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TO: Chain Drive Vehicle Manufacturers and Potential Customers
FROM: Billy Wight, Luxon Engineering
CC: Lee Williams, Williams Racing Developments
DATE: August 10, 2007
Re: Production Chain-Drive-Differential Structural Analysis – Dowel Drive System

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Summary
This memo has been written to justify the structural capabilities of the dowel pin drive system utilized on the production WRD Chain Drive Differential. The drive system uses 3 5/16 inch diameter dowels and 6 5/16-24 studs on a 2.0625 inch diameter bolt circle to transfer the torque from the sprocket mount to the differential main case. Calculations below, assuming a 1400cc engine, show that the system is sufficiently strong with a safety factor of 2.50

Drive System Specifications
Figure 1 illustrates the drive system. The dowel pins are designed to transmit the entire torque loading of the drive system. Studs, while also capable of transmitting torque, are only intended to fix the sprocket mount to the housing and are therefore not included in the calculations below. Also, the friction between the bearing and sprocket interface can support substantial torque transfer; the magnitude of torque, however, is highly dependent on the conditions of the interface and the torque applied to the nuts. For these reasons torque transfer via friction will be calculated using a conservative coefficient of friction value.

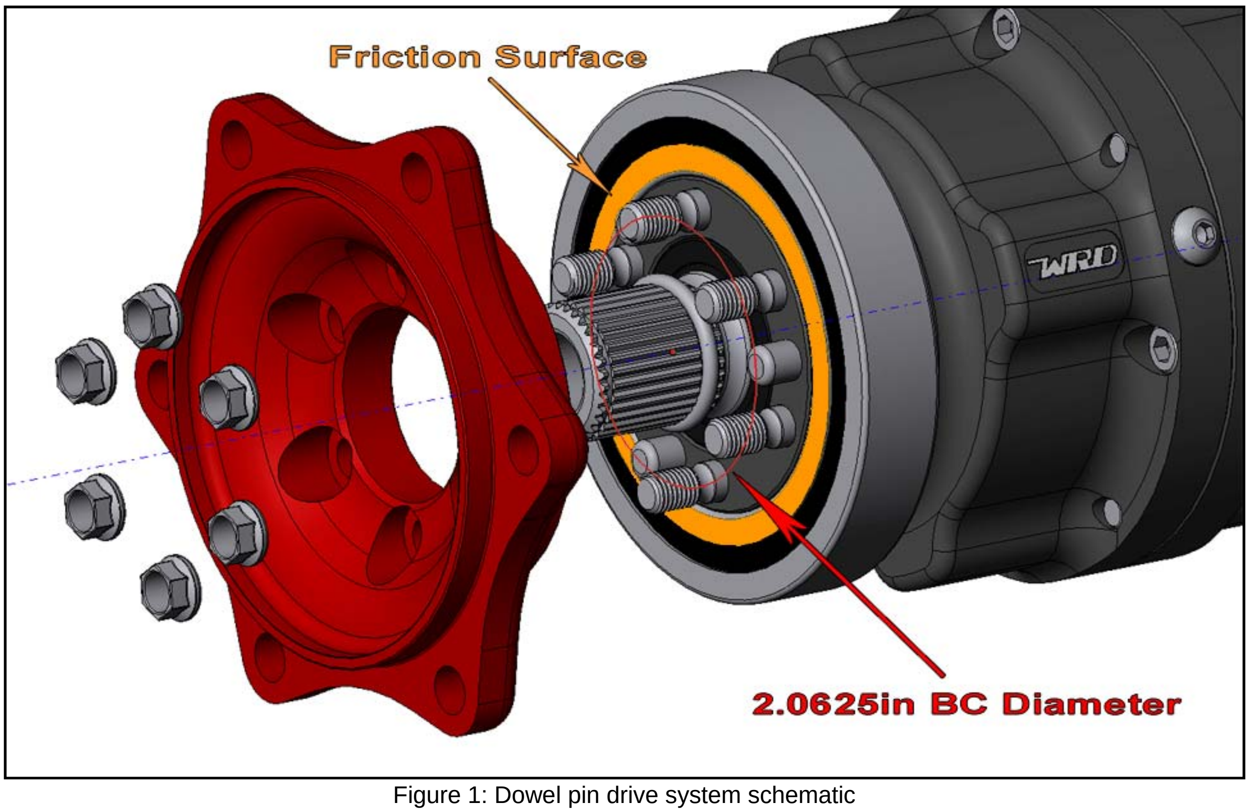

Figure 1: Dowel pin drive system schematic

Shear Strength Calculations

For simplicity, all imperial units have been converted to metric for the calculation steps with the results being reported in dual units. Strength calculations shown below determine the torque necessary to yield the dowels in shear. For shear of a circular cross section, the maximum shear stress is approximately 4/3 the average shear stress; this correction factor is applied to the calculations below.

(Dowels Only):

$$r_{dowel} = 3.9688E-3m$$

$$r_{BC} = \frac{2.0625in}{2} = 0.026194m$$

$$\tau_{dowel} = 130000\,psi = 8.9632E8Pa$$

$$A_{dowel} = \pi \cdot r_{dowel}{}^2 = \pi(3.9688E-3)^2 = 4.9484E-5m^2$$

$$T_{dowels} = 3/4 \cdot Qty \cdot A_{dowel} \cdot \tau_{dowel} \cdot r_{BC} = (.75)(3)(4.9484E-5)(8.9632E8)(.026194) = 2614.0Nm$$

(Friction Only):

Most sources claim a static coefficient of friction of steel to aluminum contact to be about .61 (dry). This analysis uses a conservative value of .30 to account for lubricated surfaces and improperly torqued nuts. The recommended nut torque (18 ft*lbs) produces an axial stud load of approximately 3800lbs (for a k value of .2).

$$\nu_{Steel-Al} = .30$$

$$F_{normal} = Qty \cdot Tension = (6)(3800.0lbs) = 22800lbs = 101420N$$

$$r_{friction} = \frac{2.8094in}{2} = 3.5679E-2m$$

$$T_{friction} = \nu \cdot F_{normal} \cdot r_{friction} = (.30)(101420)(3.5679E-2) = 1085.6Nm$$

(Dowels + Friction):

$$T_{total} = T_{dowels} + T_{friction} = 2614.0Nm + 1085.6Nm = 3699.6Nm$$

Safety Factor Calculation
The systems factor of safety has been calculated using the assumptions that maximum torque loading is dependent on engine output torque and gear reduction ratio (first gear). The analysis also assumes infinite traction (no wheel slip).

For a Kawasaki GX14 (1400cc) motorcycle engine,
Maximum output torque = 139.65 Nm (103.00 ft*lbs)
Gear ratio = 1.541(primary)*2.625(first)*2.625(sprocket, 42/16) = 10.618
So:

$$T_{acceleration} = 139.65(10.618) = 1482.8Nm$$

From the above calculations, the factor of safety is calculated with:

$$FOS_{dowels\_only} = \frac{T_{dowels\_only}}{T_{acceleration}} = \frac{2614.0}{1482.8} = 1.76$$

$$FOS_{dowels+friction} = \frac{T_{dowels+friction}}{T_{acceleration}} = \frac{2614.0+1085.6}{1482.8} = 2.50$$

Conclusion
The absolute minimum factor of safety required for a component to endure an applied loading without failure is equal to one. The above analysis shows that the sprocket drive system utilized on the Williams Racing Developments Chain Drive Differential is adequately strong with a FOS of 2.50 This factor of safety will account for the limitations of the assumptions used in the calculation such as dynamic loading, etc.

All above calculations were performed using the torques generated by a 1400cc engine (Kawasaki ZX14). The majority of racers will be using a 1000cc engine (DSR) which does not output as much torque as the 1400cc engine; this raises the safety factor for these vehicles. In addition to this, the assumptions used included full torque from a standing start with infinite traction. This is the absolute worst-case scenario and most vehicles will never see this extreme of loading. Furthermore, as discussed in the above specifications section, proper bolt torque and a dry interface between the sprocket mount and the bearing will improve the torque transfer capabilities of the drive system.

In the unlikely event of dowel failure, the six tension studs will support the torque loading, nearly eliminating the possibility of completely shearing off the sprocket mount. These tension studs are high quality ARP units and are doweled in the center to support shear loading. As with all racing components, the drive system should be inspected after each session to ensure the jetnuts are adequately torqued and everything is in proper working order.