding advantages of the SPM, particularly the extremely low investment- and operating costs as well as the unique ecological features make her first choice today over all other known water power machines.

5. Loss factors and efficiency

The SPM is a hydropower machine without any free flow of water. As a result of this special characteristic, the SPM has an extremely high efficiency exceeding 95% under all working conditiones.

The degree of efficiency of the SPM is shown in chart 2. The presented values have been determined by means of measurements at the 150 kW pilot plant.

Source	Value	Remark
Rolling losses	380 Watt at 10 rpm	SPM wheel dippek in calm water up to the hub, measured at 170 cm of water depth. This value results from bearing- and water friction.
Breakaway momentum	1315 Nm	Same conditions as above. This value results from mass inertia as well as bearing- and water friction.

Source	Value	Remark
Air-gap losses	~ 2-3 % of the entire water amount	The air-gap losses are always constant. They correspond exactly to the mechanically designed gap between sides/blades of the SPM wheel and the concrete structure. The losses depend on the technical precision of these elements.

Chart 2: Loss factors and efficiency of the SPM

We can easily see from chart 2 that the SPM will start operating already at very low forces. For this operation, the SPM needs only a fraction of the available flow energy. On overload, the SPM reacts exactly contrary to the regular turbine. The low-pressure turbine will show considerable water losses on overload as well as reduced torque and rpm.

The SPM, however, will react with an elevation of head and thus inevitably with an increase of torque. Only when the overload remains constant, unused water will be lost by means of the overflow weir or the spillway. The torque, however, will always remain at its maximum value. Eventual losses are merely water quantity losses. In partial load operation up to the nominal capacity the SPM will always work with an efficiency exceeding 90%.

6. The pilot plant

To verify the efficiency of the new technology and the exceptional performance features of the machine and also to document the test results by skilled scientists., Messrs. WICON-Generatoren, Vienna, have set up a pilot-program and measuring plant at an application oriented size of >150 kW.

Fig. 6: Pilot Plant, upstream view

Technical specification of the pilot plant:

SPM wheel diameter	4,250 mm
Width of two wheels total	4,000 mm
Hub diameter	1,400 mm
Usable head	1,400 mm

Water absorption capacity	12 m³/s
Power capability	> 150 kW

7. Advantages and characteristics of the SPM with regard to environment and ecology

Due to its unique construction and mode of operation and because the SPM doesn‘t need any large head to obtain acceptable performances it can be installed in the river bed directly. No operational channel is required. The rest water problem is also eliminated because no separate power station channel exists.

This is the first time in history that a powerful hydropower machine is available, which will maintain debris- and sedimentation transport through the machine at the bottom of the river bed without risk of building up deposits.

Fish and macrozoa can pass through the SPM safely downstream. Upstream migration of fish is not possible. Small living beings of all kinds, however, can easily move through the machine in either direction since there is sufficient space for them in the gap between the channel construction and the wheels. This fact could be proved any time at the pilot plant. In connection to this, the special peculiarity of the SPM must be pointed out, namely that there is no uncontrolled fast flow anywhere in the machine. Therefore, there is no need to protect small living animals in their movement through it.

Well known environmental groups have already emphasized that they strongly recommend and approve the application of the SPM. They confirmed uniformly that they practically exclude any possibility that living beings could be harmed in the machine. This fact is obvious, because there is no relative motion between the water (including fish) and the SPM wheel blades. A fish migrating through the machine recognizes the shovels like driftwood drifting beside or behind it.

Because the SPM needs only a coarse rake for its own protection against large drifting objects, all debris can easily pass through so that the natural substances, which are important to flora and fauna, remain in the river.

Damages such as cavities in the river bed right behind the machine are not possible since there is no flow of high velocity elsewhere. The water does not drop down over the wheels but is pushed through them, underneath the hub. The water speed is equally high before and behind the machine.

Without any exaggeration, we can summarize that the main advantages of the SPM technology are a result of its extremely high efficiency, its ability to maintain the natural flow of water in the river bed as well as the fact that no water is taken from the river. The ecological advantages of the SPM benefit exactly the points, which are critical for conventional plants and which usually, lead to inevitably long approval procedures.

8. The future of waterpower exploitation in respect to the SPM

It is yet a common belief that the theoretical resources of waterpower left unutilized in many countries is in the range of 25 to 30 %. To our knowledge, all publications about this topic refer to the possibilities of today‘s technologies, their known restrictions and limitation technical, economic and ecological possibilities.

With the SPM, a new technology is available to exploit the almost unlimited potential of water power (even below 1 meter of head) without or only marginal burden to nature. This

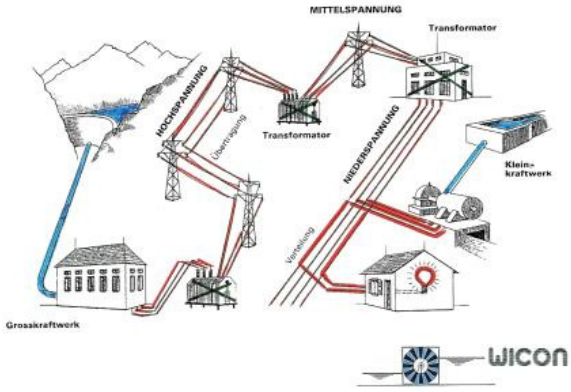
technology generates the condition base for an economical as well as ecological utilization of an innumeral figure of yet unused sites. It is a fascinating scenario to imagine that there are millions of weirs worldwide which are not energetically used but only for water management.

Let's open up these barrages for the good of nature by inserting the SPM which will securely provide the desired water mark and simultaneously generate electric power as kind of a by-product! The newly developed reliably feedback control system guarantees the required water mark even during extremely changing water supplies.

9. Advantages of decentralized electric power generation.

One of the advantages of smaller power stations, which should not be underestimated, is the fact that the electric power produced by these can often be fed directly into existing low-voltage power systems. The illustration below shows clearly the corresponding economic efficiency.

Large-scale power plants result in significant losses in the transmission of the power as a result of the use of several transformer stations and hundreds of kilometers of high-voltage cables with their corresponding well known resistance losses.



Words in the drawing above:

Grosskraftwerk = large power plant
Hochspannung = high voltage
Übertragung = transmission
Mittelspannung = medium voltage
Transformator = transformer
Verteilung = distribution
Niederspannung = low voltage
Kleinkraftwerk = small power plant

Literature: WASSERWIRTSCHAFT 2/2001 page 70 ff.
Redtenbacher, Theorie und Bau der Wasserräder, 2te Auflage
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