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HEAD LOSSES IN SMALL HYDROPOWER PLANT TRASH RACKS (SHP)

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Abstract. Small hydropower plants (SHP) are technical facilities that are part of alternative energy sources [Paish 2002]. They are primarily characterised by low unit power (in Poland below 5 MW) and are often constructed on existing barrages. Electrical current produced by these plants is used to meet local demand. Considering the exploitation of SHPs, it is important to ensure a stable flow through turbines. Aggidis et al. [2010] analysed SHP equipment costs depending on the turbine set. The turbines are protected against damage with trash racks applied for capturing water-borne detritus, such as plant debris carried by water. However, trash racks as solid equipment of SHPs cause head losses, and as a consequence reduce the efficiency of the system. These losses result not only from the spacing of bars, their shape and the technical condition of the inlet chamber, but also from plant debris, its nature, and the quantity of accumulated material that effectively limits the flow. The plant debris captured on trash racks is characterised by diversity in terms of species composition related to the vegetation period and the area where hydraulic facilities are located. Therefore, it is important to maintain trash racks clean by regular removal of the accumulated material. In this context, modernised and newly built power plants are fitted with mechanical cleaners. In older facilities, manual intervention for regular cleaning is required. The present study analyses how the bar shape and the orientation angle of trash racks as well as the accumulated plant debris affect head losses. The results were obtained from laboratory tests. The research examined the impact the inclination angle of trash racks (30°, 60° and 80°) has on head loss values for three different shapes of bars (cylindrical, angled and flat rectangular) and various weight portions of plant debris (0.25, 0.375 and 0.5 kg). The summarised losses were determined by measuring the difference in water levels in front and behind the bars using laboratory facilities. The individual components of losses were determined based on empirical relationships, excluding the losses occurring due to plant debris. Subsequently, the loss resulting from the limited flow was calculated based on the balance of calculated and measured losses.

Keywords: Small Hydropower Plant, trash racks, debris

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INTRODUCTION

Due to economic development and increasing demand for energy, primarily electricity (since its production does not affect the environment adversely), alternative sources of energy (ASE) must be found. Energy sources can be divided into two main groups: renewable (which are naturally replenished) and conventional (the use of which progresses faster than their natural reproduction). In order to reduce the use of fossil fuels, energy from renewable sources has been more frequent and more intensively provided to ensure a sustainable development and the improvement of life quality. Currently, hydropower accounts for close to 16% of the world's total power supply being the world's most dominant (86%) source of renewable electrical energy [Hamududu and Killingtveit 2012]. In the past few decades the use of SHPs as alternative sources of energy has been increasing [Li et al. 2015]. It is due to low financial expenses, quick returns on investment and no harmful effect on the natural environment [Dudhani et al. 2006, Bøckman et al. 2008, Yuksel 2010, Kosnik 2010, Bakken et al. 2012, Li et al. 2013].

It is estimated that in 2005 in Poland, the share of energy from renewable sources in gross final energy consumption amounted to 7.2% [Directive… 2009]. According to the Directive on the promotion of energy from renewable sources, which amended and subsequently repealed the Directives 2001/77/EC and 2003/30/EC, the national targets for energy share from renewable sources in gross final energy consumption in 2020 in Poland should be at least 15%. The terms and conditions for the production of electrical energy from renewable sources are governed by the Act of 20 February 2015 on renewable energy sources [Ustawa… 2015].

One of these is water energy, which is converted by means of water turbines into mechanical energy, and then transformed into electricity in hydro-generators. SHPs are located most often at barrages where energy is produced due to the difference in water surface levels in upstream and downstream of the weir. A key element of hydro-technical facility is its intake, which should limit the amount of material (dragged and drifted – bed load and suspended load) entering the flow system of the power plant. For this purpose, inlets are fitted with protective trash racks (fine and coarse) made of steel bars [Berthold 2009]. Fixed in parallel, equally spaced and of base construction, they are to withstand total water pressure without excessive distortion. The spacing between bars depends on the type of installed turbine, with values ranging 20–30 mm for Pelton turbines, 40–50 mm for Francis turbines and 80–100 mm for Kaplan turbines respectively. When designing trash racks, it is necessary to determine specific hydraulic losses because they are responsible for a real reduction in electricity production. Even only 10% coverage of a trash rack inlet, under certain conditions, may result in 10 cm gradient loss, which leads to significant energy waste. The volume of losses considerably depends on the geometry and shape of bars, their size, the inclination of trash racks to the vertical as well as water flow hydraulic characteristics and the size and amount of plant debris.

Plant debris is an organic material, e.g. grass straws, leaves, branches, brushwood, driftwood, tumbleweeds, aquatic weeds, which accumulates on bars and limit the free flow of water. The type of accumulated plant debris depends directly on the forms of land use of river valleys. Different types of material accumulate on SHP trash racks when the flow comes from fields and meadows, or when it comes from forests. The process intensifies particularly as of a result of sudden hydro-meteorological phenomena such as floods, storms and even earthquakes [Tang et al. 2012]. In addition, an important issue is to identify the characteristics of plant debris. In case of low and medium flows, transportation of fine organic matter (twigs, leaves, fragments of macrophytes) prevails. At the time of freshet flooding, when the coastline water level is exceeded, the water flow carries leaves, dry grass straws, branches, trunks remaining on slopes and in the high water river bed zone. The material accumulated over many years is activated during floods thanks to the lifting force of water. Therefore, in terms of flood, lowland rivers transport a greater amount of fresh organic matter (easy identification) as well as organic matter degraded in various processes (difficult quality and species identification). At violent flows that occur due to extreme weather phenomena (strong winds, heavy rains) the material collected from rarely flooded areas is directed with a powerful jet to the main riverbed. Even pillars of bridges have impeding characteristics [Johnson and Sheeder 2011].

MATERIALS AND METHODS

Water in rivers in its mass transports suspended load and bed load in the bottom area. Surface detritus flows with water drifting on its surface [Johnson and Sheeder 2013]. Apart from the material of plant origin, anthropogenic components are a considerable difficulty, especially during floods when bank-full water collects debris from floodplains.

The limited water flow caused by the accumulation of debris on trash racks contributes to additional head losses and as a consequence reduces performance. In SHPs, trash racks are usually cleaned manually. Nowadays, with newly constructed hydraulic facilities or re-built barrages, trash racks are equipped with cleaning mechanisms. This solution is economically justified, since automation reduces costs associated with employing additional personnel, saves cleaning time and maintains the capacity of trash screens.

Facilities without constant supervision, collecting waste and water-borne material on trash racks, cause water damming and increase workload. When calculating the spacing of trash racks it is recommended to take into account the risk of blocking the clearance as well as to design self-cleaning mechanisms. The recommended dimensions of the spaces (minimal) presented Bajkowski [2009].

Considering the spacing of bars and preventive methods of debris penetration, inlet trash racks can be divided into the following types [Balcerski 1969]

- anti-ice bars – designed in such a way to prevent ice from being immersed in water, ice pressure resistance is taken as the hydrostatic force acting on the surface submerged in water from the equation $p = 100\ \mathrm{kg} \cdot \mathrm{m}^2$;
- coarse trash racks (trash racks with wide spacing) – constructed of thick steel or reinforced concrete bars with the spacing of 0,15–0,5 m. This trash rack type is designed primarily to stop large elements from floating on the water surface or being dragged in the watercourse. They are most frequently coupled with anti-ice bars or intake thresholds and are designed with the angle of inclination to the vertical between 10°–20°;
- fine trash racks (trash racks with close spacing) – their main objective is to limit the amount of small-scale debris and fish entering turbine inlets. They are located in front of the inlet to turbine spirals, tunnels or pipelines, with the angle of inclination to the

horizontal of approx. 70° in order to facilitate their cleaning. They are also equipped with separate elements that can be replaced and removed easily. Fine trash racks are made of steel sections, which are connected by cross bars with spacers retaining equal spacing. The spacing between bars depends on water velocity, turbine type and fish species [Hassinger and Hübner 2009], while the clearance of trash racks ranges from 0,20 to 0,80 m and decreases with the increase of slope. The velocity values near trash racks are significantly lower for small hydropower plants than for power plants with larger gullets characterised by large slopes e.g. > 10 m.

The most difficult seasonal aspect of SHP work is the time of first frost, which begins before the formation of ice cover on rivers, canals or reservoirs. During the time of first frost, the so-called frazil ice or soft ice porridge starts to flow. Frazil ice deposits on trash racks above or just below the water surface, frequently blocking and immobilizing the turbine. To ensure operational safety of SHP in this context, the upper edge of trash racks should be placed from 1,5 to 1,86 m below the water surface. Deeply placed trash racks are protected with the front beam of the hydropower facility, which stops the accumulation of frazil ice and ice. If trash racks are located above the water surface, then at high frost bars freeze being covered with ice that might block trash racks totally. If this is the case, mechanical operation and maintenance of trash racks is very difficult and comes down to heating them, which unfortunately results in high consumption of energy. Another way to protect bars against getting frozen up is to use compressed air [Michałowski and Plutecki 1975].

Accumulation and erosion processes related to hydro-engineering structures develop depending on the hydrological regime, the operating life of facilities as well as morphological changes in the riverbed. Therefore, it is important that working water that is led to the turbine through inlets and intakes has insignificant hydraulic loss values, and SHP trash racks efficiently clean water from transported organic material, including solid impurities. In fact, a proper design of trash racks should minimize the amount of penetrating solids and sediment to the flow system of hydraulic structures [Walczak et al. 2014].

The methodology of laboratory tests consisted in placing a test model in the hydraulic bed (Fig.1), which structurally corresponded to coarse trash racks installed at the inlet to SHP. The selection of various shapes of bars (cylindrical, flat rectangular, angled) at three different inclinations to the horizontal (30°, 60° and 80°) was used for a detailed analysis of their effect on head losses across trash racks [Josiah et al. 2016]. The evaluation of debris weight used for laboratory tests was based on the authors' field research carried out at SHP trash racks located in Jaracz. During in-situ testing there were observed some dissimilarities in debris structure and weight resulting from different vegetation periods. It was assumed for the laboratory procedure that debris weight (0,25, 0,375 and 0,5 kg) was consistent with natural fine material accumulated within a week of a full growing season.

The tests were carried out at a stable water flow rate of $Q = 43{,}603\ \mathrm{l \cdot s^{-1}}$. After the stabilisation of plant debris on trash rack bars, in each case there were measured velocity distributions both in front and behind the bars. The distributions were measured using an electromagnetic probe: FLAT model 801. Additionally, there was determined the difference in water surface levels in front and behind trash racks with the use of a pegged river gauge, giving a total loss value in terms of clogging the trash rack with plant debris.

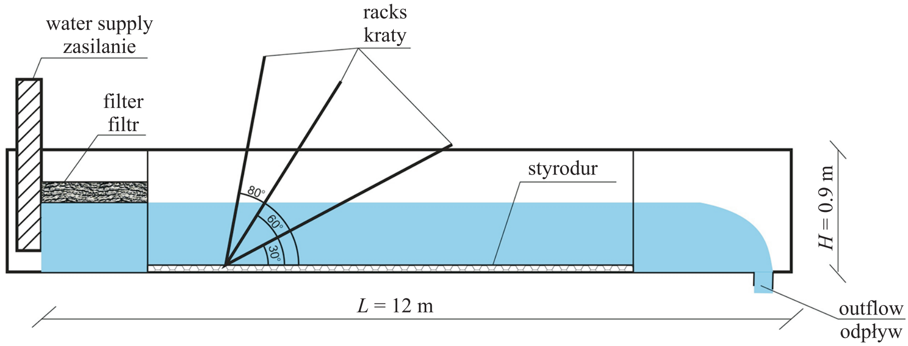

Fig. 1. Schematic diagram of the research model
Ryc. 1. Schemat modelu badawczego

The total value of head loss was determined as the sum of partial losses [Walczak et al. 2014]:

$$\sum \Delta h = \Delta h_k + \Delta h_\alpha + \Delta h_w + \Delta h_{wn} + \Delta h_v \tag{1}$$

where:
Δh_k – hydraulic gradient loss across trash rack, m,
Δh_α – loss due to a change in the direction of flowing water, m,
Δh_w – inlet loss due to a change in cross sections, m,
Δh_{wn} – loss due to side cavities, m,
Δh_v – loss due to clogging trash racks with plant debris, m.

Hydraulic gradient losses across trash racks were determined on the basis of Kirschmer's equation [Balcerski, 1969] that takes into account the shape of spacing, dimensions of bars, and their inclination. Table 1 shows the values used to calculate the β and β'.

Table 1. The values selected in order to calculate the hydraulic gradient loss of trash rack
Tabela 1. Dobrane wartości w celu wyliczenia straty spadu na kracie

Cross section of bars Kształt prętów	Values of coefficients β i β' – Wartości współczynników β i β'							
	β	β' for 30°	β' for 60°	β' for 80°	*D*, m	*a*, m	*d*/*a*, m	v_0, m · s^{-1}
Cylindrical Cylindryczny	1.79	1.90	6.05	6.2	0.01	0.033	0.33	0.226
Angled Kątownik	1.03	1.31	2.62	2.8	0.02	0.024	0.83	0.226
Flat rectangular Płaskownik	2.42	1.31	2.62	2.8	0.02	0.024	0.83	0.226

Losses resulting from a change in the direction of flowing water depend on the coefficient ξ, which is variable in the range of 0.8–0.4 and determined by the shape of the inlet α (Fig. 2).

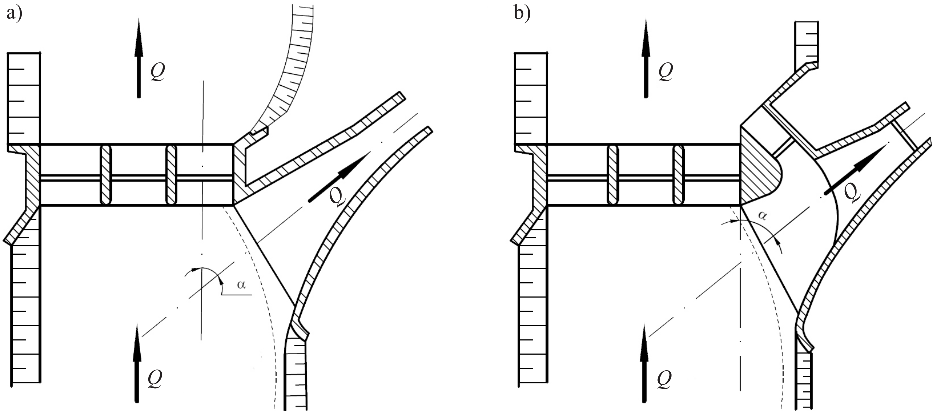

Fig. 2. The location of intakes (inlets) to the energy channel on a straight stretch of river a) with flushing through a weir, b) with a separate flushing duct [Balcerski 1969].

Ryc. 2. Usytuowanie wlotów do kanału energetycznego na prostym odcinku rzeki a) z płukaniem przez jaz b) z osobnym kanałem płuczącym [Balcerski 1969]

Inlet losses due to a change in cross sections (Fig. 3) depend on the coefficient ζ.

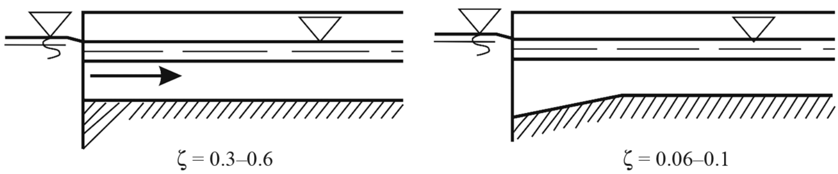

Fig. 3. Typical inlet shapes to intakes and corresponding loss coefficients – open channels [Balcerski 1969].

Ryc. 3. Typowe kształty wlotów do ujęć i odpowiadające im współczynniki strat – kanały otwarte [Balcerski 1969]

The last component is the value of loss caused by clogging trash racks with plant debris. Although debris is fine material of elastic characteristics, it can block a major part of track rack inlets [Walczak et al. 2014]. Numerous authors focused on the risk of accumulation of debris finer elements, such as parts of branches [Rutherfurd et al. 2002].

The values of losses resulting from the deposition of plant debris on trash racks were estimated based on the balance of losses by calculating partial losses (excluding Δh_v) from the measured total losses ($\Sigma\Delta h$).

RESULTS AND DISCUSSION

On the basis of laboratory measurements (Fig. 4) there were first estimated total losses across trash racks ($\Sigma\Delta h$) (Table 2), and then partial losses.

Table 2. Total losses across trash racks measured in the laboratory
Tabela 2. Suma strat na kratach pomierzona w laboratorium

Shape (cross section) of bars Kształt prętów	30°			60°			80°		
	Plant debris weight – Waga rumoszu, kg								
	0.500	0.375	0.250	0.500	0.375	0.250	0.500	0.375	0.250
	m								
Cylindrical Cylin-dryczny	$2.4 \cdot 10^{-2}$	$1.7 \cdot 10^{-2}$	$1.6 \cdot 10^{-2}$	$3.8 \cdot 10^{-2}$	$3.6 \cdot 10^{-2}$	$2.8 \cdot 10^{-2}$	$3.5 \cdot 10^{-2}$	$3.0 \cdot 10^{-2}$	$2.7 \cdot 10^{-2}$
Angled Kątownik	$1.9 \cdot 10^{-2}$	$1.5 \cdot 10^{-2}$	$2.0 \cdot 10^{-2}$	$3.9 \cdot 10^{-2}$	$3.2 \cdot 10^{-2}$	$2.5 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$	$2.1 \cdot 10^{-2}$	$2.0 \cdot 10^{-2}$
Flat rectangular Płaskownik	$2.0 \cdot 10^{-2}$	$1.6 \cdot 10^{-2}$	$1.5 \cdot 10^{-2}$	$1.9 \cdot 10^{-2}$	$1.8 \cdot 10^{-2}$	$1.7 \cdot 10^{-2}$	$2.3 \cdot 10^{-2}$	$2.0 \cdot 10^{-2}$	$2.0 \cdot 10^{-2}$

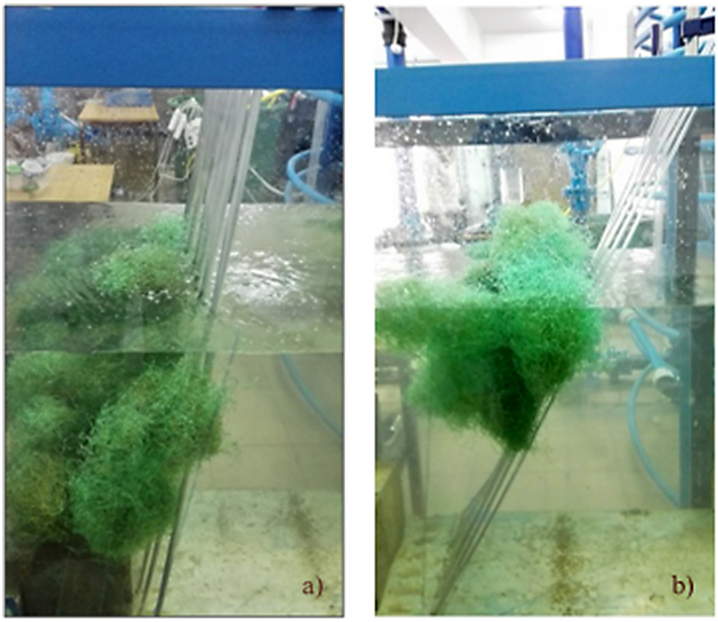

Fig. 4 a) Flat rectangular bars inclined to the channel bottom at an angle of 80° for 0.5 kg debris weight, b) Cylindrical bars inclined to the channel bottom at an angle of 80° for 0.5 kg debris weight

Ryc. 4 a) Płaskowniki nachylone względem dna koryta pod kątem 60° przy wadze rumoszu 0,5 kg, b) pręty o kształcie cylindrycznym nachylone względem dna koryta pod kątem 80° przy wadze rumoszu 0,5 kg

Losses due to side cavities do not usually exceed 0.1 mm at velocities below 0.2 m · s^{-1}, and therefore they are excluded from calculations. During the laboratory tests, low velocity values were prevailing in most cases, slightly exceeding the minimum of 0.11–0.13 m · s^{-1}.

Fig. 5–7 show the charts demonstrating the impact of bar shapes and inclination angles to the bottom on the total value of head losses.

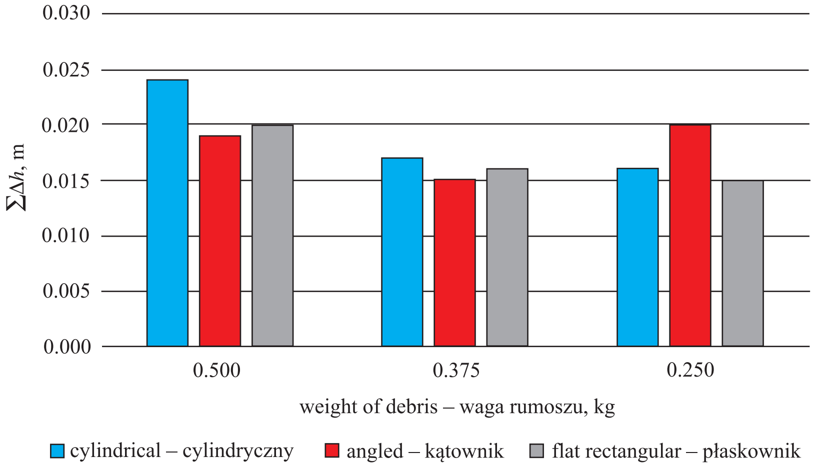

Fig. 5. Losses due to clogging trash racks with plant debris for variously shaped bars inclined at an angle of 30° with different plant debris weights

Ryc. 5. Straty wynikające z zatykania krat rumoszem roślinnym przy różnych kształtach prętów nachylonych pod kątem 30° i różnych wagach rumoszu roślinnego

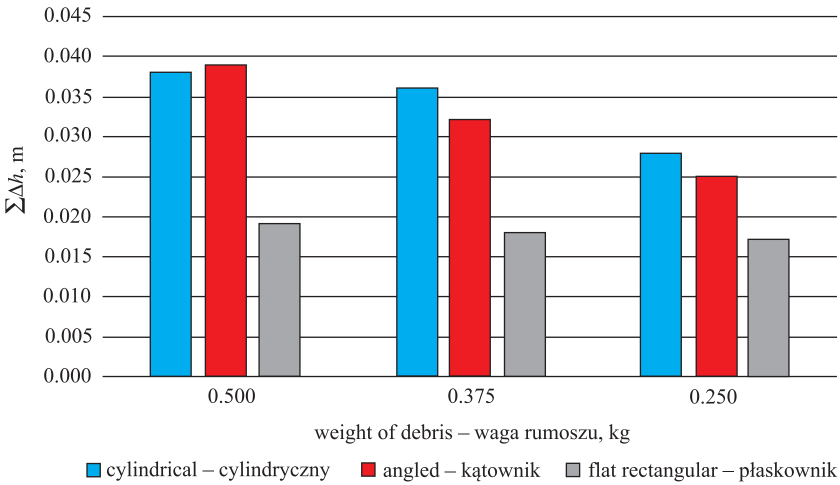

Fig. 6. Losses due to clogging trash racks with plant debris for variously shaped bars inclined at an angle of 60° with different plant debris weights

Ryc. 6. Straty wynikające z zatykania krat rumoszem roślinnym przy różnych kształtach prętów nachylonych pod kątem 60° i różnych wagach rumoszu roślinnego

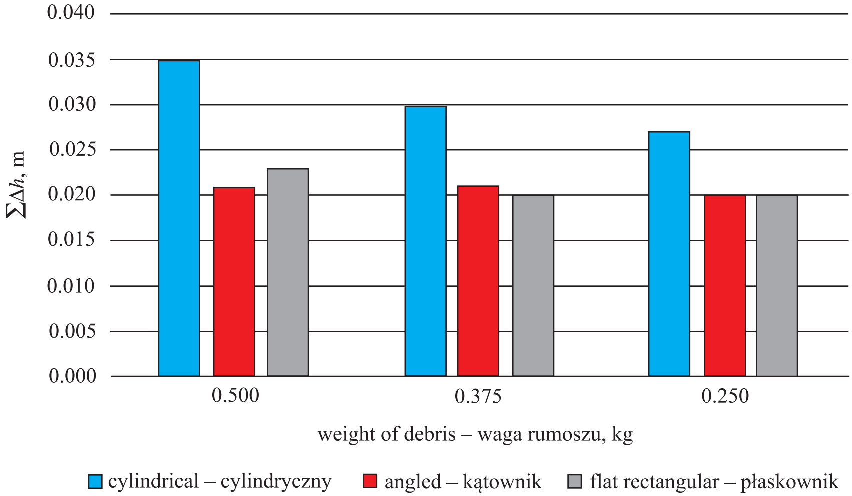

Fig. 7. Losses due to clogging trash racks with plant debris for variously shaped bars inclined at an angle of 80° with different plant debris weights

Ryc. 7. Straty wynikające z zatykania krat rumoszem roślinnym przy różnych kształtach prętów nachylonych pod kątem 80° i różnych wagach rumoszu roślinnego

Fig. 5 presents the total value of losses for trash rack bars of various shapes and for different plant debris weights at a constant inclination angle of 30°. The highest loss values were for cylindrical trash rack bars and for all ranges of analysed plant debris weights. Generally, the lowest loss values occurred when plant debris weighed 0.375 g.

As plant debris weight increased, so did the total loss value when trash racks were inclined to the bottom at an angle of 60° (Fig. 6). The lowest values of loss were generated with flat rectangular trash rack bars for all weight portions of plan debris.

When analysing Fig. 7, we can notice that regardless of plant debris weight used in the laboratory tests, the total value of loss increases for trash racks with cylindrical bars. Two other bar shapes result in similar, much lower loss values (approx. 0.02 m).

Based on the laboratory tests the following values of partial losses were obtained. Hydraulic gradient loss values on trash racks are shown in Table 3.

Table 3. Hydraulic gradient loss values on trash racks Δh_k for various shapes of bars and trash rack inclination angles

Tabela 3. Straty spadu na kracie (Δh_k) przy różnych kształtach prętów, ich nachyleniach

Cross section of bars Kształt prętów	30°	60°	80°
	Head losses at the racks – Straty całkowite na kratach, m		
Cylindrical cylindryczny	$1.01 \cdot 10^{-4}$	$5.57 \cdot 10^{-4}$	$6.49 \cdot 10^{-4}$
Angled kątownik	$1.37 \cdot 10^{-4}$	$4.77 \cdot 10^{-4}$	$5.77 \cdot 10^{-4}$
Flat rectangular płaskownik	$3.22 \cdot 10^{-4}$	$11.15 \cdot 10^{-4}$	$13.55 \cdot 10^{-4}$

The results of these tests support the observation that the lowest loss values are on cylindrical bars that are inclined to the hydraulic channel bottom at an angle of 30°. This is associated with a small diameter of bars equal to 0.01 m, and additionally a greater spacing between them 0.033 m (single space equal to 0.033 m^2) as compared to trash racks made of angle bars (single space equal to 0,019 m^2) and flat rectangular bars (single space equal to 0.017 m^2). The highest loss values occur on flat rectangular bars what might be related to the relatively high value of the loss coefficient β equal to 2.42.

Losses resulting from a change in the direction of flowing water were also calculated. They ranged up to 0.5 mm. Losses due to a change in cross sections and losses across side cavities in total did not exceed 0.5 mm for the least efficient variant, thus it was assumed that the total value of losses $\Delta h_\alpha + \Delta h_w + \Delta h_{wn}$ was 0.001 m.

Calculations of particular losses were made for each shape of bars with different inclinations and different weight portions of the applied plant debris. On this basis, there was designated the percentage share of losses due to clogging the passage with plant debris in the total value of losses (tab. 4).

By analysing the results shown in Table 4 it can be seen that the shape of bars has a significant impact on losses resulting from blocking the water flow with plant debris. The largest percentage share of losses resulting from the deposition of plant debris in relation to the total value of losses was obtained for cylindrical bars. This demonstrates that other elements of the balance Δh give the relatively low values of losses. As a consequence, it also confirms that with regular and correct operation of SHP (proper trash racks cleaning and maintenance in particular), cylindrical trash rack bars will be in this case the most efficient and generating the least possible head losses.

Table 4. Percentage share of plant debris in the total value of losses
Tabela 4. Procentowy udział rumoszu roślinnego w całkowitej wartości strat

Cross section of bars Kształt prętów	30°			60°			80°		
	Plant debris weight – Waga rumoszu, kg								
	0.500	0.375	0.250	0.500	0.375	0.205	0.500	0.375	0.250
	Losses Δh_v at the racks – Starty Δh_v na kracie, %								
Cylindrical Cylindryczny	91.6	88.2	87.4	82.7	81.8	76.5	78.6	75.0	72.3
Angled Kątownik	87.5	84.2	88.2	85.2	82.0	76.9	67.8	67.8	66.2
Flat rectangular Płaskownik	78.9	73.6	71.9	36.1	32.5	28.5	36.7	27.3	27.3

An impact of the intake of trash racks on fish was investigated by Budziło and Polk-Kowalska [2015]. The research involved the placing of the rods of various cross-sectional shapes (cylindrical and rectangular) in the open channel, at different distances and various angles of inclination to the bottom of the trough and different orientation to the wall of hydraulic trough. Authors based on the experiment claimed that coefficients of energy losses in the case of trash racks oriented at a different angle in relation to the bottom were higher than the coefficients of energy losses related to the angle of racks orientation to walls of trough.

Velocity measurements using ADV and PIV for trash racks inclined in the camber angle ranged 0º–90º in relation to the bottom were conducted by Breinnig et al. [2003], who found that for the bars of triangular cross-sectional, velocity changes occurred at small angles of inclination. Similar conclusions were drown by Raynal et al. [2013], for trash racks with the bars of rectangular and cylindrical cross-sectional. Josiah et al. [2016] dealt with similar issues, they investigated the head loss of cylindrical cross-sectional bars inclined in the range of 30° to 90° to the bottom of laboratory trough. They found the empirical formula taking into account the slope, the overrides section degree and the flow velocity, which accurately determines the value of the head losses.

SUMMARY

Improved fine trash rack design requires selecting the adequate shape of trash rack bars and their inclination towards the bottom of the riverbed. This has a considerable impact on losses resulting from clogging trash racks with plant debris. The laboratory tests carried out demonstrated which of the examined shapes of bars (cylindrical, angled or flat rectangular) inclined at different angles (30°, 60° and 80°) is the most effective for the design of hydroelectric power protective trash racks.

In addition, the analyses proved that if mechanical cleaners are applied in the hydropower facility (short intervals between cleaning and maintenance), the use of cylindrical trash rack bars inclined towards the channel bottom at an angle of 80° provides the most beneficial and preferred solution. Clean trash racks generate the lowest head loss values. However, taking into account fine trash racks serviced manually (longer intervals between cleaning and maintenance), this shape of bars with the same inclination angle will not work. The use of trash racks at hydro facilities without supervision can cause clogging, which has a negative effect on the value of losses. Therefore, it is important to keep trash screens clean. It is also essential to note that when the design of hydroelectric power plant elements is being considered, financial expenditures incurred by investors affect the process significantly and they are who decide on the selection of assistive devices for hydroelectric facilities.

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OSZACOWANIE STRAT HYDRAULICZNYCH NA KRATACH MEW Z UWZGLĘDNIENIEM RUMOSZU ROŚLINNEGO

Streszczenie. Małe elektrownie wodne (MEW) to obiekty hydrotechniczne, które stanowią element alternatywnych źródeł energii [Paish 2002]. Charakteryzują się głównie małą mocą jednostkową, w Polsce poniżej 5 MW. Powstają często na istniejących już stopniach wodnych. Prąd elektryczny produkowany w tych elektrowniach służy do zaspokojenia potrzeb lokalnych. W przypadku eksploatacji MEW istotne jest zapewnienie stałego przepływu przez turbiny. Aggidis i in. [2010] przeanalizowali koszty wyposażenia MEW w zależności od zastosowanego turbozespołu. Turbiny przed uszkodzeniem są zabezpieczone kratami, których zadaniem jest zatrzymanie zanieczyszczeń stałych takich jak rumosz roślinny, niesionych przez wodę. Kraty jako elementy stałe urządzenia powodują straty hydrauliczne, co przekłada się na obniżenie sprawności instalacji. Straty te wynikają nie tylko z rozstawy krat czy ich kształtu oraz stanu technicznego komory wlotowej, ale również rumoszu roślinnego – rodzaju oraz ilości nagromadzonego materiału tego typu, który skutecznie hamuje przepływ. Rumosz roślinny występujący na kratach charakteryzuje się różnorodnością pod względem składu gatunkowego, okresu wegetacji i zależy od obszaru, na którym budowla hydrotechniczna się znajduje. Istotne jest utrzymanie krat w czystości poprzez regularne usuwanie nagromadzonego materiału. W modernizowanych i nowoczesnych elektrowniach montowane są czyszczarki mechaniczne, w urządzeniach starszego typu wymagana jest interwencja obsługi obiektu. W prezentowanej pracy przeanalizowano wpływ kształtu oraz położenia krat, a także rumoszu roślinnego gromadzącego się na kratach MEW na straty hydrauliczne na kratach. Przedstawione w pracy wyniki uzyskano z badań laboratoryjnych wykonanych w laboratorium. W badaniach analizowano wpływ nachylenia krat (30°, 60° i 80°) dla trzech różnych kształtów prętów (cylindrycznego, zakrzywionego i płaskiego) oraz rumoszu roślinnego dawkowanego w różnych porcjach wagowych (0,25, 0,375 oraz 0,5 kg) na wielkości strat hydraulicznych powstających na kratach. Sumaryczne straty na kratach wyznaczono, mierząc różnicę położenia zwierciadła wody przed i za kratami na stanowisku w laboratorium. Z zależności empirycznych wyznaczono poszczególne składowe strat na kratach, poza startami wynikającymi z rumoszu roślinnego. Następnie z bilansu obliczonych strat oraz straty pomierzonej w laboratorium wyznaczono stratę wynikającą z ograniczonego przepływu.

Słowa kluczowe: mała elektrownia wodna, kraty, rumosz roślinny, straty hydrauliczne

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