ador WELDING
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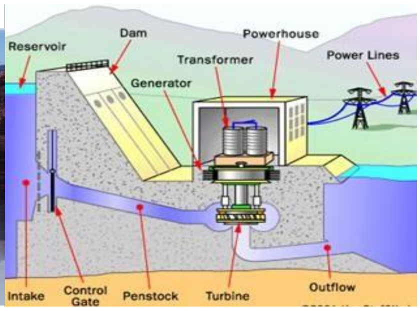
Welding Consumables for Hydroelectric Power Plant Applications

Penstocks and Turbines are critical components of a hydroelectric power plant. The Penstock is constructed with typical high tensile strength steels that arrest propagation of brittle cracks and is welded with the right consumables to ensure that they do not initiate a brittle fracture. Three types of turbines are commonly used in hydroelectric power plants viz:

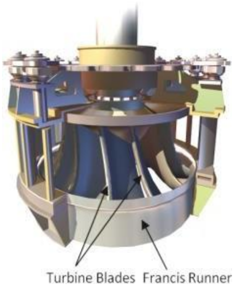
a) Pelton b) Francis & c) Kaplan. The Francis turbine is the most commonly used due to its high operating efficiency of approx. 90 %.



Types of Turbines

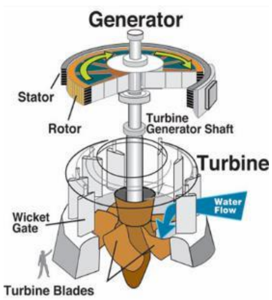
PELTON TURBINE

- The Pelton wheel is an impulse-type water turbine.
- The Pelton wheel extracts energy from the impulse of moving water, as opposed to water's dead weight like the traditional overshot water wheel.
- Pelton's paddle geometry was designed so that when the rim ran at half the speed of the water jet, the water left the wheel with very little speed; thus his design extracted almost all of the water's impulse energy—which allowed for a very efficient turbine.



Francis Turbine

- It is an inward-flow reaction turbine that combines radial and axial flow concepts.
- They operate in a water head from 40 to 600 m (130 to 2,000 ft) and are primarily used for electrical power production.
- Francis turbines are almost always mounted with the shaft vertical to isolate water from the generator. This also facilitates installation and maintenance.



Kaplan Turbine

- The Kaplan turbine is a propeller-type water turbine which has adjustable blades.
- The Kaplan turbine was an evolution of the Francis turbine.
- Its invention allowed efficient power production in low-head applications which was not possible with Francis turbines.

Wear Mechanism involved in Hydro Equipment

Underwater turbine components; mainly runners, blades, guide vanes, spiral case, head cover, bottom ring etc. come directly under the attack of water jet and wear occurs by corrosion, erosion and cavitation.

Erosion wear is a kind of metal cutting process due to highly particle loaded water. The most important factors influencing erosion are the content, the mass, the hardness, the relative velocity and the angle of attack of the particles. Cavitation on the other hand is a form of surface fatigue. Cavitation is generally associated with high head and varying load and tail water values. Both wear types, erosion and cavitation, may occur at the same time and reinforce each other.

The normal life of a hydroelectric power station is 30-35 years after which renovation becomes necessary. But plants located in the Himalayan region, the European Alps, the Andes or the Yellow River in China suffer heavy silt erosion, especially during monsoon season. Highly abrasive silt laden water containing a high percentage of quartz passes through machines and damages components extensively causing frequent forced outages of the plant

Material used for Turbine

Selection of the proper material for underwater turbine parts is important for ensuring their long service life and to avoid frequent shut-downs. The materials, apart from meeting other requirements, should be erosion-resistant and possess a good degree of weld ability to enable repair welding on site.

Recently martensitic 410NiMo steel has been used; this steel offers good mechanical characteristics, especially good impact value, along with satisfactory machinability, weld ability and considerable resistance against erosion and cavitation.

When subjected to cavitation stresses a martensitic structure allows good deformation energy absorption due to fine deformation (twinning) mechanisms. During the impact and low cycle fatigue stresses detachment of particle occurs at the intersection of the deformation twins. Since the twins are relatively small, only small metal particles detach and as a result, the cavitation damage is relatively slow.

Materials used for various parts of Turbines:

Turbine Parts	**Type of Steel**
Runner	410NiMo stainless steel
Labyrinth Seals	410NiMo or 304L stainless steel
Guide Vane	410NiMo stainless steel
Guide vane sealing rings	Martensitic forged 16 Cr-5Ni-0.5Mo stainless steel
Guide vane bush housing	Cast steel
Liners for top cover and pivot ring	304L stainless steel
Fasteners in water path	Stainless steel
Tubes for bearing coolers	Cupro-nickel
Cheek plates	Martensitic forged 16Cr-5Ni-0.5Mo stainless steel

Welding Filler Materials

ER 410 NiMo type welding consumables are used for welding of 410 NiMo stainless steels.

Weld metal of this type greatly overmatches the strength of equivalent parent material and is remarkably resistant to softening during post weld heat treated (PWHT).

- The 410NiMo weld metal produces a high strength deposit (>760MPa) with better resistance to corrosion, hydro-cavitation, sulphide-induced SCC, and good subzero toughness when compared with plain 12%Cr (410) steels.
- ER 410NiMo martensitic range includes MMA/SMAW electrodes, MIG/GMAW wires, TIG/GTAW rods, and flux cored wire. They can be used for welding hydraulic turbines, valve bodies, pump, and high pressure pipes, where high hardness levels are not acceptable.
- Welding consumable shall provide improved toughness and improved cold cracking resistance

ER 410 NiMo welding consumables for welding of 410 NiMo martensitic stainless steel:

Process	AWS Code of consumable	Ador Brand	C	Mn	Si	Cr	Ni	Mo
MMA	E410NiMo	Betachrome 13/4 LB R	0.03	0.8	0.25	12.0	4.5	0.5
TIG/MIG	(ER410NiMo)*	Miginox 410NiMo / Tiginox 410NiMo	0.02	0.8	0.4	12.3	4.5	0.5
FCW	E410NiMoTX-X	Miginox FC 410NiMo	0.06	1.0	1.0	11 – 12.5	4.0 – 5.0	0.5

*Doesn't always meet specification as AWS requires 0.6%Mn maximum and 0.50%Si maximum.

Mechanical properties with TIG (GTAW)/ MIG (GMAW)

Typical mechanical properties from all-weld metal of TIG ER410NiMo, after PWHT at 610 °C/1hr.

Properties	Test temperature Degree Celsius (Degree Fahrenheit)	Unit	Typical Value
Tensile strength	+20 (+68)	Mpa (ksi)	890 (129)
0.2% proof stress	+20 (+68)	Mpa (ksi)	850 (123)
Elongation on 4d	+20 (+68)	%	23
Elongation on 5d	+20 (+68)	%	20
Impact energy	0 (+32)	J (ft-lbs)	90 (66)
	-50 (-58)	J (ft-lbs)	60 (44)
Hardness cap/mid	+20 (+68)	HRC	25-33
	+20 (+68)	HV	300/305

Mechanical properties with MMA (SMAW)

Typical mechanical properties from all-weld metal of MMA Electrode, after PWHT at 550 °C/2hr.

Properties	Test temperature Degree Celsius (Degree Fahrenheit)	Unit	Minimum Value	PWHT (1)	As-welded (2)
Tensile strength	+20 (+68)	Mpa (ksi)	760 (110)	940 (136)	1000 (145)
0.2% proof stress	+20 (+68)	Mpa (ksi)	500 (73)	695 (101)	780 (113)
Elongation on 4d	+20 (+68)	%	15	17	4.5
Elongation on 5d	+20 (+68)	%	15	16	3
Reduction of area	+20 (+68)	%	--	45	10
	+20 (+68)	J (ft-lbs)	--	45 (33)	27 (20)
Impact energy	-40 (-40)	J (ft-lbs)	--	35 (26)	13 (10)
	-60 (-76)	J (ft-lbs)	--	30 (22)	8 (6)
Hardness	+20 (+68)	HV (10)	--	270-300	350

(1) AWS & BS PWHT: 595-620̊ C for 1 hour , air cooled.

(2) This weld metal is not usually recommended for use in the as-welded condition ,except for surfacing applications where a hardness of 330-400HV is useful.

Mechanical properties with FCAW

Typical all-weld metal tensile properties of ER 410NiMo FCAW.

PWHT, °C(°F)/hour	UTS, Mpa(ksi)	0.2% Proof strength, Mpa (ksi)	Elongation,%		Reduction of area,%
			A4	A5	
605 (1125)/1	970 (141)	880 (128)	19	16	55
610 (1130)/10	870 (126)	705 (102)	22	18	54
610 (1130)/1	940 (136)	870 (128)	20	18	50
610 (1130)/1	940 (137)	870 (125)	20	18	50

Welding Process Recommendations

- TIG:

  The particular features associated with TIG are_

  - Suitable for all positions
  - Precise control in root weld deposits
  - Argon gas for both shielding and back-purging is recommended.

- MIG (GMAW):

  The particular features associated with MIG are_

  - 1.2mm diameter wire and, typically, 210-230A, 27-30V spray transfer arc conditions, high purity Argon + 1-2% O_2 or 1-5% CO_2.
  - Proprietary gas mixtures with <5% CO_2 are also suitable
  - Operation on DC+ is required; for all-positional welding pulsed current is required.

- MMA (SMAW):

  For joint filling in material above ~15mm, the MMA process can be use. The particular features are_

  - Rutile metal powder type moisture resistant coating made on pure low carbon core wire giving very low weld metal hydrogen levels.
  - Recovery is about 130% with respect to core wire, 65% with respect to whole electrode.
  - Operation on DC+ or AC is required with OCV 70V minimum.
  - 2.5 diameter electrodes can be used in all positions including ASME 5G/6G positions
  - The 3.2mm, 4.0mm and 5.0mm are suitable for down hand position.

- FCAW:

  For high deposition rate and productivity FCAW can be used. The particular features are_

  - All-positional Rutile flux cored wire made on a high purity stainless steel strip.
  - Metal recovery about 90% with respect to wire.
  - Shielding gas; Ar-20%CO_2 or 100% CO_2 at 20-25l/min.
  - Operation on DC+ at 180A/29V for 1.2mm and 260A/30V for 1.6mm diameter. For
  - 100% CO_2 an increase of 2-3 V is required.