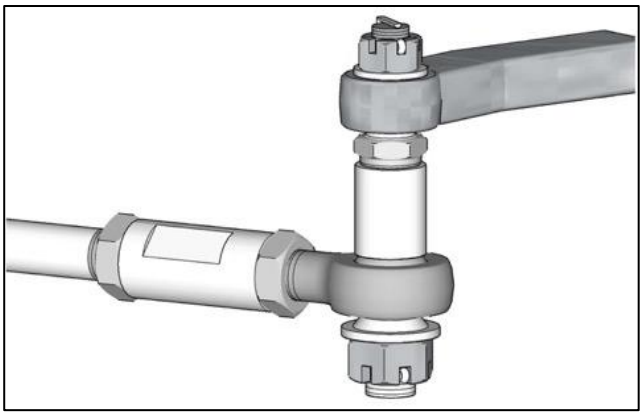
Spherical Bearing Rod End Conversion for

Steering Tie-rod Ends and Unloaded Suspension Ball-joints

Introduction



During the development of the New Zealand Car Construction Manual (NZCCM) in 2007, there were few off-the-shelf aftermarket parts available in New Zealand in comparison to the abundance we see today. It is for that reason some parts commonly seen now are not provided for in the NZCCM. This Information Sheet has been developed to assist modifiers by providing solutions for the safe optimisation of steering and suspension geometry, with modifications that can be approved by any category 1D-authorised LVV Certifier, specifically relating to:

- steering tie-rod end conversion to spherical bearing rod ends; and
- unloaded suspension arm ball-joint to spherical bearing rod end conversions (*unloaded in that the arm **does not** have the spring-load passing through it*).

Background

Excessive bump-steer or incorrect roll-centre adjustments can have a negative effect on a vehicle's steering and suspension geometry, which could result in undesirable and potentially unsafe handling characteristics. There are many cases where bump-steer may be present after a steering modification; a custom suspension system may need fine-tuning to correctly dial-in the roll-centres and remove or reduce bump-steer, or a lowered vehicle might have roll-centre adjustments made without consideration to the effect on other aspects of the vehicle's geometry, and the potential introduction of bump-steer.

Often the most cost-effective solution is to replace the outer tie-rod end or ball-joint with a high-strength steel tapered pin, and a spherical bearing rod end. This conversion facilitates relocation of a pivot centre, allowing for correction of various geometry issues. This method is especially useful when bump-steer correction is necessary on a vehicle that has had steering system modifications and the vehicle has a steering arm that is integral with the stub axle (i.e., it is not possible to fabricate a custom steering arm), or when it is not possible to reposition the steering rack due to engine sump, chassis, or cross-member position. It is also useful when roll-centres need to be corrected, or ball-joint bind occurs, both common issues encountered due to lowering a vehicle's suspension.

While spherical joints can have their drawbacks, provided the joint is a premium quality component incorporating a self-lubricating Teflon or Kevlar liner, has the correct load rating, and the tapered pin is correctly fabricated and installed, this is a robust and safe way to address geometry-related issues.

Important notes

- Tapered pins are a good way to resolve geometry issues, however the modifier should always look to re-position the steering rack or steering arms to their optimum location whenever possible.

- Tapered pins and associated parts are critical function components. All parts must be manufactured to a high-quality professional standard to suit the critical nature of the application, and components must be installed and assembled in a tradesman-like manner.
- Spherical bearing rod ends with threaded sections should not be used in a situation where a vehicle's corner weight and suspension loads will travel directly through the threaded section of the joint 'in bending'. In some cases, a spherical bearing rod end can be used as an *inner joint* on a loaded arm where the loads are significantly lower; however, the suitability is dependent on the position of the spring on the arm (the further inboard the spring, the greater the load on the inner joint), and such a situation may require engineering analysis to validate the loads, or may require individual approval from the Technical Advisory Committee (TAC).
- For methods of converting Original Equipment Manufacturer (OEM) steering or suspension joints not covered within this Information Sheet, the modifier should contact an LVV Certifier for advice and guidance in the first instance. If an LVV Certifier suggests another method as a suitable alternative, full and clear details will need to be provided to the LVVTA technical staff to determine if individual approval from the TAC will be required.
- The TAC approval process is detailed in the NZCCM Chapter 4 (Build Approval Process), or refer to the Design Approval section on the LVVTA website, under the Approvals tab (www.lvvta.org.nz/approvals.html#design).
- Custom spherical bearing rod ends are also referred to as *rod ends, rod end bearings, rose joints, spherical joints, or heim joints.*
- Tapered pins are also referred to as *tapered studs*, *spindle studs*, *tie-rod droppers*, *tie-rod drop pins*, *hub pins*, or *central shafts*.

Steering arm suitability

- Some steering arms are not suitable for a tapered pin conversion. The physical dimensions of the steering arm, including thickness, shape, length, boss, taper size, and the attachment of the steering arm to the stub axle, must be carefully assessed by a category 1D-authorised LVV Certifier to ensure that all loads are within the tolerance of the arm (especially bending loads, which will increase due to the extra mechanical advantage of the extended or cantilevered pin).

  The increase in leverage on the steering arm is why it is critical these parts are correctly assessed and installed, particularly when a vehicle has power assisted steering (essentially a hydraulic ram) which allows for much higher steering output loads than is possible with a manual system.

- Some OEM tie-rod ends utilise very small diameter studs. For conversion to a spherical bearing rod end, the taper in the steering arm may need to be enlarged. In such cases a category 1D-authorised LVV Certifier must ensure the steering arm has sufficient physical size to allow for over-sizing the hole.

  Based on the minimum requirements, specified in NZCCM Chapter 7 (Steering Systems) for a custom steering arm, there should be no less than 8mm of material at the narrowest point surrounding the taper; however, this can vary based on the LVV Certifier's assessment of the steering arm including material specifications, and the physical material surrounding the taper.

  The LVV Certifier must ensure all aspects of the steering arm are suitable as stated above.

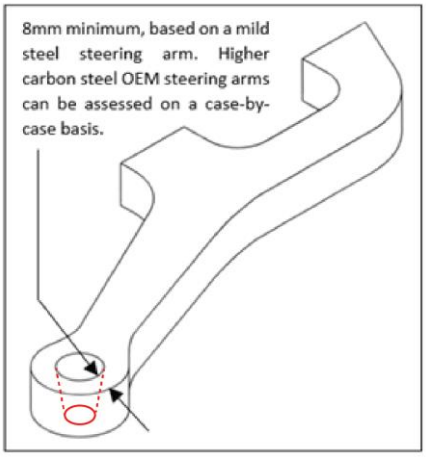


Diagram 1 *– steering arm physical size*

Drilling or reaming of steering arms

Correct tools and equipment must be used to ensure fine and accurate tolerances, and a durable wear-resistant fit.

Creating or Modifying Tapers

Tapered reamers must always be used when creating or modifying a taper, and must precisely match the taper of the joint or pin being fitted.

Drilling

Twist-drills do not provide a smooth finish, leaving high and low areas. Good engineering practice is for holes to be drilled slightly under-size, followed by a parallel hone or reamer to create smoother sides, which achieves improved bolt tolerances (especially important when high side-loadings will be present).

Measuring pin drop length, and maximum allowable tapered pin dimensions

Measuring pin drop

The distance must always be measured from the surface of the steering arm (on the tie-rod side) to the vertical and horizontal centreline of the ball of the spherical bearing rod end.

Maximum pin drop and diameters

The maximum pin drop must not exceed 2.5 times the pin diameter (measured at the 'major diameter' of the taper). The minimum size of the 'major diameter' can never be less than 16 mm. *Note: The major diameter of the taper should be the same as the diameter of the straight-shank part of the pin with a +/- tolerance of 0.5mm.* (See Diagram 2).

The tapered pin thread 'minor diameter' (small end of the taper) should be no less than the OEM tie-rod end pin dimension. The recommended minimum 'minor diameter' is 13 mm. (See Diagram 2).

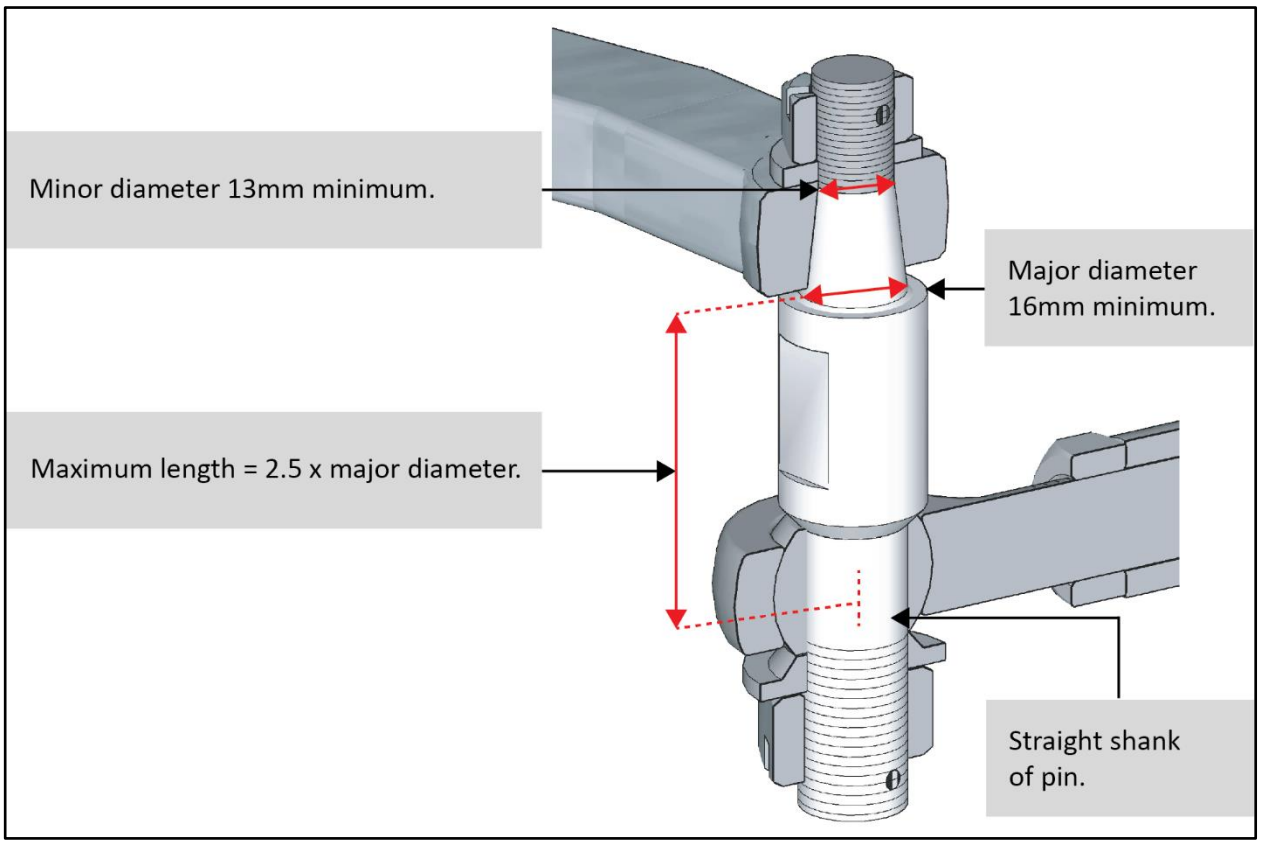


***Diagram 2**: Correct tapered pin length measurement method (GW illustration)*

Custom spherical bearing rod ends

All technical requirements for custom spherical bearing rod ends can be found in the NZCCM Chapter 7 (Steering Systems), Section 7.28.2, or Chapter 6 (Suspension Systems), Section 6.43.

For convenience, the requirements most commonly referred to are copied below:

A custom spherical bearing rod end fitted to a low volume vehicle must:

(a) be of premium quality, having a radial load-rating appropriate to the rod end size of not less than that specified in Table 6.3 (partially copied below); *and*

(b) be positioned in such a way that binding of the end cannot occur throughout the full range of suspension travel; and

(c) incorporate sufficient thread engagement to ensure the rod end is securely held in position; and

(d) be injected with a high-quality flexible lining material such as Teflon or Kevlar (this specifically precludes the use of brass-lined rod ends); and

(e) incorporate a retaining washer to prevent pull-out if the end becomes worn.

ROD END SIZE	LOAD RATING
▪ 16 mm (5/8”)	3340 kg (7350 lb) radial load
▪ 19 mm (3/4”)	5230 kg (11,500 lb) radial load

Table 1. *Custom spherical bearing rod end (radial) load-rating table.* ***Note****: This is an abridged version of the NZCCM, Table 6.3, showing only the typical sizes for this type of conversion, and omitting smaller sizes.*

Spacer tubes

Multiple spacer tubes or washers can be used for geometry set-up purposes to achieve ideal joint position, but to reduce any likelihood of incorrect assembly, a single-piece spacer tube must be used for final assembly and LVV certification.

Spacer tubes must be no less than 3mm wall thickness and can be made from mild or higher-grade steel, but no aluminium alloys. (See Diagram 4).

When a custom tapered pin is being manufactured, the spacer should be integral and machined into the pin, at the correct height (See Diagram 5).

Tie-rod adjusters

Non-OEM tie-rod adjusters must be made from mild or higher-grade steel, with a minimum dimension of 22mm OD x 5mm wall thickness. They must be manufactured from a single piece of material and attach to the drag-link or tie-rod ends by the use of threading and jamb-nuts. (See Diagram 4).

No aluminium alloys may be used, as it is difficult to prove grade/strength, and is more prone to galling, thread, and body damage.

Retaining washers and misalignment washers

Retaining washers are required on all single-shear mounted custom spherical bearing rod ends, to prevent bearing pull-out in the event of an end becoming worn.

In some cases, due to higher joint articulation, a misalignment washer may be required. In all cases a washer should be at least 2mm thick and must be large enough in diameter to positively prevent joint separation.

Washers must be made of steel and can be custom-made or aftermarket.

Geometry

As with any geometry-changing modification, the vehicle will require its own bump-steer inspection, which must be witnessed and signed off by an LVV Certifier.

- If custom pins are made, bump-steer should be optimised before the final manufacture of the pins.
- For details on performing a bump-steer swing-check, including helpful diagnostic information, refer to the Information Sheets section of the LVVTA website, under the Documents tab at www.lvvta.org.nz for the following Information Sheets:
    - Info 04-2010 - Bump-Steer Measurement Background Information
    - Info 05-2010 - Bump-Steer Swing-Check Procedure
- All other applicable steering and suspension geometry requirements should be considered concurrently, as often geometry changes have flow-on effects to other geometry aspects of a vehicle. These will all need to be checked by an LVV Certifier.
- Vehicle Operation requirements which are contained in NZCCM Chapter 19 (Vehicle Operation) give clear guidance on what is expected of your vehicle in terms of driving characteristics, including steering, suspension, and braking performance.
- All technical requirements for fasteners must be met.

These requirements can be found in NZCCM Chapter 18 (Attachment Systems), which can be downloaded at no charge at www.lvvta.org.nz.

For convenience, the requirements most commonly referred to are copied below:

A fastener used in a safety-related application within a low volume vehicle must:

(a) be of an appropriate size and grade for the application; and

(b) be secured with a 'nyloc' nut, spring washer, split-pin, or other vibration-proof locking device; and

(c) be in good condition.

Note: 'Loctite' or other thread adhesives are not an approved vibration-proof locking device for the purpose of LVV certification, as such a system would require an LVV Certifier to 'approve' something he is unable to see.

A fastener used in a safety-related application within a low volume vehicle that is used to perform a critical function, attach critical components, or attach components that are under, or transmit, high loadings must, in addition to 18.2 and 18.3:

a. have the correct shank area for the application (See Diagram 3)

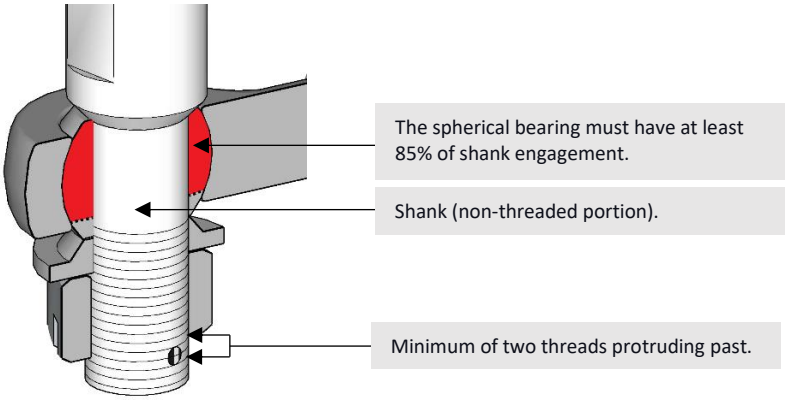


Diagram 3: *Correct shank area. (GW illustration).*

Aftermarket tapered pin requirements (off-the-shelf aftermarket components)

When aftermarket tapered pins are used, they must be manufactured by a reputable steering component manufacturer.

4140 grade alloy steel (or comparable steel) is recommended for all tapered pins. Documentation from the manufacturer must be supplied confirming the material specification, and proof of purchase will be required by the LVV Certifier, and copies of these are to be included with the form-sets.

An aftermarket tapered pin assembly should incorporate the best-practice engineering principles shown in Diagram 4 below.

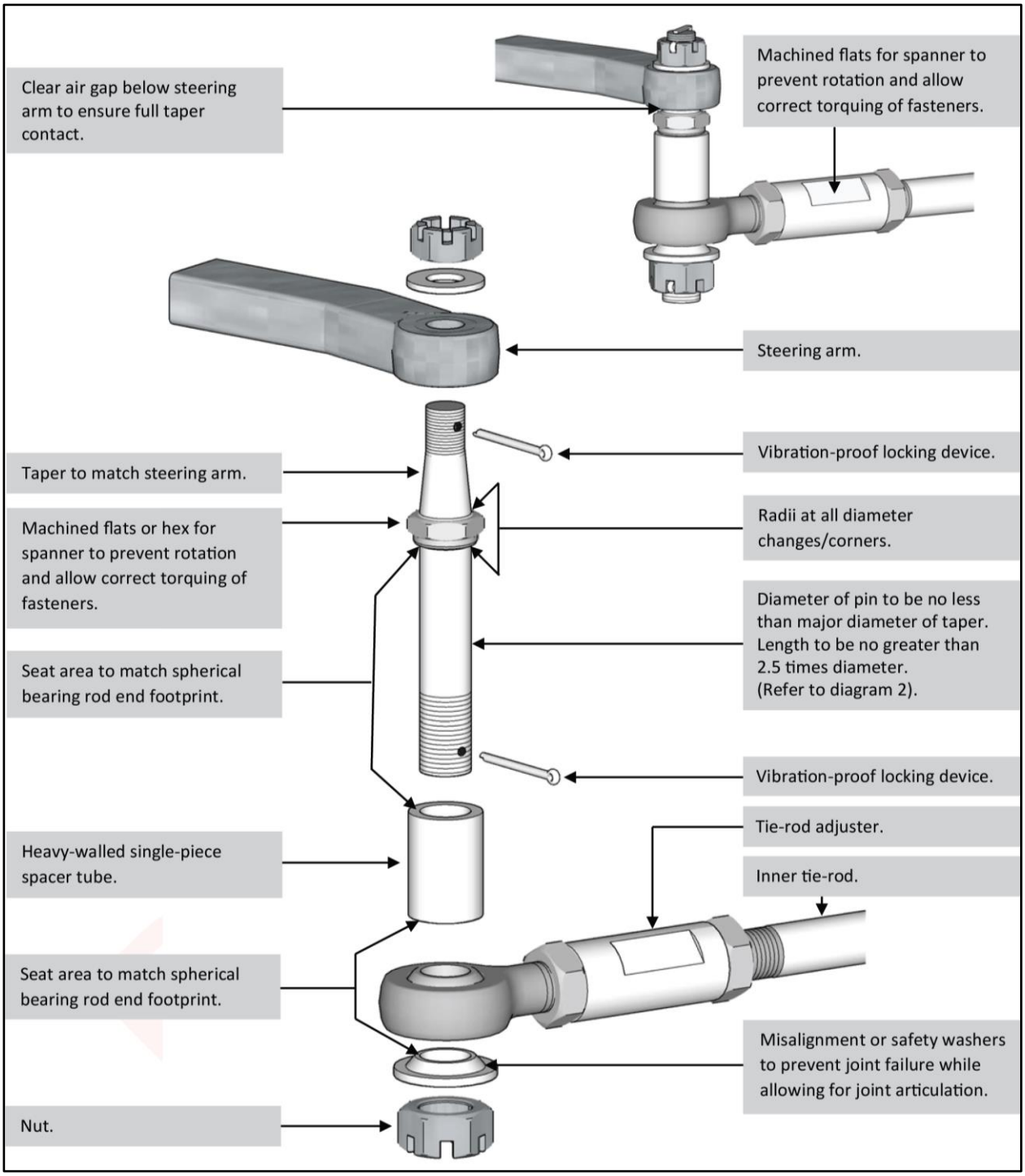


Diagram 4: *Aftermarket Tapered Pin Assembly (GW illustration).*

Custom-made tapered pin requirements (custom-manufactured on a one-off basis)

The use of a custom-made pin may be necessary or preferable in a situation where a suitable off-the-shelf aftermarket pin is not available.

A custom-made tapered pin assembly should incorporate the best-practice engineering principles shown in Diagram 5 below, and within the text on the following page.

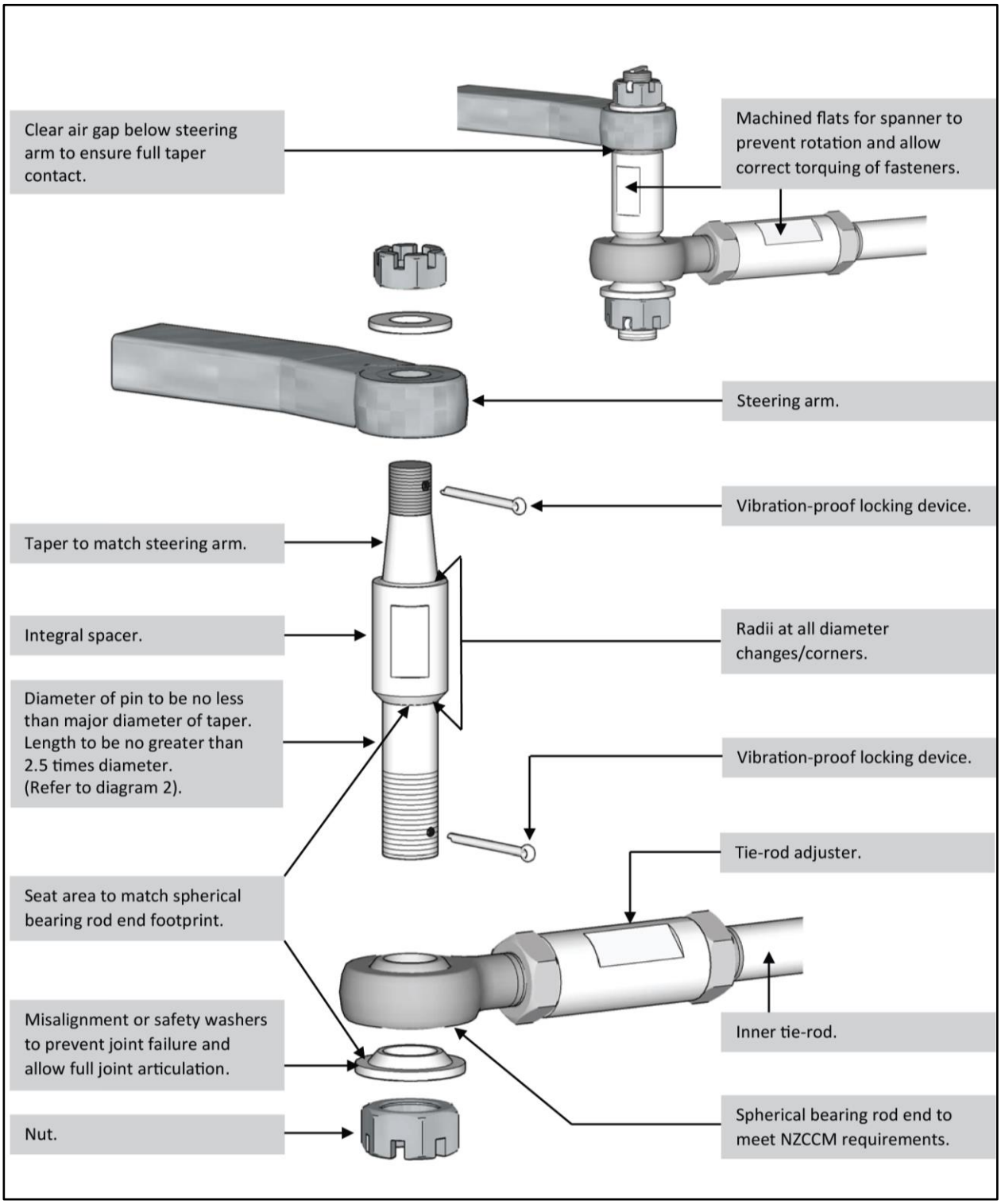


Diagram 5: *Custom-made Tapered Pin Assembly (GW illustration).*

A custom-made tapered pin assembly must meet the following requirements.

- 4140 grade alloy steel (or comparable steel) is required for all tapered pins. Documentation (i.e., a material test report) must be supplied verifying the specification of the material, along with proof-of-purchase. The LVV Certifier will require copies to include with the form-sets.
- Machining must be carried out by a competent precision machinist. Sound engineering practices and principles must be adhered to throughout manufacture; surface finish and adequate radii at diameter changes are important requirements.
- Assembly tolerances and clearances are required to be a snug, or soft interference fit.
- Minimum seat area for an integral machined shoulder should be no less than the seat area of the spherical joint that it will seat against. For example, a 16mm rod end generally has a 3mm seat area.
- Parts are required to be made in one piece if possible. This avoids installation errors now and in the future.
- If used, spacer tubes must be no less than 3mm in wall thickness. If larger spacer tubes are used, they can be chamfered to provide joint clearance as required to match the seat area of the spherical joint. They must be made with steel pipe, with a minimum specification of 250MPa mild steel.
- Threads must be well-formed, no smaller in diameter than the shank on the joint side, and no smaller in diameter at the smallest end of the taper on the steering arm side.

Other methods

There are a number of other methods of achieving geometry improvements, as alternatives to the tapered pin system described in this Information Sheet. Some of these other methods are as follows.

Bolt-through method (removal of taper in steering arm)

This method is detailed in the NZCCM Chapter 7 (Steering Systems) Section 7.28.2(h). It requires drilling and precision reaming and is suitable when the spherical joint will be clamped directly to the steering arm, or when only a small spacer is required. The maximum pin drop must not exceed 2.0 times the bolt shank diameter.

To measure the drop, the distance must always be measured from the surface of the steering arm (on the tie-rod side) to the vertical and horizontal centreline of the ball of the spherical bearing rod end.

Reverse tapers

When a tie-rod end is 'flipped' from top to the bottom on a steering arm (or vice-versa), the hole must be enlarged to allow for the larger taper. The steering arm should first be assessed to ensure adequate material will remain in the area surrounding the largest part of the new taper, once created. The newly created taper must include suitable surface contact area with the tie-rod or tapered pin.

- Adding a half-taper to the other side of the steering arm reduces taper contact and is not suitable.
- Tapered inserts must not be used.

For all other methods

For alternative methods of converting OEM steering or suspension joints to spherical bearing rod ends not covered here, you should contact your 1D-category LVV Certifier for advice and guidance in the first instance.

In some cases, an LVV Certifier may refer a modifier to an LVVTA technical staff member for advice, who may if necessary, refer the modifier to the TAC for individual approval in writing.

Further assistance

For any assistance in the use of this Information Sheet please contact your LVV Certifier, or a member of the LVVTA Technical Team by emailing tech@lvvta.org.nz.

A special thanks to: *LVVTA Technical Advisory Committee Member Graham Walls, for the illustrations/diagrams used throughout this Information Sheet.*