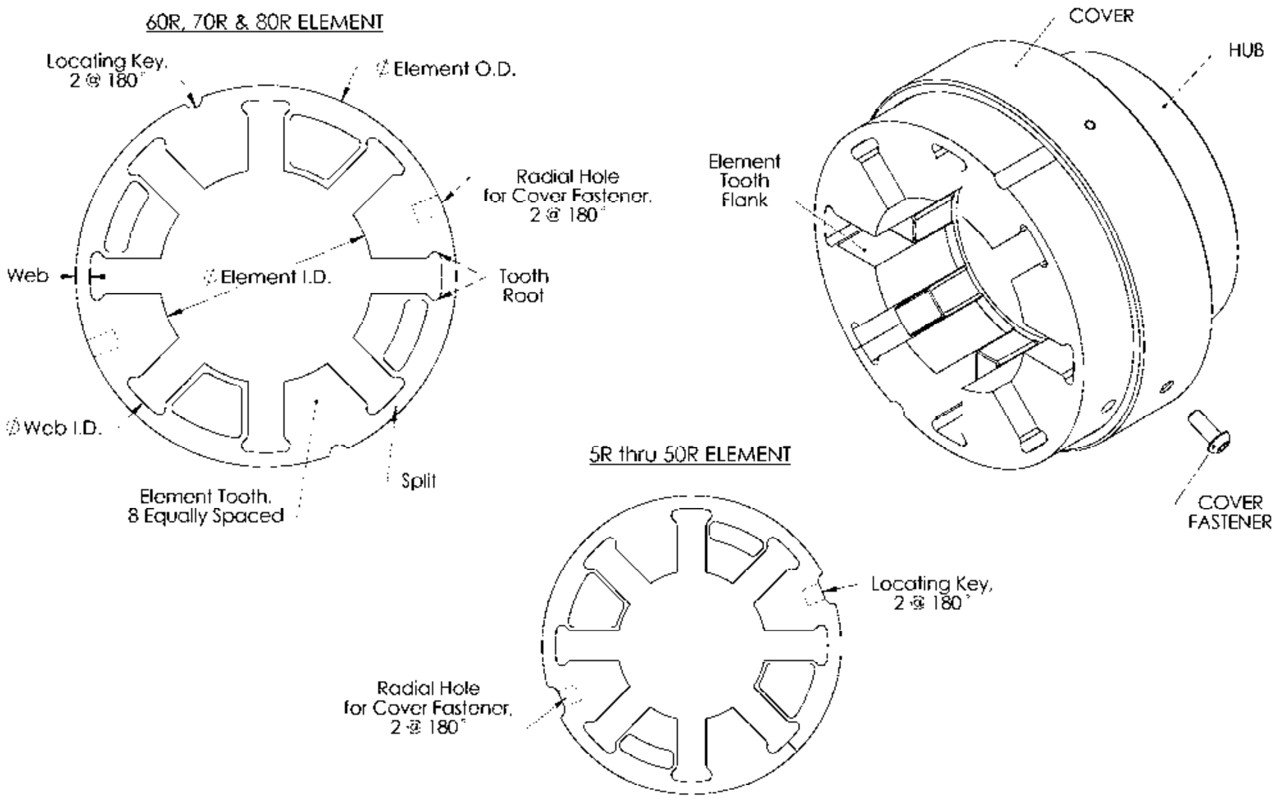


<u>Figure 1</u> – WRAPflex Coupling & Element Features

The Falk WRAPflex coupling transmits torque primarily through “shearing” action of the flexible elastomeric element between the teeth of the driving and driven hubs. To a lesser extent, there is a “compression” component of loading on the element that will increase with higher torque loads (higher angular deflection) or higher angular misalignment. There is also a “radial” and axial component of load on the element because of the “V”-shaped element tooth. The flexible element, as shown in *Figure 1*, is the most highly stressed component of the WRAPflex coupling.

Hub teeth act as cantilevered beams under a bending stress, supporting a distributed load from contact with the flexible element. Because of the number of teeth and their relatively short length, bending loads on the hub teeth are low. Hub keyway stresses are also low, because the hub barrel diameter is relatively large compared to maximum bore.

A radial hoop load acts outward and uniformly on the entire internal diameter of the nylon or steel cover. This hoop stress-type loading on the cover is due to a component of the torque load acting to push the element radially outward. Based on test measurements, radial hoop stress on the cover is low under normal operating conditions. Since hubs and covers are lightly stressed, this analysis focuses solely on element failures.

There are three primary modes of element failure, not including environmental influences. The three modes of element failure are: 1) Torque Overload, 2) Torsional Fatigue, and 3) Wear. All three modes of element failure were reproduced in controlled testing. The predominant mode of failure seen thus far from the field is “wear” due to excessive angular misalignment. “Torque overload” and “torsional fatigue” incidences from the field have been uncommon.

<u>Torque Overload</u>

During ultimate strength testing of the 20R, under ambient conditions, the coupling withstood 7 to 8 times its rated torque before the element failed. This same performance should not be expected for all sizes. Larger WRAPflex couplings will tend to have a lower ultimate strength capacity and lower fatigue capacity than smaller sizes. The WRAPflex coupling is generally more vulnerable to fatigue than to overloads, and thus it is rated primarily on its fatigue performance. For this reason, the coupling’s ultimate strength performance is simply a function of the required fatigue capacity. It is also important to keep in mind that ultimate strength may vary considerably depending on the operating environment. For instance, higher temperatures will tend to soften and weaken the element.

During a torque overload, angular deflection of the hubs is high. It can be as high as 10 times the normal deflection at rated torque. At such high angular deflections, the hub teeth act almost like shears. The forward, outer edge of the hub teeth begins to embed and tear/shear through the element material at the element tooth root, as shown in *Figure 2*. If torque continues to increase, the hub teeth will shear completely through the element and actually tear out portions of element teeth, as shown in *Figure 3*. If the equipment continues to run after an element failure, there is an increased possibility of cover failure.

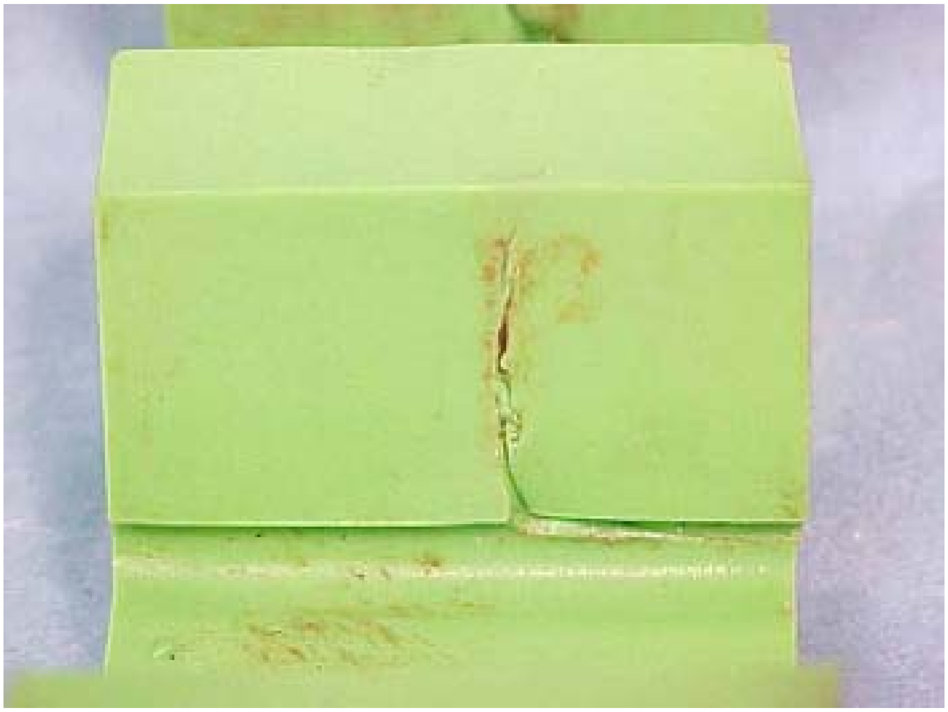


Figure 2 – *Tear in Element Tooth from Hub Tooth embedding under Torque Overload*

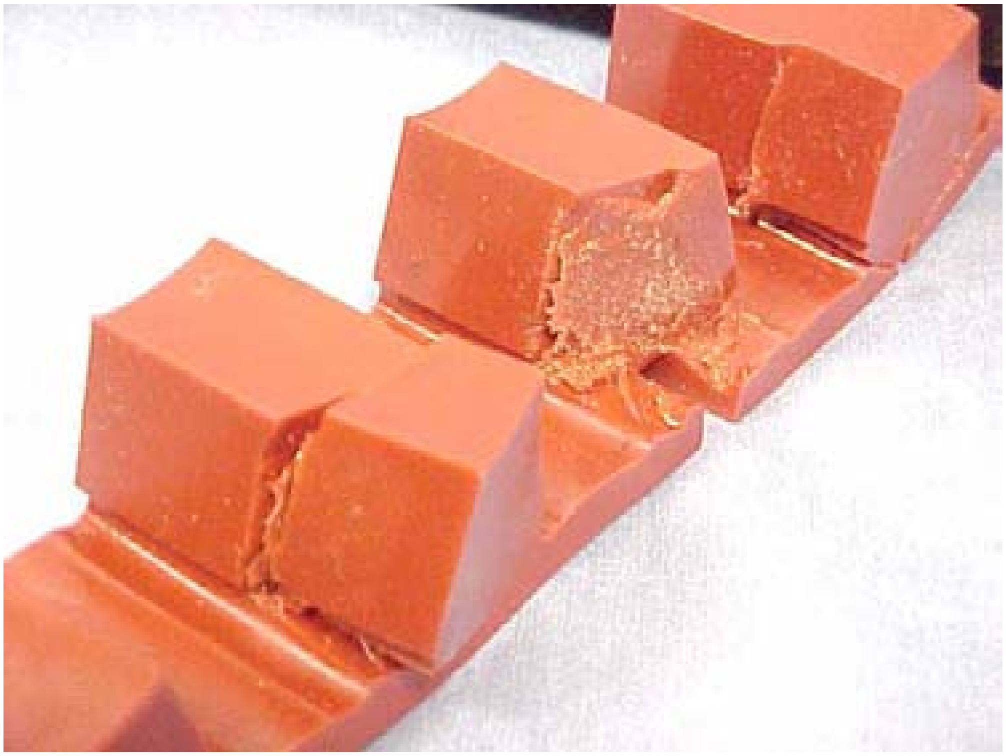


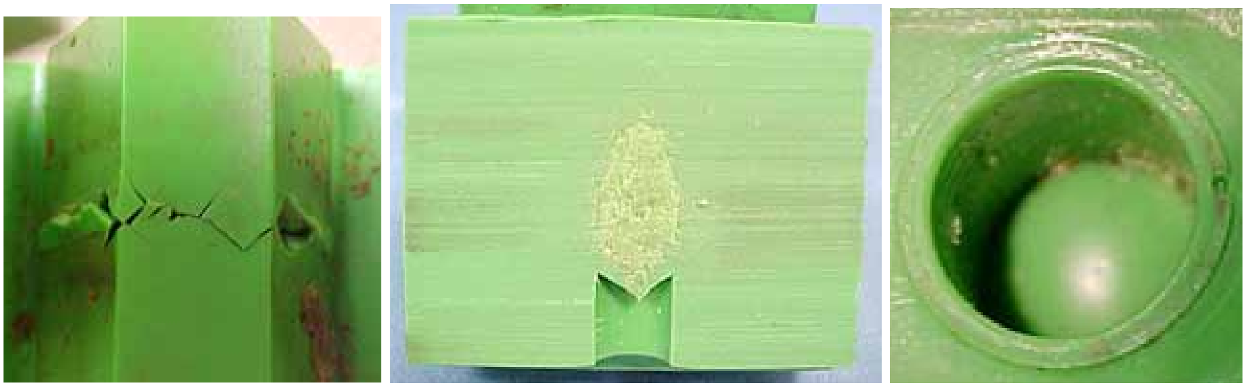
Figure 3 - *Shearing of Element Teeth under Torque Overload*

If properly selected, an ultimate strength failure should be rare. However, environmental factors can play a role and must be considered when analyzing a failure. Obviously, the best time to consider operating environment is prior to coupling selection. Certain chemicals or fluids, as well as exposure to extremes of hot and cold, can substantially weaken the element or even the nylon cover. In such cases, the WRAPflex coupling may not be appropriate. *Refer to Bulletin 497-110 for WRAPflex fluid/chemical compatibility.*

Lastly, there has been some tendency for end-users to want to use the WRAPflex coupling for overload protection. The assumption the end-user is making is that the element will shear during an overload or lock-up at some "predictable" level of torque and thereby disconnect. This is a very erroneous and potentially dangerous assumption, primarily because of the variability in element properties under different environmental operating conditions and partly because of the wide manufacturing tolerances typical of rubber and plastic parts. Even if the element were to shear as desired, it is impossible to predict how the coupling will perform while free spinning. There would be potentially many loose pieces of element material that could work out of the cover or even jam up between the cover and hub, causing a cover failure. **Even though the Wrapflex coupling can potentially protect connected equipment during an overload, it should not be promoted as a shear device for overload protection for the reasons noted above.**

Torsional Fatigue

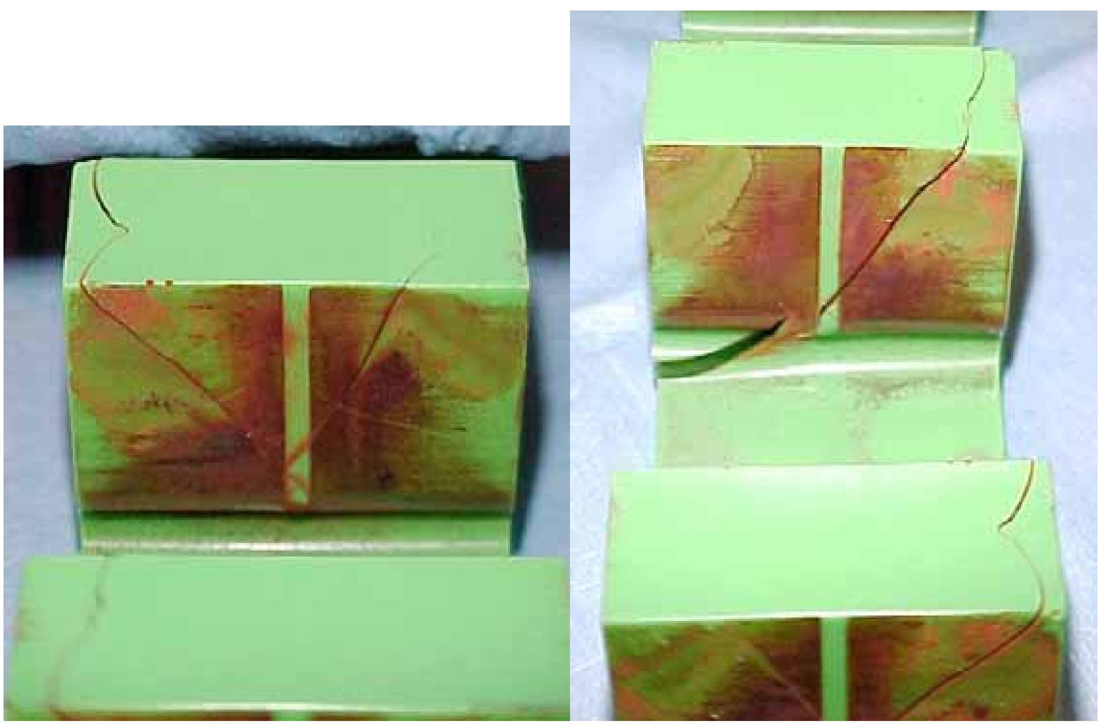
Under cyclical loading, the WRAPflex element dampens and absorbs a portion of the vibratory torque energy. The energy that the element absorbs is transformed as heat inside the element. If the amplitude or frequency of vibratory torque is so great that the element is not capable of dissipating the energy, internal temperatures within the element may become high enough to physically alter or break down the element material from the inside out. If this occurs, the element material will lose strength rather rapidly and will likely fail. A failure of this nature may appear outwardly similar in appearance to a torque overload or fatigue failure *Figure 4a*. The difference between the two types of failure can be discerned by either taking a cut through the center of a single element tooth, as shown in *Figure 4b* or by examining the element cover screw hole bottom for a "bulged" appearance (*Figure 4c*). *Figure 4b* reveals how heat build-up due to vibratory torque breaks down and transforms (melts) the element material from the inside out. An element that has failed due to pure torque overload or low frequency/load fatigue will not show any physical break down of the element material. As with torque overload, exposure to certain chemicals or extreme hot or cold may also be a factor in a fatigue type failure.



a) Element Tooth Failure *b) Cut Thru Element Cover Hole* *c) Element Cover Hole Bulge*

<u>Figure 4</u> - Heat-Effected Element Tooth due to Vibratory Loading

Vibratory torque can also give rise to a relatively slow fatigue failure, if heat build-up within the element is not excessive. In this case, cyclical loading leads to a slow progression of cracks in the element, without physically breaking down the element material. Cracks begin to form on the tooth flank and at the tooth root. Often, two cracks will converge near the center and root of one tooth flank and angle outward to the element I.D., as shown in the left-hand photo of *Figure 5*. Over time, flank cracks will continue across the I.D. and actually join the cracks on the opposite flank. Cracks at the root or web of the element typically start on one side and progress towards the center of the element. Surprisingly, the WRAPflex element will continue to carry full torque even after it has become severely cracked. For this reason, a replacement element is recommended only if a piece of element tooth has broken off or is close to breaking off, or the element is close to separating at the web.



<u>Figure 5</u> - Flank & Web Cracks on Element Teeth due to Vibratory Loading (Fatigue)

A rusty orange residue is visible on the element tooth flanks, as shown in *Figure 5*, and on the hub teeth. This residue is due to fretting corrosion. Fretting is a result of friction when the hub teeth slide against the element teeth during vibratory loading. It is not uncommon for this type of coupling and should not be construed, in and of itself, as an indicator of failure.

As with vibratory loading, fretting corrosion is common with high angular misalignment due to the sliding action of hub teeth on element teeth. Again, fretting corrosion alone is not an indicator of failure.

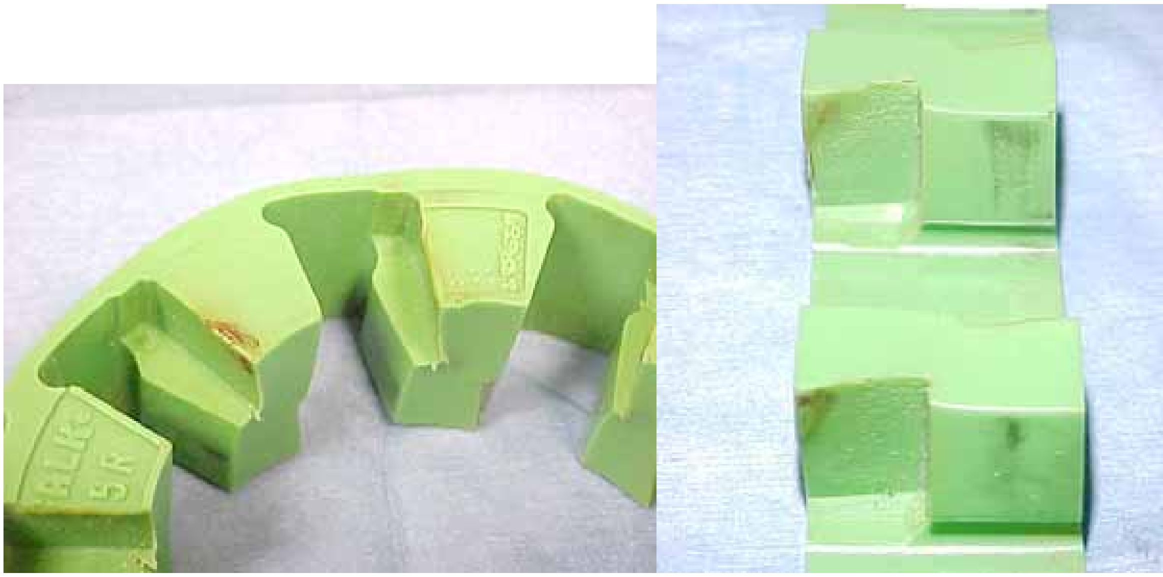
<u>Wear</u>

Element wear is typically a direct result of high angular misalignment. Parallel misalignment alone has little effect on the coupling, but may induce relatively high radial shaft loads. Based on testing at various levels of angular misalignment, element wear will become noticeable somewhere between 1.0 to 1.5 degrees of misalignment. The element wear rate also appears to be directly proportional to the amount of angular misalignment. In other words, the element will wear faster at 2.0 degrees of misalignment versus 1.5 degrees.

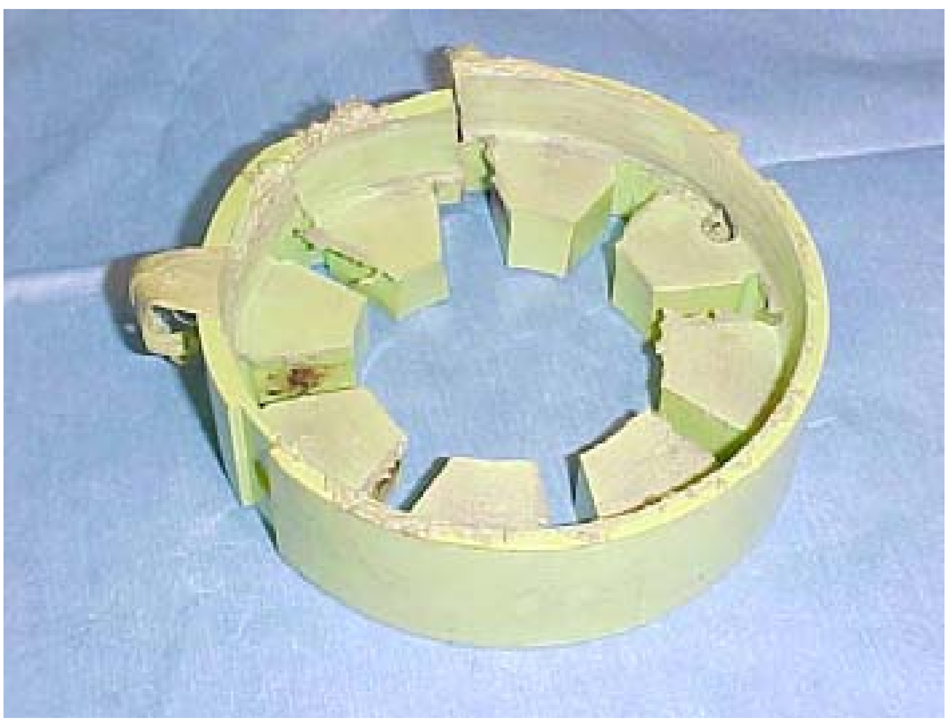
When the WRAPflex coupling runs under high angular misalignment, one hub tends to grip the element while the other hub works back and forth against the element. This back and forth working motion and the related friction is the mechanism that causes wear. Wear debris, as shown in *Figure 6*, will accumulate over time and is a good indicator of high angular misalignment.

<u>Figure 6</u> - Element Wear Debris due to Excessive Angular Misalignment

One side of the element is generally unaffected (typically compression set or distortion of urethane rather than abrasive wearing of urethane contact surface), but the other side that sees the working motion from one hub begins to wear away, as shown in *Figure 7*. Eventually, enough of the element tooth will have worn away so that the remaining portion of tooth can no longer carry the load. At this point, the remaining portion shears away and the coupling fails. If the problem is not discovered until after the element has failed, the hubs spin free. While free spinning, the cover may be damaged and the element will actually begin to melt due to the high speed friction forces, as shown in *Figure 8*.



<u>Figure 7</u> - Partial Element Tooth Wear due to Excessive Angular Misalignment



<u>Figure 8</u> – Complete Wear Failure & Melting of Element after Free Spinning, due to High Angular Misalignment

In addition to wear caused by very high angular misalignment, the urethane surfaces may begin to experience wear or cracking due to extended service life**. Although predictable**

urethane element life is difficult to determine, it is advisable to replace the element in applications that are sensitive to unplanned downtime (i.e. process critical equipment or backup equipment) after 26,000 hours of operation, 10% tooth wear or every three (3) years. In such applications, the coupling should be inspected quarterly for signs of wear or damage (look for signs of urethane dust or iron oxide dust). Following is a chart that lists calculated urethane wear amounts for establishing replacement criteria (does not account for element skewing or torsional deflection of the urethane due to torsional windup):

SIZE	ELEMENT TOOTH WIDTH (IN)	ALLOWABLE WEAR @ 10% TOOTH WIDTH	CALCULATED BACKLASH @ 10% WEAR (IN)	ALLOWABLE WEAR @ 20% TOOTH WIDTH	CALCULATED BACKLASH @ 20% WEAR (IN)
5R	0.516	0.052	0.102	0.103	0.154
10R	0.623	0.062	0.113	0.125	0.175
20R	0.841	0.084	0.135	0.168	0.219
30R	0.984	0.098	0.149	0.197	0.247
40R	1.212	0.121	0.172	0.242	0.293
50R	1.477	0.148	0.190	0.295	0.338
60R	1.929	0.193	0.252	0.386	0.445
70R	2.291	0.229	0.288	0.458	0.517
80R	2.754	0.275	0.334	0.551	0.610

Environmental Effects

Exposure to certain chemicals or fluids (including steam) or exposure to high or low ambient temperatures may promote failure. The operating temperature range for the WRAPflex coupling is –40^{o}C (-40^{o}F) to 95^{o}C (200^{o}F). When analyzing a WRAPflex coupling failure, it is very important to consider operating environment. Elastomer couplings are more sensitive to environment than most non-elastomer couplings. Exposure to incompatible chemicals will usually result in softening and thus weakening of the element material. To a lesser extent, certain chemicals or fluids may also affect the nylon cover. In cases of fluid or chemical exposure, refer to *Bulletin 497-110* for WRAPflex fluid/chemical compatibility. Also keep in mind that higher temperatures will increase the element's or nylon cover's vulnerability to damaging fluids. Even without exposure to chemicals, temperatures approaching 95^{o}C (200^{o}F) will reduce overall strength of the coupling.

Miscellaneous

Under severe vibratory loads (i.e. pump cavitation, system resonance frequency or non-flywheel engine drive systems) or lightly loaded applications (i.e. very large service factors due to bore capacity, etc.), the urethane element may wear the hub steel teeth. This aggressiveness may create a fretting corrosion condition (a red powdery abrasive dust) that may wear the hub teeth as shown in *Figure 9.*

Figure 9 - Abrasive Wear due to Element Material Fretting Corrosion

This condition is usually observed by excessive red dust covering the coupling and surrounding surfaces as shown in *Figure 10.*

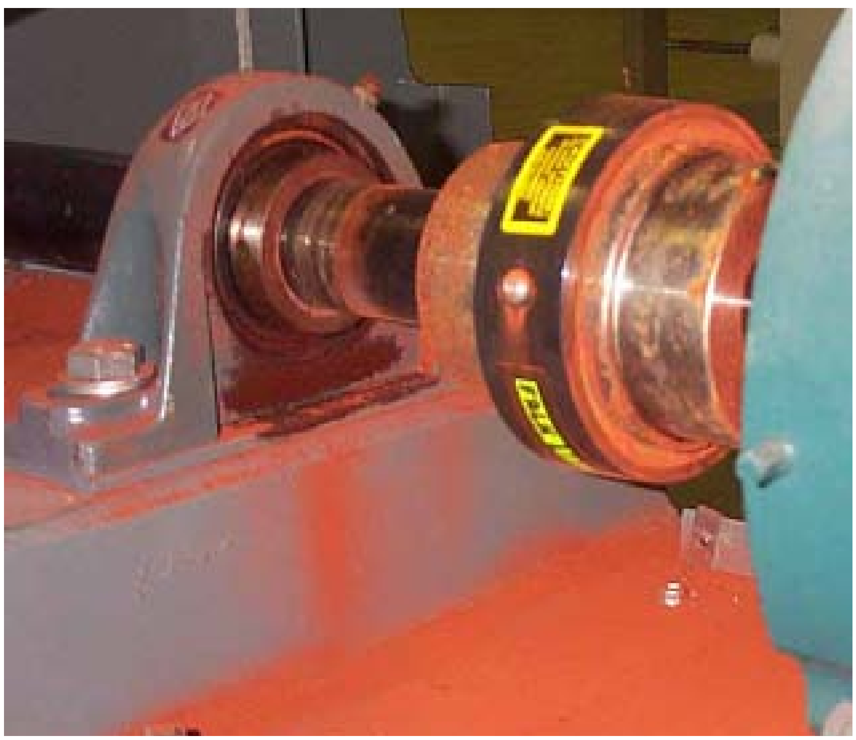


Figure 10 - Red Fretting Corrosion Dust when element Operating Under Severe Vibratory Loads