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Discussion Paper

Effect of Link Design in Anti – Roll Bar Assembly.

Example used is alloy with polyurethane bushes vs. plastic composite and rubber bushes as used on Subaru rear

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Introduction

A new series of anti-roll bar links has been developed to tackle the problem of excessive OEM link deflections and failure. This new series is for the Subaru WRX and similar platforms (wagon, sedan, RX, STI…). The new links (KLC28 rear, KLC30 front) are of alloy construction and are designed to be stiffer yet provide a level of comfort and provide relatively free rotation and articulation of the link itself and the lateral link (suspension arm). Of interest is the effectiveness of the rear, KLC26, link in its actual stiffness and its impact on the anti-roll bar system in the car.

The following paper will give experimental results of the link stiffness (both OEM and alloy) and its effect in replacing the OEM link in the anti-roll bar system. Though specific to the application mentioned, the results are indicative of the differences between various materials and the interplay between links and anti-roll bars in general and what affect this may have on vehicle dynamics.

Link Stiffness

The first objective is to evaluate the performance of the alloy link against the OEM link it will be replacing.

The original OEM link is manufactured from a glass fiber reinforced nylon (PA66 – GF50) and has compliant rubber bushes at its ends, the link material has an elastic modulus of E = 17 500 MPa. The replacement Whiteline alloy link is manufactured from an aluminum alloy and has polyurethane bushes at its ends, the alloy has an elastic modulus of E = 69 000 MPa.

From the material alone, the alloy link is 4 times stiffer than the original link. However the bushes at the link ends will primarily affect the stiffness during initial loading of the links.

Both links were tension tested on a simple beam type rig. This consisted of a freely swinging beam (pivoted about one end), which was loaded up at its free end. The links (placed near the pivoted end) were used to restrain the arm movement and hold up the load. The rig was loaded up to approx. 50kg; the rig had a multiplication factor of 10 onto the restraining link, which therefore loaded the link to 500kg approx.

The following results show the force-deflection curve for both the Subaru standard link and Whiteline alloy link. The only variable that may influence results was the temperature at time of testing versus operating temperature.

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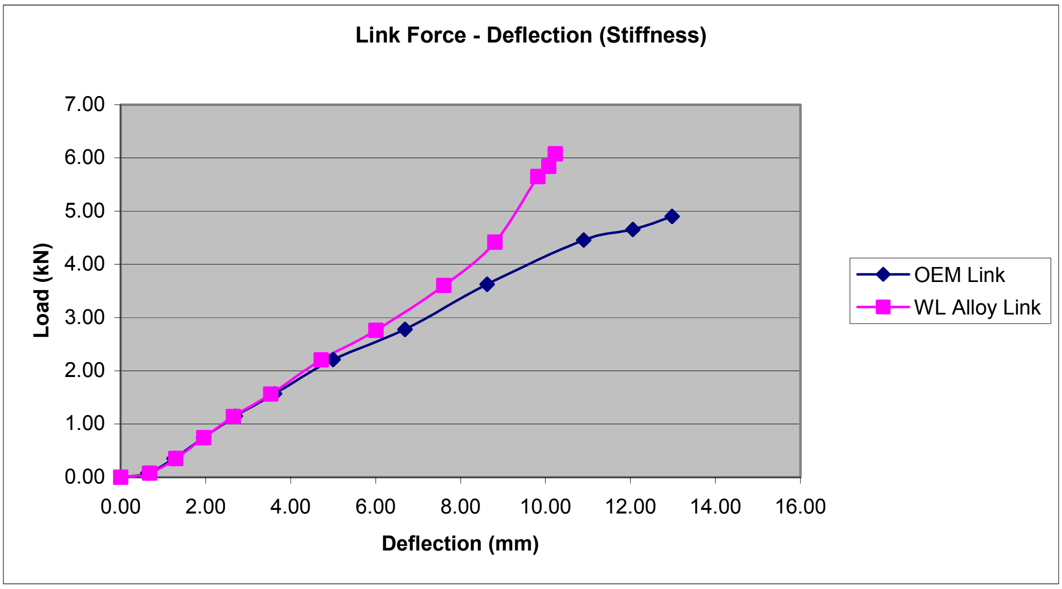
It can be clearly seen that the last 4 points in both curves represent the true stiffness of the link (alloy link some 4 times stiffer than OEM). Before that there is an effect from the poly bushes present, although generally the alloy link is stiffer than the OEM link.



The bushes will allow some compliance to take place; this will greatly enhance NVH isolation as opposed to a design incorporating non-compliant bearings.

In the results there seems to be little difference, up to a load of 1.5 kN, between the two links, even though the alloy link uses polyurethane bushes. One factor that should be noted is friction within the testing rig. It was assumed that the load, which was applied to the rig, was transmitted 100% (and multiplied by a factor of 10) to the test piece. Some friction could have been present and may have an effect on the curves.

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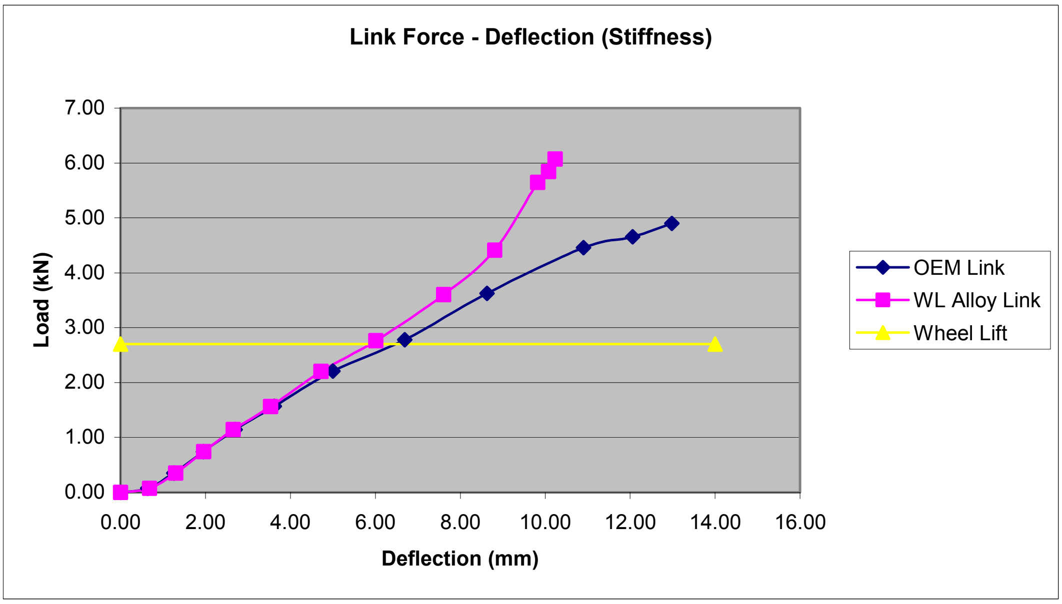
Link in Anti – Roll Bar Assembly

Knowing how much stiffer the alloy link is, it is now required to know how this effects the entire anti–roll bar assembly.

Another factor that also needs to be highlighted is the wheel lift off point, beyond this point there is no more one can do to increase the stiffness of the suspension in cornering. For a standard GD WRX, wheel lift off would occur around the limit at 1g steady state cornering, this corresponds to approx. 2.7 kN link load, as shown in the following graph.



This value (2.7 kN) was calculated from "Race Car Vehicle Dynamics" (Milliken & Milliken) roll rates for "firm high (performance imports)" using the standard suspension geometry. For more heavily modified "track cars" running larger diameter bars (24mm) and cornering up to 1.2g, the load transmitted through the link would be approx. 3.5 kN. If momentary peak cornering loads were also to be assumed, say around 1.5g cornering, this would incur loads of up to 4.5 kN (for track cars).

The effect the increase in stiffness of the link has on the entire system is very dependant on the stiffness of the other components (anti–roll bar), as the anti–roll bar system is effectively a series of springs.

In any system the resultant spring rate is governed by the stiffness of the softest spring. Therefore increasing the rate of a single component in a soft system will have little

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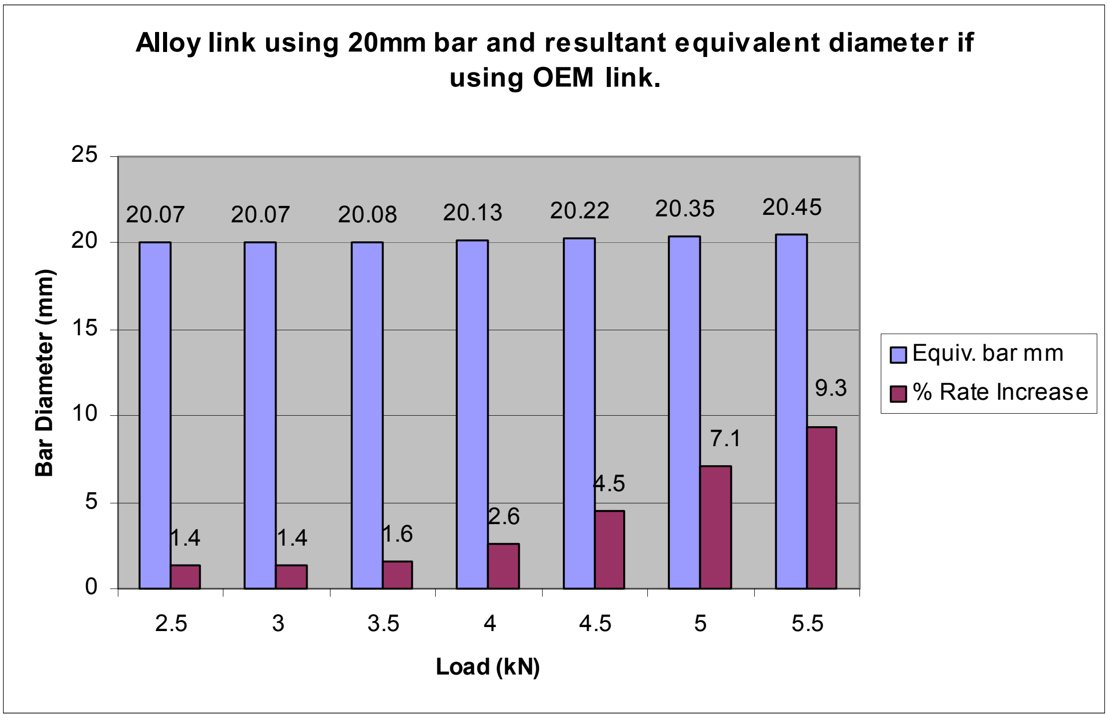
impact to the entire system, however increasing the rate of a soft component in a relatively hard system will have a large effect. This means that by replacing the links in a soft anti–roll bar set-up, the effect will be less than (and relatively low compared to) replacing the links in a vehicle with a large diameter, stiff anti–roll bar setup.

Because the stiffness is also dependant on the load, the effect is also dependant on the load applied to the anti–roll bar assembly. Following set of graphs show 3 different bar diameters using the alloy link. The values represent the equivalent bar diameter required with an OEM link and also the increase in bar rate this represents.

For example, at a 4.5kN load, the alloy/poly link fitted to a 20mm anti-roll bar (typical OEM size) provides the same roll resistance equivalent to a 20.22 mm anti-roll bar if using the OEM plastic/rubber link.



This table clearly shows a relatively insignificant change in anti-roll effect when using standard or relatively small bar diameters even at high cornering loads.

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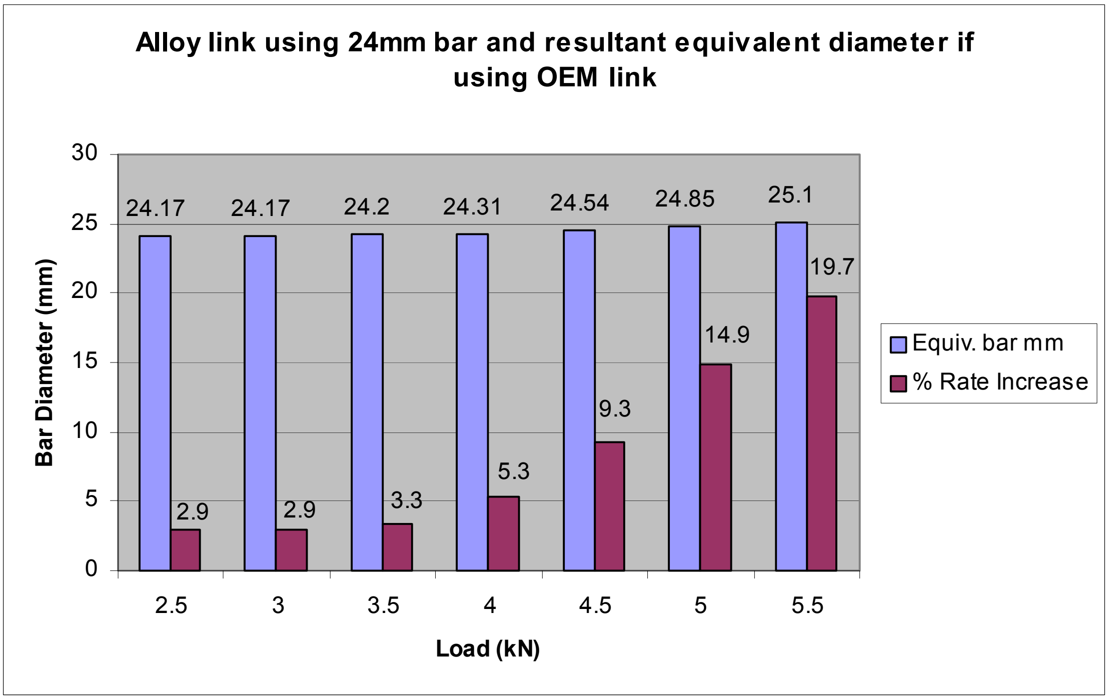

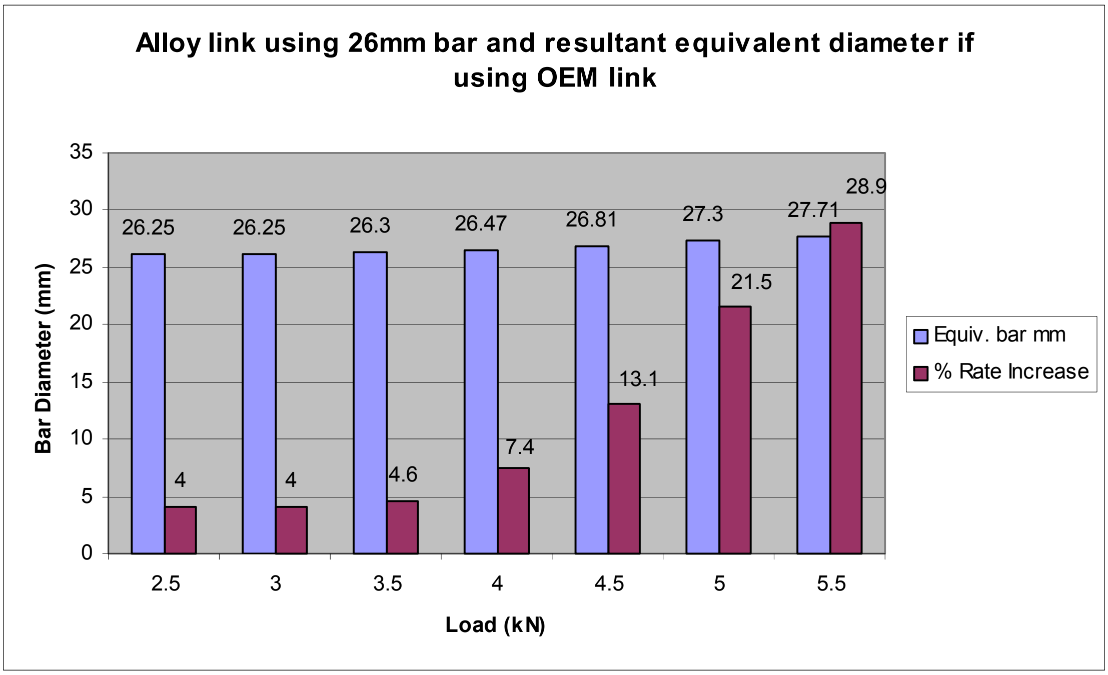

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As can be seen in the three graphs, as the load increases the effect of the extra stiffness in the alloy link increases. This is because of the alloy link stiffness profile being stiffest at higher loads.

Also note the difference between a 20mm bar application and a 26mm bar. Because the OEM links are much softer (compared to the bar) in a 26mm bar than a 20mm bar, the most effect is seen in the stiffer setup (28.9% increase in rate versus 9.3% at 5.5 kN load).

Conclusion

To conclude the alloy link is stiffer than the OEM link at all loads but effectively stiffer at higher loads or roll resistance values (anti-roll bar sizes). During lower loads the compliance of the polyurethane bushes comes into the picture and reduces this stiffness slightly in order to tackle NVH issues. This gives the link a non-linear, load dependant stiffness, which operates stiffer, or more effectively, the bigger the anti-roll bar (or the larger the load).

The effect of the alloy link on the entire system is dependant on the load and size of anti-roll bar used. The largest effect is gained when running heavy bars at high loads which is consistent with the design brief and performance objectives of this product. Introducing this link into softer set-ups gives less effect as the system is governed by the softest element (bar becomes the softer component).

Assuming a peak load of 4.5 kN being transmitted by the link, this would give an installation using the alloy/poly links a rate increase of between 4.5% (20mm bar diameter) and 13.1% (26mm bar diameter) over an installation using standard OEM links.