Reconditioning the Teebus sluice gate

This article, by Leanne Matthysen and Jan Lourens of Thermaspray; Volkmar Kohlmeyer and Jan Adriaan Nel of the Department of Water Affairs; and Hugo Howse of United Surface Technologies, describes the reconditioning of the sluice gate wheel, shaft and assembly at Teebus on the Orange-Fish Tunnel.

***Figure 1**: Shaft assemblies prior to reconditioning at Thermaspray.*

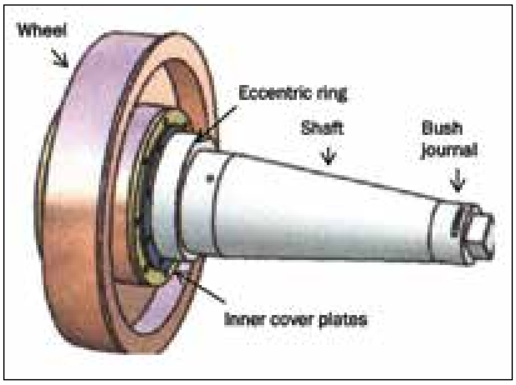

***Figure 2**: The typical sluice gate wheel assembly, which was approximately 1,4 m in length before refurbishment.*

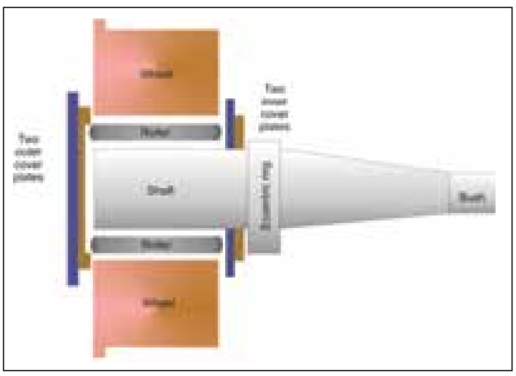

***Figure 3**: A schematic cross-section of the sluice gate wheel assembly prior to refurbishment.*

The Orange-Fish Tunnel was completed in 1975 and is the key structure by which water is delivered from the Gariep Dam to the Teebus Spruit and the Great Brak River and from the valley of the Great Fish River and the Sundays River.

With a length of 82,8 km, the 5,35 m diameter tunnel is the longest continuous enclosed aqueduct in the southern hemisphere and the second-longest water supply tunnel in the world. The main purpose of the tunnel is to divert water to the Eastern Cape for irrigation, urban and industrial use. Over 200 000 m^3 of concrete was used to line the tunnel, which has a maximum capacity of 54 m^3/s.

Recently, the sluice gate wheel, shaft and assembly at Teebus (***Figure 1***) were removed for reconditioning and repair work due to severe deterioration of the components. This is the first work performed on the sluice gate wheel assembly since its installation some 37 years ago.

The ingress of water and other contaminants were not prevented by the old design and this lead to significant damage to the various parts exposed to the immediate water environment. The basic construction and set up of the assembly is as follow:

- Each sluice gate/emergency sluice gate is positioned by manoeuvring the wheel assemblies on eccentric bushes.
- The shaft is positioned into the wheel, separated by 20 rollers of 60 mm in diameter.
- The inner and outer cover plates keep the wheel, shaft and roller assembly intact.
- The bush journal is connected to the gate and locked into position by means of key plates.
- The eccentric ring on the shaft is used to push the gate assembly closed once the gate is in place at the bottom of the tunnel.
- The wheel/sluice gate assembly is lowered into position into the 85 m deep tunnel by means of a guide rail and extension rod system.
- The OD of the wheels runs on the rolling surface when the gate opens and is subjected to full load when the gate is closed against flow.

The sluice gate assemblies are moved very infrequently, ie, on average only once every five years. During this prolonged stationary period, significant damage to the wheel assembly results due to: crevice and electrolytic corrosion between cover plates and wheels, shafts and rollers; general corrosion due to the stationary position; the failure of lubricants after extended periods of immersion; mechanical and adhesive wear damage due to inadequate lubrication when the wheels were forced into motion; and wear damage between the roller ends and the cover plates.

The refurbishment of the shaft

Each component of the assembly was removed and the extent of the damage assessed. The main focus of the reconditioning of the sluice gate assembly was to repair worn components and, where relevant, upgrade the surface of the components through the use of best practice materials and processes, such as thermal spraying, plasma transferred arc (PTA) welding, and other welding processes. All components needed to be brought back to their original dimensions and surface finish through applicable machining and grinding practices.

The first challenge was the reconditioning and upgrade of the components exhibiting surface damage. These had to be either resurfaced or remanufactured from new materials. The interesting challenge was applying newer coating technologies to old castings of unknown integrity.

Secondary challenges were the prevention of water ingress into the shaft's wheel assembly and the prevention of damage to the cover plates by the roller ends.

A schematic of the sluice gate shaft wheel assembly is shown in ***Figure 4***. The damage on the shafts was observed to be due mainly to a combination of fatigue, corrosion and wear between the shaft and the rollers, as well as corrosion between the bush journal and the gate. The wear damage resulted from inadequate corrosion protection of the components by the hard chrome coatings on the outer diameter of the shafts (A) and the eccentric rings (C).

Severe damage, cracking of the hard chrome coating and corrosion deposits were observed on the shaft bush journals (B). The wear damage on surfaces (A) and (C) resulted from inadequate lubrication or the lack of wear resistant properties of the base materials. This situation was significantly worsened by the ingress of solids during the protracted period of no movement. The cracking of the hard chrome coating on Region B is as expected due to the porosity of the hard chrome coatings, which are inherently full of cracks. Cracks in hard chrome coatings lead to the ingress of water onto the base material and this results in base material corrosion driven by electrolytic potential.

Metal shavings were taken from the shaft in order to determine the chemical composition. The results from the analysis indicated that the material of manufacture of the shaft is comparable to EN8.

The initial reconditioning solution was to pre-machine the outer diameters (A) and eccentric rings (C) and then build up the shaft with Stellite 6® using the plasma transferred arc (PTA) process. A thermal spray coating could not have been applied in this region of the shaft as the loads experienced by the bearing are too high.

A Stellite® 6 PTA trial. however, revealed that this method of reconditioning the surfaces was not going to be successful, due to significant variation of the 40 year-old as-cast base material. This limitation led to the manufacturing of a sleeve from ST52 seamless hollow bar. The outer diameter of the sleeve was PTA welded with Stellite 6® prior to fitting the sleeve onto the shaft at Region A. The PTA surface thus became the contact area for the rollers, improving anti-galling and wear resistant properties.

This solution required that the outer diameter of the shaft be reduced by approximately 20 mm per side prior to fitting the sleeve.

The hard chrome coating on Region B (the shaft bush journal) was machined off and a thermal spray coating alternative, namely chrome carbide/nickel chrome was recommended using the HVOF (High Velocity Oxygen Fuel) process. This coating was selected due to its enhanced corrosion and wear resistance and HVOF thermal spray coating was the most appropriate process choice.

Reconditioning the wheel

A schematic diagram of the wheel from the sluice gate assembly is shown in ***Figure 5***. Severe corrosion damage was observed on the outer diameters (G) of the wheels, while wear and galling damage was observed on the inner diameter (H). The galling damage was as a result of the bearing roller surfaces contacting the surface of the inner diameter of the wheel due to a lack of lubrication and the accumulation of corrosion products in the bearing.

Metal shavings were taken from the outer diameter and inner diameter of the wheels and analysed via wet chemical analysis. The results indicated that the base material was comparable to EN9.

After pre-machining of the inner diameter (H), liquid penetrant testing (LT) was performed to determine if

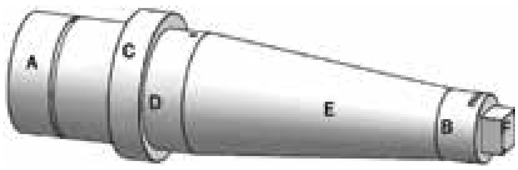

Figure 4*: The sluice gate shaft showing the areas that were reconditioned.*

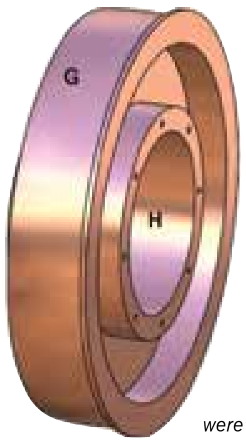

Figure 5*: Sluice gate wheel showing the areas that were reconditioned.*

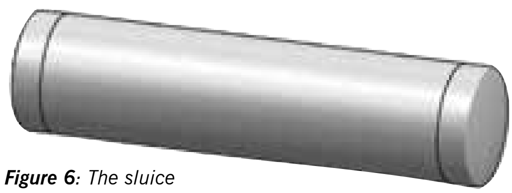

Figure 6*: The sluice gate wheel assembly bearing rollers.*

there were any cracks on the machined surface. A Stellite® 6 PTA welding trial was performed on the inner diameter of the wheel. This was, again, not successful due to significant variations in casting material integrity resulting in inadequate fusion between the Stellite® and the base material.

The same approach as with the shaft was therefore adopted and a sleeve was manufactured from ST52 seamless hollow bar. Instead of PTA welding Stellite 6 onto the inner diameter, however, it was decided to submerge arc weld a butter layer of 430 stainless steel followed by a final layer of 410 stainless steel with the same welding process. The buttering technique is commonly used to provide a suitable transition layer when dissimilar metals are not compatible to each other. The higher chrome (16 to 18% Cr) 430 material is welded onto the base metal followed by the lower chrome (11,5 to 13,5%) 410 material. This prevents excessive dilution of the 410 material and gives full corrosion resistance.

The outer diameter of the wheel was welded with a 430 butter layer followed by a final layer of 410 stainless steel.

After welding the internal diameter (ID) of the sleeve, the outer diameter of the sleeve was machined to the wheel's internal diameter.

After rough machining of the inner and outer diameters, liquid penetrant testing (LT) was performed to assess weld quality before completing the machining. The sleeve was then shrink-fitted into the inner diameter of the wheel and machined to final size.

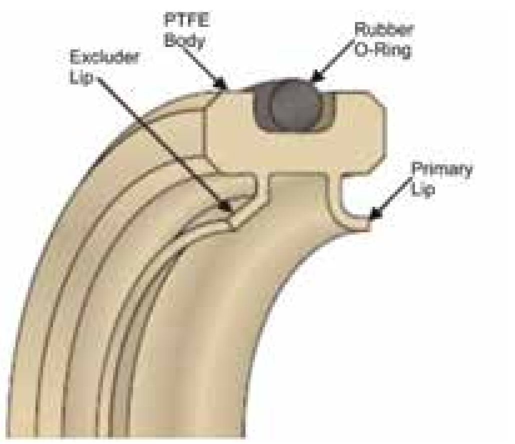

Figure 7*: The custom-designed seal manufactured for the sluice gate wheel assembly.*

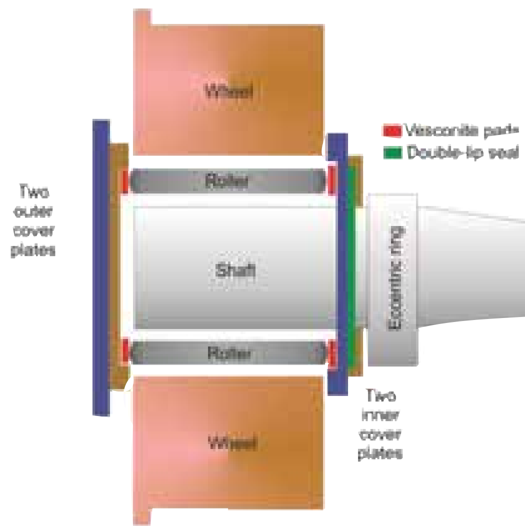

Figure 8*: The final assembly.*

Bearing rollers

The rollers in the sluice gate wheel assembly are placed between the shafts (A) and the wheel ID's (H) to facilitate movement after prolonged stationary periods. There are 20 rollers per wheel/shaft assembly.

Severe corrosion damage – due to the ingress of water – and wear – due to roller surfaces contacting the surface of the inner diameter of the wheel – was observed on the rollers. The damage was so severe that salvaging the surface of the rollers was not justified and the rollers were replaced.

For the refurbishment of the gate assemblies, different bearing configurations were investigated. Three bearing configurations were considered: Configuration 1: Keep the existing arrangement with 20 rollers of 60 mm diameter per wheel; Configuration 2: Reduce the diameter of the rollers to 30 mm and have 37 rollers per wheel assembly; and Configuration 3: Remove the rollers and insert a brass bush or a plain bearing assembly.

Configuration 1 and 2 were the most optimal when the weight per wheel of each option was calculated and it was decided to keep the existing configuration for the refurbishment process. The bearing rollers (***Figure 6***) were manufactured from 431 stainless steel, rough machined from billets, then heat treated to the required hardness, before being machined to final tolerance and finish.

Cover plates

Corrosion was observed on the plates of the sluice gate wheel assembly and after assessing the extent of the damage, it was decided that these parts could be salvaged. Subsequent removal of the corroded layers followed.

There are four plates per sluice gate wheel assembly, two inner cover plates and two outer cover plates. The original corrosion protection layer was removed by abrasive grit blasting. The plates were inspected and, where required, machined to original specifications. An epoxy coating was applied to the prepared plates for further corrosion protection. The inner cover plate closest to the eccentric ring on the shaft bush journal side of the wheel assembly was profiled in order to fit the double-lip seal.

The following additional design changes were also performed.

Two Vesconite thrust pads per sluice gate wheel assembly were inserted between the cover plates and the rollers. Vesconite was selected due to its good wear protection properties when under water for prolonged periods of time and its resistance to swelling.

Double lip (high pressure) seals – one double lip seal (***Figure 7***) per sluice gate wheel assembly – were inserted between the two inner cover plates to prevent the ingress of water to the roller bearing and wheel internal diameter surfaces.

The addition of the double lip seal was one of many unique development aspects to the refurbishment of the sluice gate wheel assembly. The seals were custom manufactured from Carbon PTFE and rubber material.

Specialised grease (Kluber Staburags MBU 30 – specifically developed as sealing grease for components subjected to water and aggressive media – was applied to the roller bearing and the wheel's ID surfaces. This grease has a high resistance to mechano-dynamical loads and good wear protection. It also offers good corrosion and water resistance.

Conclusion

The team, consisting of engineers from the Department of Water Affairs and from Thermaspray, successfully reconditioned the sluice gate wheel assembly of the Teebus shaft by adopting a combination of technologically advanced welding and metal spraying processes.