The report objective is to show the findings from development work done by center gravity for the prototype fitment of the XYZ Corp coilover suspension to the Tygan Speedster.

The report has 4 sections;

1. Ride heights
2. Geometry
3. Ride and Handling
4. conclusion

Ride Heights

This section describes the two extremes of ride height achievable with the prototype Red9 Design coilover kit. Key observations for each ride height were spring collar position, wishbone and tie rod angles and cambers.

One of the objectives of the XYZ Corp was to achieve a ride height for the Tygan similar to the original Porsche Speedster.

Lower design height (as delivered)

After initial installation of the XYZ Corp kit the ride heights were;

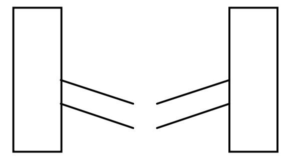
Front 190mm (centre of lower wishbone mount)
Rear 232mm (centre of spring plat mount)

Photograph Original ride heights

The angles of the front lower wishbone and track rod are circa 4degrees sloping up towards the wheel from the centre-line of the car. Note this will give bump steer issues.

Ideally the angle should be zero or a downwards slope.

Bump steer – front wheels and tie rod angles



The front and rear lower spring collars at this height are within 10mm of the bottom of threaded part of the damper (allowing even further lowering). The rear bump stop has been modified to allow this ride height to be achieved.

Photograph Rear damper lower spring collar

The collars allow ride heights to be changed by 50mm

The customer is likely to want to run at this ride height (or lower) so as to emulate the Porsche 356.

A brief test drive highlighted a crashing from the rear offside over high speed bumps (man-holes). This was due to the trailing arm hitting the chassis on bump.

Photograph showing rear trailing arm V-cut out

Original factory cars running ride heights of 260mm at the rear are not known to have shown this problem. This may be due to a combination of COFAP damper /spring and factory rubber bump stop and slightly higher ride heights.

Maximum ride height

Photograph Maximum ride height

The ride heights with the front and rear damper spring collars at their highest

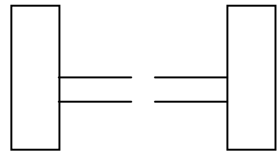
Front 210mm
Rear 250mm

These ride heights compare vary well with the default heights from the Tygan factory.

Tygan default ride heights

Front 215mm
Rear 265mm

Bump steer – front wheels and tie rod angles



The front bump steer characteristic is much improved. The lower wishbone and tie rods are now horizontal which is ideal. This should be the optimum ride height for the car.

Lower ride heights can be achieved with impact on bump steer. This in itself can be addressed through modified tie rod ends or Ackerman arms.

This is the maximum ride height that can be achieved as the spring collars are at now set at the top of the threaded damper body. Further increase in ride height is not possible without changing the length of the supplied springs.

Photograph offside wishbones damper spring collar at highest setting

Despite the further ride height increase, the offside rear trailing arm still hits the chassis on high speed bump. Either the extra driver weight or differing tolerances of chassis/arm are suspected to be the reason.

A 'v' was cut from the seam of the trailing arms where they fouled the chassis on bump. The yellow paint in the photograph below is on the chassis which is adjacent to the 'v' cut into the trailing arm. The 'v' increased clearance from 20mm to 27mm. Despite this damper/spring bump travel exceeds 27mm on occasion causing bump.

Photograph rear trailing arm modification

Photograph Modified rear bump stop

The trailing arm/chassis issue could be resolved in several ways

a. introduce a modified rubber bump stop for the chassis
b. introduce a modified bump stop for the damper
c. increase the ride height
d. modify the chassis (allowing further ride height reductions)
e. increase the spring length
f. increase the spring rate

The options will need to be discussed with XYZ Corp in terms of availability of different springs and feasibility and trailing arm modifications.

The recommendation is that spring lengths and rates will need changing to put the lower spring collar midway on the threaded body for design ride height.

Car handling and quality of ride is currently very good on the current spring rates, increasing rates may create a harsher ride.

Geometry

This section explains the geometry of the prototype car for minimum and maximum ride heights.

Geometry is given in terms of;

a. Camber of front/rear wheels
b. Castor of the front wheel
c. Toe of front and rear wheels

The geometry is highly specific to the car and the modifications made. Ultimate handling at the limit has not been tested, however the geometry will have been tested and set to give a safe ride at high speed (90mph) and safe cornering without extremes of under/oversteer.

Geometry at minimum ride height

Rear Axle		Initial Measurement
Camber	left	-3°46'
	right	-3°35'
Individual Toe	left	+0°23'
	right	+0°27'
Total Toe		+0°49'
Geometrical driving axis		+0°02'
Front Axle		**Initial Measurement**
Castor 10°	left	+6°08'
	right	+4°40'
K.P.I. 10°	left	+3°47'
	right	+4°16'
Camber	left	+1°03'
	right	+0°36'
Individual Toe	left	-1°10'
	right	-1°08'
Total Toe		-2°17'
Setback		+0°04'
Included Angle 10°	left	+4°50'
	right	+4°52'

Front Axle

The front axle cambers, toes and castors are acceptable and are highly tailorable. This a function of the new XYZ Corp coilover frame. Camber can be adjusted by the conventional eccentric upper balljoints, toe by tie rod/end and castor by moving the packing washers of the upper wishbone. Even at the minimum ride height all angles can be achieved.

Toe in turns could not be measured and is not shown due to the limitation of the steering rack. Turn was limited to less than 15degrees. Lock to lock of the current rack is 1 ½ turns. Turning circle was reported at 12.8m compared to 11m for an original Speedster.

As mentioned in the previous section the lower wishbone and tie rod angles in relation to the vertical were incorrect. This would have created a problem bump-steer effect.

Also noted was the extreme angle of the tie rod from the Ackerman arm at the wheel to the rack end. This may cause accelerated wear and/or lock/stress the balljoint at the rack end on full lock.

Photograph Angle of Tie Rod viewed from above

Rear Axle

The rear cambers at the minimum ride height are too high at circa 3 ¾ degrees negative. This is a function of the design of the Beetle trailing arm geometry.

High negative camber will cause instability on bumpy roads, understeer and uneven tyre wear. Overall grip will not be optimum at the rear leading to traction, cornering and braking issues. Camber should ideally be between 1 and 2 degrees negative.

This could be corrected by using XYZ Corp custom spring plates. However their design would have to be combined with the new coilover spring plate design fitted to the Tygan.

Photograph New Rear Spring Plate

A small amount of camber adjustment should also be available. This is normally achieved by using an eccentric / slot on the foremost spring plate bolt. Adjustment would allow for synchronisation of the camber across the rear axle which should be less than 30minutes of a degree for fine handling (removal of camber thrust effect).

Geometry at maximum ride height

Rear Axle		Initial Measurement	Target Data	Final Measurement
Camber	left	-3°02'	-0°40' [-1°00'] +0°40'	-3°01'
	right	-2°53'		-2°59'
Cross Camber		-0°08'	[0°45']	-0°02'
Individual Toe	left	+0°27'	-0°12' [+0°00'] +0°12'	+0°14'
	right	+0°26'		+0°14'
Cross Toe		+0°01'	[0°10']	+0°00'
Total Toe		+0°52'	-0°15' [+0°00'] +0°15'	+0°28'
Setback		-0°06'		-0°07'
Geometrical driving axis		-0°01'		+0°00'
Front Axle		**Initial Measurement**	**Target Data**	**Final Measurement**
Castor 20°	left	+4°55'	-0°35' [+2°00'] +0°35'	+3°56'
	right	+3°52'		+4°27'
K.P.I. 20°	left	+4°01'		+4°07'
	right	+4°05'		+4°24'
Toe out on turns	left	+1°00'	-0°30' [-1°00'] +0°30'	+1°05'
	right	+1°01'		+1°00'
Camber	left	+0°46'	-0°40' [+1°00'] +0°20'	-1°04'
	right	+0°41'		-1°02'
Cross Camber		+0°04'	[0°30']	-0°02'
Individual Toe	left	-0°03'	-0°15' [+0°15'] +0°15'	+0°04'
	right	+0°07'		+0°03'
Total Toe		+0°04'	-0°15' [+0°30'] +0°15'	+0°07'
Setback		+0°23'		+0°14'
Included Angle 20°	left	+4°49'		+3°03'
	right	+4°44'		+3°21'

Front Axle

Target data for the later model Beetle was used albeit that the front values are for a McPherson strut which are not applicable to the XYZ Corp double wishbone.

An attempt was made to synchronise the castor angles to the higher of the two (circa 4 ½ degrees). The limit of adjustability for the near side front was reached on the upper wishbone. Whilst further adjustability is available on the lower wishbone, it could not be achieved as the rear wishbone fixing bolt could not be removed as it fouled the car bulkhead.

Toes were set neutral to slightly toe-in due to the modern bushing used on the front axle.

Cambers were set using the eccentric adjusters. Negative camber of 1 degree was set to reflect the cambers on the rear axle. This was done to minimise understeer. The balljoint would need to be changed with one of a greater offset to achieve more negative camber.

The new Ackerman arm addressed the turning circle issue (now sub 10m), however the lock of 1 ½ turns remains an issue. This will be address with the fitting of a modified steering rack.

Toe out in turns (TOT) – The lock now produces over 20 degrees of turn at the wheel is a modern standard. The final results showed that at least 1degree of TOT was obtained at each wheel. Ideally this should be 2degrees at 20deg of turn. This again could be improved through further development of the Ackerman arms.

Rear Axle

The rear negative camber has reduced to -3 degrees by raising the car 20mm, with ½- ¾ degree less than the lowest ride height. This however must still be reduced and addressed in further development.

The Toe angle was set to a similar angle as the improved Beetle and Porsche 911. 14minutes of toe-in per wheel was used. This could be reduced if the camber issue was resolved.

The new stiffer spring plate design and stiffer spring plate pivot reduces variations in toe experienced with the classic design (i.e. lift off oversteer)

Cross camber has been reduced to a minimum although separate fine camber adjuster would be ideal. (see Elephant Racing camber adjuster for the 911). The trailing arm will also require modification (slotting) for the adjuster to work.

Handling

The uprated springs and dampers have reduced the amount of roll. The Tygan is not fitted with anti-roll bars.

Reduced roll has reduced the amount of roll-steer from the rear axle. This is apparent when accelerating into and out of hard corners. Cornering speed has improved.

It is easy to break traction at the rear under heavy acceleration and turn, although oversteer at modest speeds is not a problem.

Good steering feel, little effort and good road feedback. The turn-in compared to the original Tygan is crisp resulting from the harder bushings, steering rack and quicker ratio.

Cornering performance is very neutral, progressing to manageable oversteer under light throttle. Wheelspin can be induced on turning and hard throttle. This is due mainly to high negative cambers at the rear.

The car is stable at high speed (90mph) with good steering control and feedback

Conclusion

A very worthwhile upgrade improving the handling of the car to modern car standards. Outstanding!

The upgrade is a pre-requisite for obtaining ride heights similar to the original Porsche 356 for the Beetle underpinnings.

The car cannot be lowered more than 210mm front / 245mm rear without further chassis modifications.

Modifications required for lower ride heights;

a. trailing arm / chassis
b. further modified spring plates
c. front lower wishbone angles
d. front bump steer adjustment

Further modifications to the XYZ Corp kit are required to allow the current ride height (210/245mm). Currently there are issues;

a. rear chassis/trailing arm conflict on high speed bump
b. spring platforms at end of their travel – review of spring rates/lengths needed
c. rear bump stops inadequate

Further modifications can be made to ensure the success of the kit;

a. more strong mounting of the front frame to the car chassis. Currently high loadings at the wheel can

deform the frame causing camber/toe variations
b. adjustable camber function for spring plates on the rear axle
c. steering rack with better lock to lock
d. installation of bolts (the correct way around when frame built) to allow castor adjustment on the lower wishbone

Steering Rack Turning Circle

The initial turning circle is a constraint of the current steering rack. Whilst a permanent fix to this requires a new rack to be built (in progress), a temporary solution has been provided by XYZ Corp. The current Ackerman arms have been modified allowing them to be re-positioned further back on the hub carrier. Once the revised steering rack is fitted, the arms will be returned to their original design position.

This modification has compromised the angle of the tie rod even further, potentially putting the inner rack end joint under load. Furthermore, the tie rod end bellows currently touch the disk rotor.

See picture below of the modified Ackerman arm.