

SUGAR-MILL COUPLING DEVELOPMENTS SINCE 1987

By

C.T. TOSIO

Eurogear (Pty) Ltd, Johannesburg, South Africa

eurogear@global.co.za

KEYWORDS: Coupling, Mill, Rope.

Abstract

SINCE the installation of the first Eurogear patented ‘rope’ coupling at the Umfolozi (South Africa) factory in 1987, the design has undergone numerous developments with respect to the materials of construction and the method of fixing to shafts. The material of construction of the main coupling components has been changed from cast steel grade A3 to fabricated steel grade 300WA and cast steel grade A4 to reduce its cost. Because of fatigue problems caused by excessive misalignment, steel wire ropes have been replaced by two new types of flexible members: polyester slings and the link plates with spherical plain bearings. The coupling hub to be connected to the shaft square has been significantly redesigned to simplify installation and to ensure a more even distribution of stress, even on damaged shafts. Shear pins have been introduced to provide a mechanical torque limitation system to protect the coupling, shaft and gearbox components. With all the developments over the last 24 years, the rope coupling is now a mature product and can provide enormous benefits to consumers.

Introduction

Since the installation of the first Eurogear patented ‘rope’ coupling at the Umfolozi (South Africa) factory in 1987 (Tosio, 1992), the design has undergone numerous developments with respect to the materials of construction and the method of fixing to shafts.

The paper discusses these developments and the reasons behind them, and also outlines new design options.

Background

Under misaligned conditions (which is nearly all the time), traditional ‘tail-bar’ couplings have the following detractions:

- They generate thrust between the mill and final-drive gearbox, resulting in wear to mill components, and gearbox bearing failures.
- In the event of a transverse mill shaft break, the gearbox can be severely damaged by the resulting thrust generated.
- They apply bending moments to the gear shaft that misalign the gear teeth because of bearing clearances, resulting in premature deterioration and failure.
- They are inefficient, and the power loss can affect mill performance if the available power is marginal.
- They require regular lubrication during operations, significant repair costs to shaft squares in the off-crop, and sometimes even cause shaft breakages.

Rope couplings

The ‘rope’ coupling, as it became known, was designed in 1986 to eliminate all of the undesirable effects of tail-bar couplings.

The SWR (Steel-Wire-Rope) coupling is shown in Figure 1.

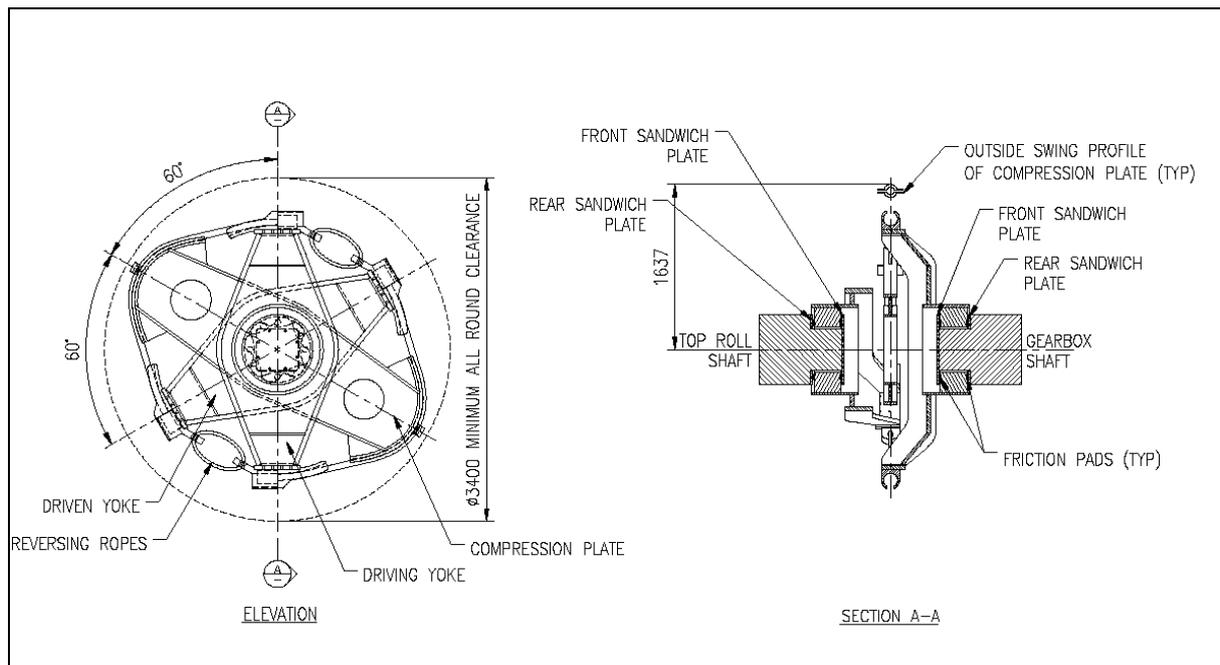


Fig. 1—The SWR coupling.

The ropes connect the driving and driven yokes in a plane normal to the shaft axes via a floating strut that bends the ropes into two parallel pairs of flexible members roughly at right angles to one another.

Considered in static mode, the pair of near-horizontal ropes can absorb vertical misalignment, while the near-vertical pair of ropes can absorb horizontal misalignment. In addition, any axial movement can be absorbed by all the ropes flexing sideways.

The coupling can absorb any misalignment that may be required in driving a sugar mill, without causing any ill-effects to the mill or gearing.

Coupling developments

Introductory remarks

Over the years, numerous changes have been made to the design, all in the interests of improving the product.

Materials of construction

The yokes of the first 1987 coupling were made of cast steel, grade A3. This material proved to be very good, but expensive, and so other materials of construction were investigated.

Local foundries strongly advocated the use of SG iron, also known as ductile iron. The grade selected, for strength reasons, was SG60. This material worked well for about seven years, but costly failures occurred.

The first failure was caused by a severely out-of-square shaft that caused contact on only two points in the bore that resulted in extreme stresses in the material. The second failure was a casting failure caused by casting the yoke with the hub up. This process led to very slow cooling of the hub section that resulted in carbide separation and very brittle properties.

The material failures led to a re-think and, since then, all couplings have either been fabricated in mild steel grade 300WA of 280 MPa minimum yield strength, or cast steel grade A4, with minimum yield strength of 320 MPa.

Flexible elements

The flexible elements that provide the misalignment capability of the coupling have seen a much more radical change. The steel wire ropes proved perfectly suitable for driving mills that are

well aligned to the final drive gearing and well operated (as they should be). In these circumstances, the normal maximum misalignment is less than 20 mm.

In 1997, one installation in South Africa and numerous installations in Brazil suffered premature rope failure. Although lift-indicators showed that misalignment was minimal, this assessment was incorrect. Subsequent irrefutable tests proved that the actual misalignment was, in all of these cases, in excess of 35 mm. As a result, the steel wire ropes had to flex back and forth more than 70 mm every revolution. This movement proved far too much for the steel-wire ropes, especially in Brazil where milling speeds are typically 7 r/min, and alternative designs had to be sought to cope with this type of problem.

Two other flexible members have subsequently replaced the steel wire ropes, namely polyester slings (Figure 2) and link plates fitted with maintenance-free spherical plain bearings (Figure 3).



Fig. 2—Rope coupling with polyester slings.



Fig. 3—Rope coupling with link plates fitted with spherical plain bearings.

The polyester slings (Figure 4) are proving very reliable, although attention has to be paid to the following to ensure they work as designed:

- It is essential that the slings are all the same length so they share the load equally.
- The slings have to be manufactured very uniformly in cross-section so that all the strands share the load equally.
- Frequent destructive tests should be carried out on slings to be sure design service factors are maintained, and that fabricators are not cutting corners.



Fig. 4—Polyester sling undergoing destructive test.

Spherical plain bearings have not achieved the life predicted by the suppliers, but there are numerous reasons for this, the main causes being abuse during operations and poor storage practices during the off-crop.

Fixing hubs to shafts

The biggest challenge in the first 10 years of making couplings was to design a good system of fitting yoke-hubs onto shaft-squares that were never, in fact, square. From very early days, all engineers have been advised (in our data sheet that they complete) to restore shafts to original dimensions, and make sure they are square. A typical, non-square, shaft square is shown in Figure 5.



Fig. 5—An un-repaired shaft square.

The first (1987) coupling was fitted to the shaft square with keys. This design required excessive fitting time because of poor machining, so a better system was needed.

Subsequently, cast SG iron couplings were profile cast and machined to slide onto the squares and were fixed in position using reversing screws. This method worked reasonably well until a seriously out-of-square shaft caused failure due to uneven loading and high stress-generation. The practice was subsequently discontinued.

Hubs were then fitted onto shafts using heavy-duty shrink-discs (Figure 6). This method works very well if squares are accurately machined and square, so is good for new installations such as at the Komati factory in South Africa in 1994. This method also requires excessive fitting time and was not deemed suitable for retro-fit installations. Lighter shrink-discs (quicker to fit) were tried but also required close shaft-tolerances. Old shaft-squares are never properly repaired or restored to original dimensions, so this system was also discontinued.

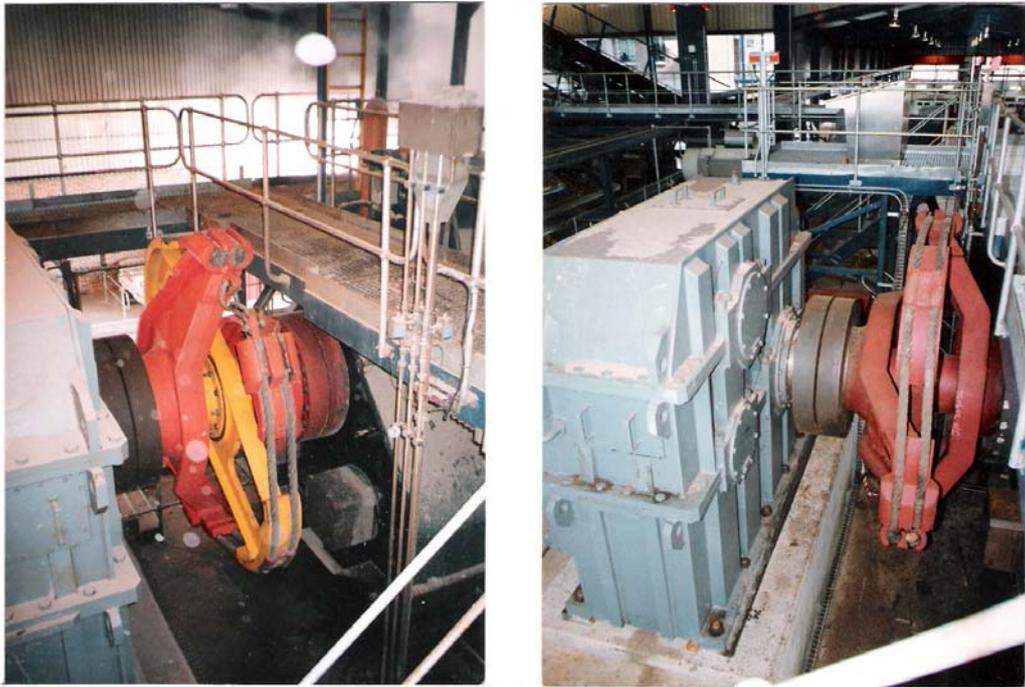


Fig. 6—Shrink-discs used to fit couplings to shafts.

The final solution to fitting problems was introduced in 1996 when a new profile bore design was introduced (Figure 7), and it has been so successful there is no intention to change it.



Fig. 7—Hub fitting on shaft.

This strange-looking slide-on design has a cast or profile-cut bore with very large corner radii, which minimises stresses. In taking load, the bore makes contact close to, but not quite on, all four corners of the square. Note each bore-profile has to be specially designed to fit in the optimum position. Initially the arc-to-flat contact is only line contact, but this line crushes immediately load is applied until the flattened area is so large that the stress falls below the yield point of the hub material, which is always softer than the shaft.

This design caters to small shaft-square dimensional inaccuracies, and always ensures four-corner load-sharing. It also optimises the hub thickness and therefore minimises the cost of manufacture. It can distort slightly should this be necessary, thereby ensuring that all corners are equally loaded. The hubs are retained on the outside ends of the squares by sets of ‘Sandwich’ plates (Figure 8).

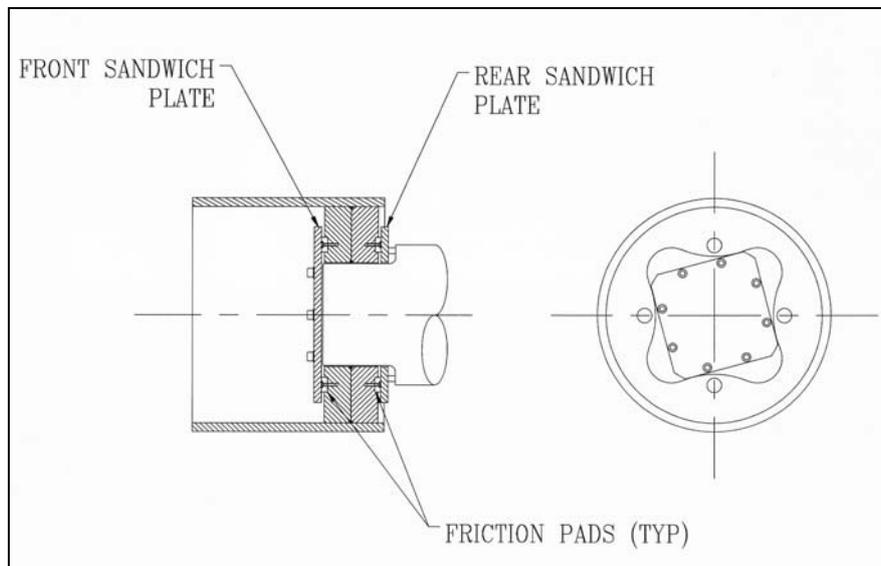


Fig. 8—Hub fitting on shaft.

Torque limitation

For the past five years, all designs have had a torque limitation option in the form of shear pins to protect the mill and (more importantly) gearbox from damage should a pinion break or a large object enter the mill and cause a stall. For design purposes, a break torque of 150% of estimated normal driving torque has been used.

The shear-pins, shown in Figure 9, are always fitted to a pair of flanges integral with the gear-side hub or tube-to-yoke connection. The flanges are fitted with hardened bushes to support the shear pins without themselves being damaged.

In the event of the shear pins failing, the coupling stops turning, providing a very visible indication of a problem. The cause of the failure can then be investigated and the shear pins can be replaced. Shear pin replacement takes only a few minutes.

New Designs

The following new designs are available:

1. Eurogear's MKI 'Link' coupling, which is of similar construction to the polyester-sling coupling, but which utilises link-plates containing spherical plain bearings to impart the flexibility required.
2. Eurogear's MK VI 'multi-link' coupling, that utilises spherical plain bearings to give it misalignment properties. This coupling is similar to a universal coupling, but has the added advantage of end collapsibility. It was designed for customers who did not like the large swing of the other designs.



Fig. 9—Yoke-to-Hub connection showing shear pins.

Conclusions

Since its introduction in 1987, the rope coupling has undergone significant further development.

The material of construction of the main coupling components has been changed from cast steel grade A3 to fabricated steel grade 300WA or cast steel grade A4 to reduce its cost.

Because of fatigue problems caused by excessive misalignment, steel wire ropes have been replaced by two new types of flexible members: polyester slings and the link plates with spherical plain bearings.

The coupling hub to be connected to the shaft square has been significantly redesigned to simplify installation and to ensure a more even distribution of stress, even on damaged shafts.

Shear pins have been introduced to provide a mechanical torque limitation system to protect the coupling, shaft and gearbox components.

With all the developments over the last 24 years, the rope coupling is now a mature product and can provide enormous benefits to consumers.

REFERENCES

Tosio, C.T. (1992). Sugar mill drive couplings—an alternate design. Proc. Int. Soc. Sugar Cane Technol., 21: 807–817.

DEVELOPMENTS DES MANCHONS POUR LES MOULINS DEPUIS 1987

Par

C.T. TOSIO

Eurogear (Pty) Ltd, Johannesburg, South Africa

eurogear@global.co.za

MOTS CLEFS: Manchons, Moulin, Corde.

Résumé

DEPUIS l'installation de la première 'corde' brevetée Eurogear comme manchons à l'usine de Umfolozi (Afrique du Sud) en 1987, les matériaux de construction et la méthode de fixation d'arbres ont subi de nombreux développements. Le matériau de construction des composants principaux est maintenant l'acier 300WA et l'acier grade A4, au lieu de la fonte A3, pour réduire les frais. En raison de problèmes de fatigue, causés par un mauvais alignement, les câbles d'acier ont été remplacés par deux nouveaux types de membres flexibles: écharpes polyesters et les plaques de lien par des rotules. On a simplifié l'installation du manchon pour assurer une répartition plus uniforme du stress, même sur les arbres endommagés. Des mesures ont été introduites pour limiter le couple mécanique afin de protéger le manchon, l'arbre et la boîte de vitesse. Avec tous les développements au cours des 24 dernières années, le manchon à corde est maintenant un produit bien établi et peut fournir des avantages sérieux pour les consommateurs.

DESARROLLOS DE ACOPLER PARA MOLINOS DE CAÑA DESDE 1987

Por

C.T. TOSIO

Eurogear (Pty) Ltd, Johannesburg, South Africa

eurogear@global.co.za

PALABRAS CLAVE: Acople, Molino, Cable.

Resumen

DESDE la instalación del primer acople 'de cable' patentado de Eurogear en el ingenio Umfolozi (Sudáfrica) en 1987, el diseño ha tenido numerosos desarrollos respecto a los materiales de construcción y el método de fijación a los ejes. El material de construcción de los componentes principales del acople ha sido cambiado del acero fundido grado A3 a acero laminado grado 300WA y acero fundido grado A4 para reducir su costo. Debido a problemas de fatiga causados por excesivos desalineamientos, los cables de acero han sido reemplazados por dos nuevos tipos de elementos flexibles: eslingas de poliéster y platinas de conexión con cojinetes planos tipo rótula. El cubo de acople que se conecta al cuadrante del eje ha sido significativamente rediseñado para simplificar la instalación y asegurar una distribución más pareja de esfuerzos aún en ejes deteriorados. Se han introducido pasadores de corte para proveer un sistema mecánico de limitación de torque para proteger el acople, el eje y componentes del reductor. Con todos los desarrollos durante los últimos 24 años, el acople de 'cable' es ahora un producto maduro y puede dar enormes beneficios a los usuarios.