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REPAIRING CAST PELTON RUNNERS: PROBLEMS AND MODERN SOLUTIONS

M. Mione and G. Mazza, Fravit s.r.l.

The periodic repair of Pelton runners manufactured by casting presents various problems, which it is worth investigating, in view of the large number of runners of this type still operating. These problems are linked to the characteristics of castings, as will be discussed here.

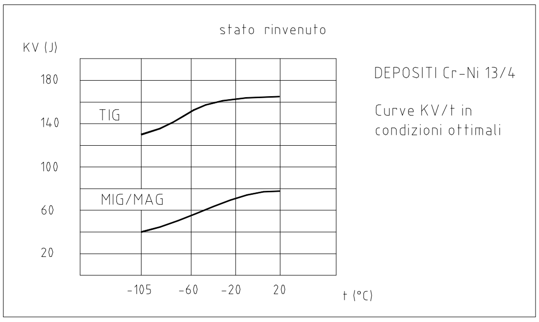
The traditional casting of the Pelton runner involves producing a sand mould, in which the bucket is positioned the required number ot times around the circumference of the central hub.
The positioning of the buckets, which is done by hand, is typically not accurate, particularly as regards the angular and radial bucket position.
The complex geometry of buckets, and the considerable variation in thickness, make it difficult to obtain uniform cooling rates in the different parts of the runner during casting; therefore the material structure can incorporate a large number of defects (such as sand and gas inclusions and cracks), from the beginning.
Because of the complex shape of the buckets, particularly the curved surfaces, the evaluation of defects within the material by non-destructive tests such as radiography or ultrasonic methods is very difficult [ASTM A609, 1990].
Therefore during the finishing of runners it is normal that only a small proportion of defects that result in surface discontinuities can be repaired (that is, the surface defects, which can be detected by liquid penetrant or magnetic particle inspection).
Summarizing, cast Pelton runners have:

- imprecise angular position, which can often be out of tolerance
- the wrong bucket slope in the radial direction, so that the tangent circle of the bucket plane is not exactly the same for all buckets (influencing the discharge efficiency of buckets); and
- the presence of many defects, which remain hidden in the runner for all of its life and tend to grow under stress.

Problems concerning the repair of cast Pelton runners

To achieve the best results, for the repair of Pelton runners Fravit uses TIG (tungsten inert gas) welding with homogeneous fillet material and numerically controlled (CNC) milling of the repaired buckets.
This approach has a number of advantages:

- Pulsed-TIG welding: by TIG-welding (s. Fig. 1) the lowest heat rate and the best control of the weld quality can be achieved. The mechanical properties are also better than those achieved by other methods (s. Diagr. 1).



Diagr. 1 – Comparison between TIG and MIG/MAG, taken from [2]

Fig. 1 – TIG welding of the buckets

- Numerically controlled milling of the profiles makes it possible to obtain symmetrical buckets in accordance with the drawings (s. Fig. 2).

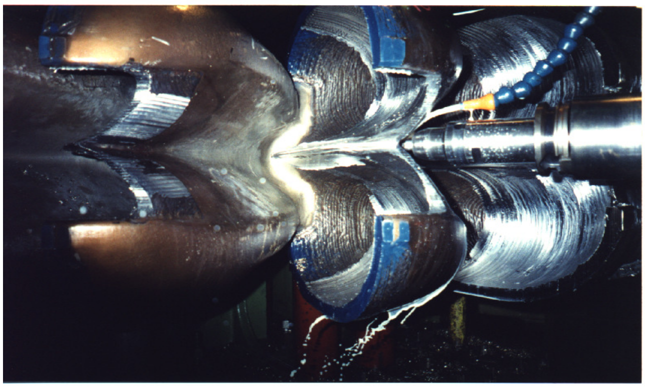


Fig. 2 – CNC milling of the bucket's profile

There are two problems when the runners are cast, as follows:

- *The quality of the material,* because of the presence of many internal defects in the runner which tend to increase under stress during its lifetime. As a result of wear, the hidden defects tend to come to the surface. The welding on a base material with defects cannot have the best possible quality, as some of the inclusions already present in the base material become part of the welded material. Low quality of base material has an influence on the quality of welding.
- *The geometry*, and particularly the fact, that the tangent circle of the bucket's planes is not always the same for all buckets. Thus the erosion will be slightly different for each bucket, as the discharge is not always the same. The CNC machine is able to compensate the wrong angular division of buckets, but there is no way of compensating the bucket's wrong position in the radial direction without affecting the hydraulics of the runner. It is important to point out that checking of profiles with templates is not enough to guarantee the correct hydraulical profiles, as it does not allow evaluation of the wrong position of the bucket in the radial direction.

  A repair process which uses milling machines to produce a small part of the bucket's profile, but uses manual grinding for the rest does not give any guarantee that the bucket's plane is positioned correctly in space.

A process to reproduce the theorical geometries

The process, adopted by Fravit, consists of the following steps:

Preparation of hydralulic profiles

- Initial measurements: verification of bucket's angular position with CNC machining, using the internal bottom of the buckets as reference point, given that the planes are not relieable.
- Pre-machining with a CNC machine of the bucket's profiles and planes (s. Fig. 3), on the basis of the theorical CAD/CAM surface, to make the bucket's division as uniform as possible and the surfaces as regular as possible, to make the subsequent welding easier.
- Pre-welding: the initial measurements are used to decide whether to fill some zones by welding, so as to make the surface more uniform.

Fig. 3 – Preliminary CNC machining – also shown are the "spots" in the milled surface

Runner repair

- Non-destructive inspections of the runner (in accordance with CCH70-3), to eliminate the defects appearing, and TIG welding of the profiles.

  As a result of the pre-machining, the welding is uniform with respect to the exact surface of the bucket, compensating for the possible wrong position of buckets in the radial direction.
- CNC milling of the profiles, by the references traced in the phase of the preliminary machining (s. Fig. 4). The milling program of the hydraulic profiles is written on the basis of templates and drawings, if available, or by an analysis of the most suitable hydraulical profile.

Fig. 4 – CNC milling of bucket's profile

- Heat treatment.
- Polishing of the profiles.
- Final check: non-destructive tests (s. Fig. 5), balancing of the runner and a dimensional check.

Fig. 5 – Non-destructive inspection (PT)

Influence on efficiency

The most important aim of reproducing the original profile during repair is to achieve the originally guaranteed efficiency. Most of the times this is unfortunately difficult for the owner of the runner, because:

- complete drawings of control sections are not available; and
- available templates do not allow for reproducing the whole profile precisely.

Therefore the repair can hardly assure the original guaranteed efficiency.

The authors' opinion on this matter is that a model reproducing the theoretical complete profile (including cutout) should be created, to allow for the whole profile of the runner to be checked whenever necessary.
This was done by Fravit in 1993 for the Swiss company Electricité d'Emosson for the La Bâtiaz plant, in collaboration with some of the company's engineers who were concerned to ensure the very high efficiency (close to 91per cent for 100 MW) of the runner.
A shape-retaining resin model was manufactured by CNC-milling, with the same CAM program that was later used for the milling during the runner repair. The program for the hydraulic profiles was written on the basis of the (few) existing templates and drawings and by acquiring the actual profile from the existing reserve runner.
Using this model, the whole surface of the buckets could be checked; a complete set of the section templates were also produced.
The same procedure was used for the Pelton runners for the Vallorcine plant, owned by the same company.
The turbine runners at both plants were repaired several times by Fravit, allowing the original guaranteed efficiency to be maintained for the units.

Advantages of forged Pelton runners

In the last few years the need to produce Pelton runners by more modern methods has become urgent, with a view to achieving better mechanical characteristics and to reduce drastically the number of defects.
The Pelton runners made out of forged disks have three characteristics which make them different from cast runners [4]:

- the forging process allows for very high quality mechanical properties to be obtained and materials with very few defects;
- the disk can be checked through by ultrasonic inspection (a guarantee of the absence of defects); and
- the bucket's geometry is produced by CNC milling, and therefore the position of buckets is exact.

It is clear that the problems described for cast runners are not applicable to forged runners, with great advantages in terms of: quality, the cost of each repair and the frequency of repairs.

Conclusions

Most of the Pelton runners that are in service in Europe today were produced by casting. Depending on the aggressiveness of water, the frequency of repairs of worn profiles varies. These interventions, repeated over time, have together had a remarkable influence on the management cost of hydro plants; therefore it is important to study the problems associated with repairs, with the aim of minimizing costs.
The manufacture of a shape-retaining model, reproducing the complete theoretical profile, allows the originally guaranteed efficiency to be maintained after repair, so that the most important characteristic of the hydraulic profile, that is, its efficiency, can be reproduced at the time of each repair.
On the one hand, the problems of the periodic repair of Pelton runners are caused by the low quality of material, because of the presence of many internal defects; on the other hand they result from the inexact geometry, and particularly to the fact that the tangent circle of the bucket's plane is not always the same.
The approach we have described allowed us to remedy the geometrical problem, by making the buckets more uniform using preliminary CNC machining. Unfortunately there is no solution to the presence of defects in the runner, except a radical solution such as limiting the manufacture of Pelton runners to forged ones. Altogether, taking into account the long-term costs associated with the periodic repairs, this is the most economical solution. Moreover, it has a significant advantage in terms of plant security, by eliminating the risk of cracks appearing in the buckets.

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Mario Mione has been responsible for several developments in the field of high efficiency machining and welding and brought this experience to the hydropower sector as Chief Director of Fravit, which is a company specializing in the manufacture of forged Pelton runners.

Gianluca Mazza graduated as a doctor of engineering from the Politecnico di Milano, Italy, in 1995. After participating to the refurbishment of some Swiss powerplants, he joined Fravit in Italy, where he has been a project manager since 1997.

Fravit s.r.l. Italy, via Alle Fornaci 27, 23868 Valmadrera, Italy