New pump coupling reduces effects of torque, misalignment and unbalance

At last year's International Pump Users Symposium, Baltimore-based Kop-Flex®, a division of Emerson Power Transmission, introduced a new design of elastomeric coupling featuring dual-flex elements. In this article, Matt McGinnity and Jon Mancuso discuss the design's characteristics, and present experimental data comparing its performance to existing elastomeric couplings.

In 2004, Kop-Flex introduced a unique elastomeric coupling. Trade-named 'Odyssey', this patented new development features dual-flex elements in the form of urethane diaphragms bonded to each end of a composite spacer (Figure 1). The dual-flex elastomeric diaphragm element was designed using the latest engineering technology: finite element analysis (FEA) and 3D CAD.

The characteristics required of this new pump coupling were defined based on an industry survey of pump manufacturers and pump users, which yielded 16 desirable qualitative coupling characteristics:

1. Good torque capacity compared to OD
2. No lubrication
3. Ease of field installation
4. Ease of maintenance

Figure 1. The Odyssey dual-flex elastomeric diaphragm coupling.

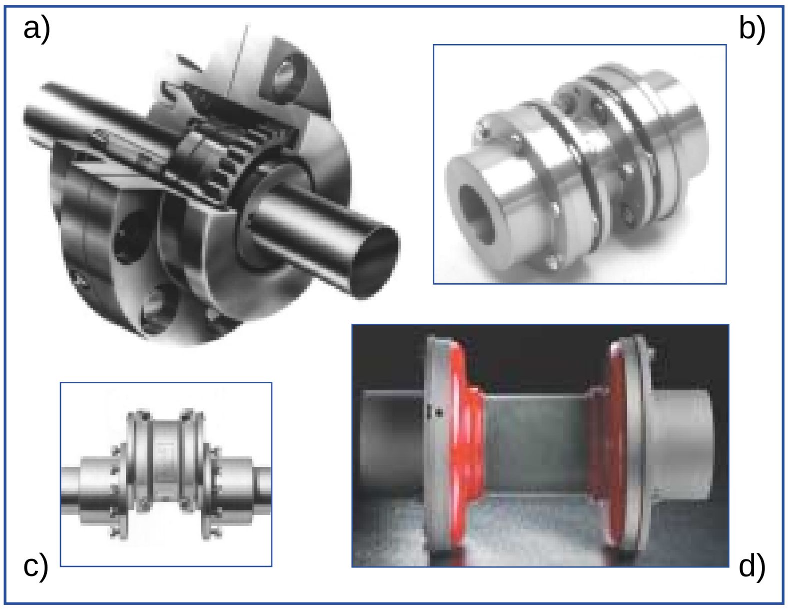

Figure 2. Various types of pump couplings: (a) gear coupling, (b) disc coupling, (c) grid coupling, and (d) dual-flex diaphragm elastomeric coupling.

5. Ease of field replacement
6. High reliability
7. Low weight
8. Good balance quality (meet API 610 AGMA Class 9 requirements)
9. Low reaction forces on bearings
10. At least five years of life without replacement
11. Reserve operating angular misalignment capacity and also parallel offset misalignment capabilities without producing excessive loads on equipment
12. Reasonable axial capacity to accommodate reasonable errors in shaft-to-shaft errors for applications using interference hubs
13. Operate in ambient temperature of at least 65.5°C (150°F)
14. Predictable mode of failure that does not cause excessive damage to equipment
15. Low axial stiffness
16. Some torsional damping.

The dual-flex elastomeric element provides not only high angular misalignment capacity, but also high offset misalignment capacity, with low reaction moments and forces transferred to the connected equipment. The spacer is made from lightweight composite material, which makes the dual-flex concept feasible for an elastomeric type coupling, and, because of its low weight, it reduces the unbalance

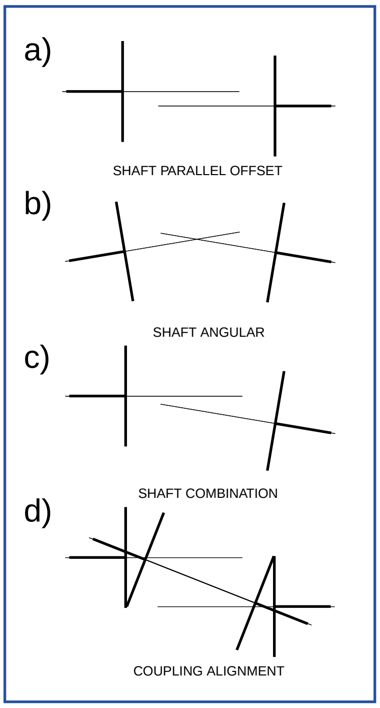

Figure 3. Types of misalignment (see text for full discussion).

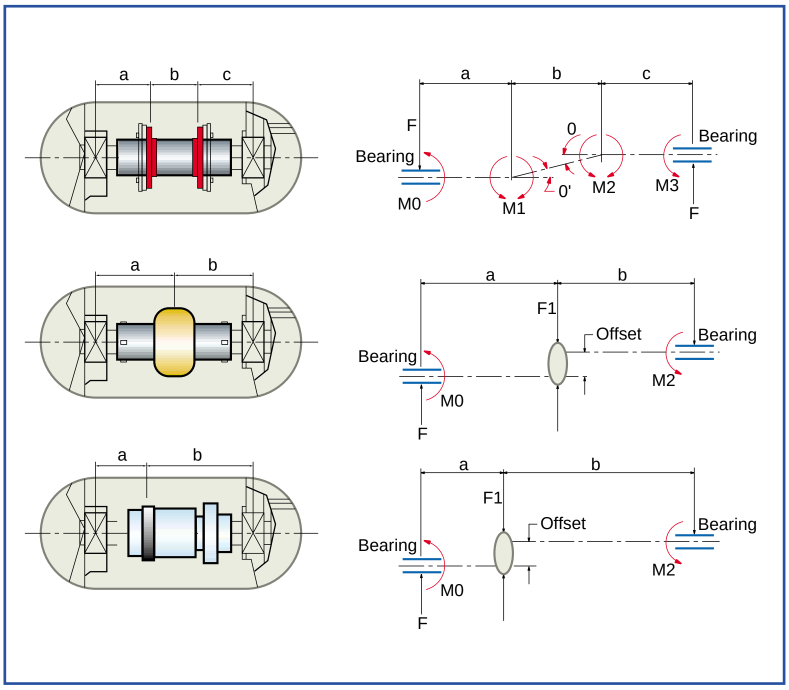

Figure 4. Comparison of reaction loads for Odyssey dual-flex elements (top), tyre-type with the flex element in the centre (middle), and a wrap-jaw type with the flex element on one end (bottom).

effect from eccentricity of the centre section. Reducing the force and moments at the bearings should increase seal and bearing life, and ultimately increase the equipment life cycle and decrease operating costs.

Types of couplings

There are four basic types of couplings used on pumps: gear, disc, grid and elastomeric (Figure 2). Today, the most common coupling used on pump applications is the elastomeric type. These typically transmit torque and accommodate misalignment by deflection and/or sliding of a rubber or urethane flexible element. Looking more closely at the various types of elastomeric couplings used on pump systems shows they can have widely different characteristics. These characteristics can greatly affect how a pump will perform and ultimately the overall operating cost of the equipment – which includes installation cost, maintenance cost, downtime, etc.

Misalignment

There are two types of misalignment – shaft misalignment and coupling misalignment.

Shaft misalignment

Shaft misalignment is the physical relationship between the driving and driven shafts. This can be broken down into two components: parallel offset – the axes of the connected shafts are parallel, but not in the same straight line (Figure 3a); and angular – the axes of the shafts intersect at the centre (Figure 3b). Typically, the actual misalignment is a combination of parallel offset and angular misalignment (Figure 3c).

Coupling misalignment

Coupling misalignment comes into play when you look at how the coupling accommodates for shaft misalignment. There are two general approaches. One is when using a double-flex coupling, such as a gear, disc or diaphragm, which has flex elements that can only accommodate angular misalignment at each flexing plane. This means there must be two flex elements per coupling in order to accept shaft misalignment (Figure 3d). The second is to use a single flexible element that is capable of

Table 1: Forces and moments summary for Odyssey versus the urethane tyre coupling

	Force (lbs)		Moment (lb-in)	
(a)	5-inch spacer@ 0.060 inch	5-inch spacer@ 0.090 inch	5-inch spacer@ 0.060 inch	5-inch spacer@ 0.090 inch
Odyssey	30	42	260	400
Tyre coupling	70	NA	575	NA
(b)	7-inch spacer@ 0.060 inch	7-inch spacer@ 0.130 inch	7-inch spacer@ 0.060 inch	7-inch spacer@ 0.130 inch
Odyssey	30	30	100	275
Tyre coupling	70	NA	650	NA

Table 2: Summary of Balance Force at Various Speeds & Obtained AGMA Class							
Type-Size	Bore Size Inches	[mm]	Unbalance Force @ 1800 rpm Lbs	[Newtons]	Unbalance Force @ 3600 rpm Lbs	[Newtons]	AGMA Class
Unclamped Donut-112	1.12	[28.4]	11	[48.9]	45	[200.2]	9
Urethane Tyre-112	1.12	[28.4]	7	[31.1]	28	[124.5]	9
Odyssey-112	1.12	[28.4]	4	[17.8]	16	[71.3]	9
Wrap-Jaw-138	1.38	[35.1]	26	[115.6]	105	[467.0]	7
Odyssey-138	1.38	[35.1]	6	[26.7]	24	[106.8]	9
Odyssey-162	1.62	[41.1]	8	[35.6]	33	[146.8]	9
Wrap-Jaw-175	1.75	[44.5]	59	[262.2]	235	[1045.3]	7
Unclamped Donut-188	1.88	[47.8]	47	[209.1]	189	[840.7]	8
Urethane Tyre-188	1.88	[47.8]	28	[124.5]	112	[498.2]	8
Odyssey-188	1.88	[47.8]	13	[57.8]	64	[284.7]	10
Odyssey-212	2.12	[53.8]	22	[97.9]	90	[400.3]	9
Odyssey-238	2.38	[60.5]	30	[133.4]	120	[533.8]	9
Urethane Tyre-288	2.88	[73.2]	97	[431.5]	387	[1721.4]	8
Odyssey-288	2.88	[73.2]	43	[191.3]	171	[760.6]	9

Figure 5. Miscellaneous types and sizes of couplings tested, including dual-flex elastomeric diaphragm, urethane tyre, unclamped donut, jaw in shear and wrap-jaw.

accommodating offset misalignment as well as angular misalignment by deflection or deformation in the radial direction.

Difference between equipment alignment and coupling tolerances

When selecting a coupling, it is important not to be confused by the term 'allowable misalignment'. Coupling catalogues specify this as the capacity of the coupling. The misalignment capacities given by the coupling manufacturer are usually based on the life or fatigue limits of the various coupling components. This should not to be confused, however, with the allowable limits set for successful operation of the equipment. In some cases, the coupling capacity can be ten times the limit that the equipment can accept.

Moments and forces

Most elastomeric couplings accommodate both parallel offset and angular shaft misalignment through one elastomeric flex element. But, because the Odyssey coupling is a dual-flex diaphragm-style elastomeric coupling, its elements flex from OD (outside diameter) to ID (internal diameter) rather than compressing the element radially. Figure 4 shows the difference between a dual-flex coupling arrangement and two single-flex style coupling arrangements. The dual-flex allows for greater parallel offset misalignment with lower moments and forces back at the equipment. To verify this, Kop-Flex measured the forces and moments for several different types (Figure 5) of elastomeric couplings. Table 1 shows the comparison of Odyssey to one of the urethane tyre-type couplings tested.

As illustrated by Table 1, the offset capacity of this dual-flex elastomeric coupling increases with the increase in the spacer length, whereas offset capacity of the tyre-type coupling remains constant. The tyre coupling at 5-inch shaft–shaft separation (s-s) is limited to 0.060 inches offset, whereas the Odyssey can handle 0.090 inches. When the separation increases to 7 inches, the tyre coupling has no increase in offset capacity but the Odyssey can now handle 0.130

inches, more than twice the capability of the tyre coupling.

If we consider the radial forces at the bearings due to offset misalignment, based on an offset of 0.060 inches and a 5 inches s-s, the tyre coupling will react with 70 lbs (311 N), whereas the Odyssey will react only with 30 lbs.

As to the bending moment, the tyre coupling will react at 0.060 inches with 575 lb-ins (65 N.m) of moment at 5-inch s-s and with 650 lb-ins at 7-inch s-s (a greater moment as s-s increases), whereas the Odyssey will react with 250 lb-in for the 5-inch s-s and only 100 lb-in for the 7-inch s-s coupling – a lower moment as the s-s increases.

Reduced forces and moments increase bearing and seal life and reduce operating costs.

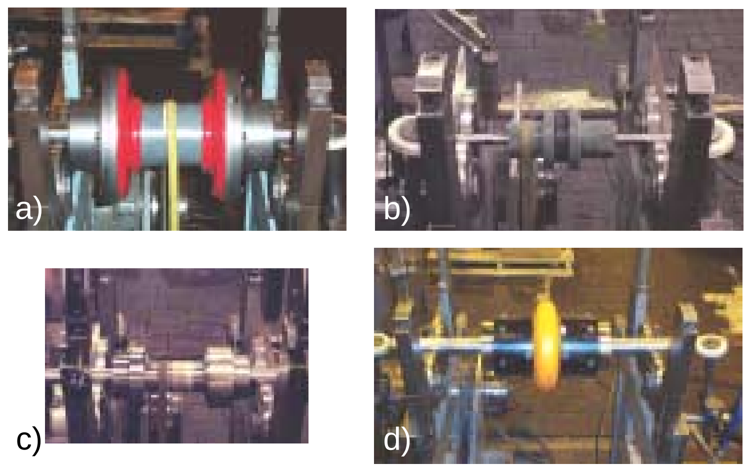

Figure 6. Elastomeric couplings being tested on balancing equipment: (a) Odyssey, (b) unclamped donut type in spacer configuration, (c) urethane tyre type in spacer configuration, (d) wrap-jaw type in spacer configuration.

Table 3: AGMA classes and equivalent micro-inch displacement

AGMA class	Mass eccentricity (equivalent displacement) in micro-inches
6	16 000
7	8000
8	4000
9	2000
10	1000
11	500

Effect of balance on equipment

Most elastomeric couplings fall into the AGMA 7-8 category (8000–4000 micro-inches). When single-flex elastomeric couplings are used in the spacer configuration they tend to be closer to a class 7. This is because the flex element is in the centre, or at one end, and any force is multiplied by the distance from the flex centre to the bearing centre. Figure 6 shows the configurations of four different couplings on balancing equipment.

Kop-Flex measured the amount of residual unbalance for three different types of comparable elastomeric couplings. It checked two or three sizes of each, and two different couplings of each size. The data in the following table are for the highest readings measured in any plane of these coupling samples. The company also checked all seven sizes of the Odyssey current product series. As can be seen in Table 2, all the small-size 112 couplings met AGMA 9 (NB: Size 112, 138, etc. couplings have a 1.12 inch, 1.38 inch, etc. bore). But the larger sizes of the other couplings tested only met AGMA 7 or 8. Six sizes of the Odyssey met AGMA 9 and one size consistently met AGMA 10 or better. Table 3 shows the equivalent displacement in micro-inches for the various AGMA classes.

Table 2 shows the magnitude of the force that will be seen back at the bearing for the various AGMA classes met by the different elastomeric coupling designs. The unbalance force was calculated for 1800 rpm and also 3600 rpm. One can see that the magnitude of the unbalance is proportional to the square of the speeds [the multiplication factor = $(3600/1800)^2$] so at 3600 rpm the unbalance force is four times than at 1800 rpm. Also the data show the difference in unbalance force seen by the Odyssey lightweight composite spacer design compared to the other types of elastomeric couplings. For example, the Odyssey 188 shows lower unbalance forces at both 1800 rpm and 3600 rpm (13 lb and 64 lb, respectively) compared to identically sized urethane tyre and unclamped donut types, as well as the wrap-jaw 175 size.

In summary

As a result of innovative technology, advanced materials and new computerization techniques, the dual-flex design can now be applied to elastomeric couplings – a concept that has been unattainable for the past 75 years. With operating stresses for the elastomeric element lower for a given misalignment and reduced loads due to unbalance, coupling life cycles increase, ensuring high reliability and better-than-ever equipment life. ■

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