ADR COMPLIANCE SERVICES

CONSULTING ENGINEERS

A DIVISION OF CHAMONIX (AUST) PTY LIMITED * ABN 38 123 915 793

Report on Hoffman Group Helix Brand Aftermarket Steering Column

Introduction

The Hoffman Group manufactures a tilt adjustable steering column to be used in modified vehicles. It has requested ADR Compliance Services to test the column to confirm its compliance with applicable standards and design rules and its suitability for use in modified vehicles.

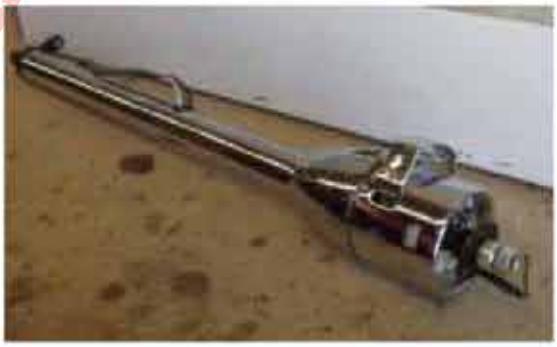
Specifically ADR compliance services has been requested to confirm:

1. that the polymer bush at the centre of the tilt joint is adequate for the loads imposed and sufficiently resistant to wear
2. that the lower shaft upper "eye" is satisfactory for the usage.
3. that the universal joint that permits the column the tilt is of similar design to the unit used by Ford between 1981 and 2001
4. that the nut that secures the upper column in its housing is adequately retained;
5. that the pivot pins that permit the upper housing pivot relative to the lower are adequately retained;
6. that the tilt lock mechanism pivot pin is adequately retained; and
7. that the column is in itself of failsafe design.

The Hoffman group also requested that a torque load test be performed on a new Flaming River aftermarket "FR20001" tilting steering column to provide a point of reference.

Background

The Hoffman Group steering columns (part number STCOL1 tested) are not collapsible and are therefore only suitable for use in vehicles not required to comply with ADR 10/--. There are two versions available from the Hoffman group, one suitable for use with floor change and the other for column shift transmissions. In all respects relevant to this analysis the two versions are identical. In each case the external casing is chrome plated. They provide a tilt adjustment via a Cup and Pin type universal joint with a central self-lubricating polymer bush. The inner column that transmits steering effort is a 1" diameter double D shaft designed to mount to a steering box or rack via a suitable universal joint. The tilt mechanism provides five locking positions.



Hoffman tilt adjustable steering column

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Process

A Helix Brand STCOL1 steering column was randomly selected from the group's Australian stock of over 50. The selected column came from the centre position on the pallet.

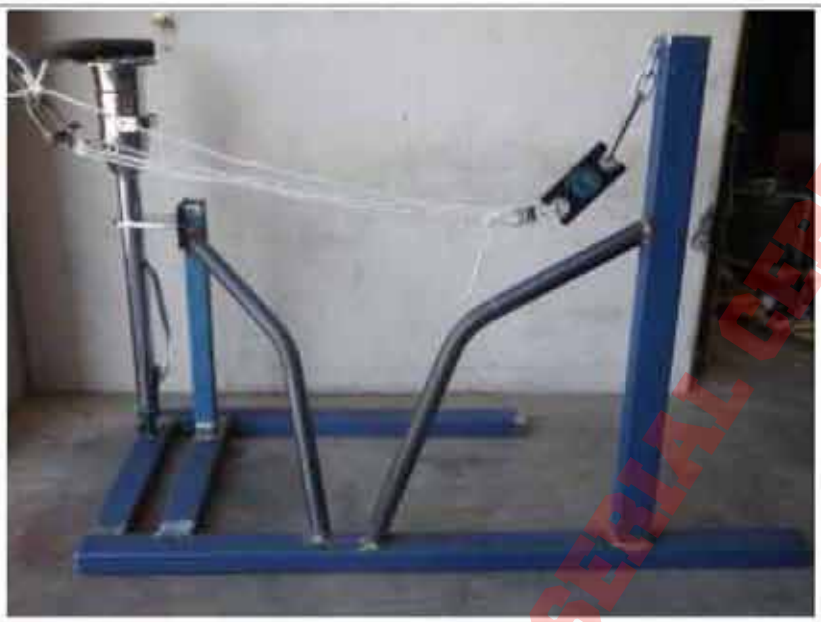
1. Torque Capacity

The column was removed from the new and sealed packaging and installed in a special-purpose jig. The jig has been designed to allow simulated steering loads to be applied to the column, with the objective of determining its torsional strength.

The jig supports the column to be tested and allows loads to be applied via a standard steering wheel adapter and a 500 mm long torque arm secured to the steering wheel adapter. A block and tackle allows sufficient force to be generated and a calibrated load cell records the load applied. It is noted that as the load is applied the effective torque arm becomes shorter through small elastic (and then plastic) rotation of the column. The effective length of the torque arm is measured at peak load to adjust for this.

Column installed in test jig

Detail of inner column locating spigot



Immediately prior to test.

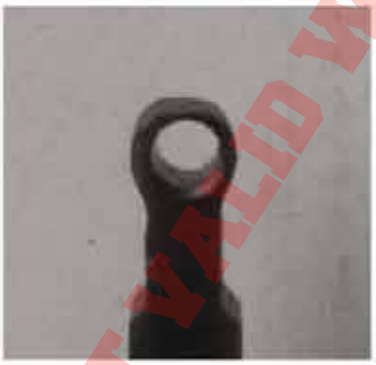
The tests were recorded on video and are available for review.

Findings

A 194Nm torque was applied to the column and no plastic deformation was observed. The applied torque was then gradually increased to 225Nm at which time some apparent plastic deformation was observed. When the load was released the column was measured to have twisted by 3.5 degrees from its starting position.

2. Lower Shaft Eye Joint

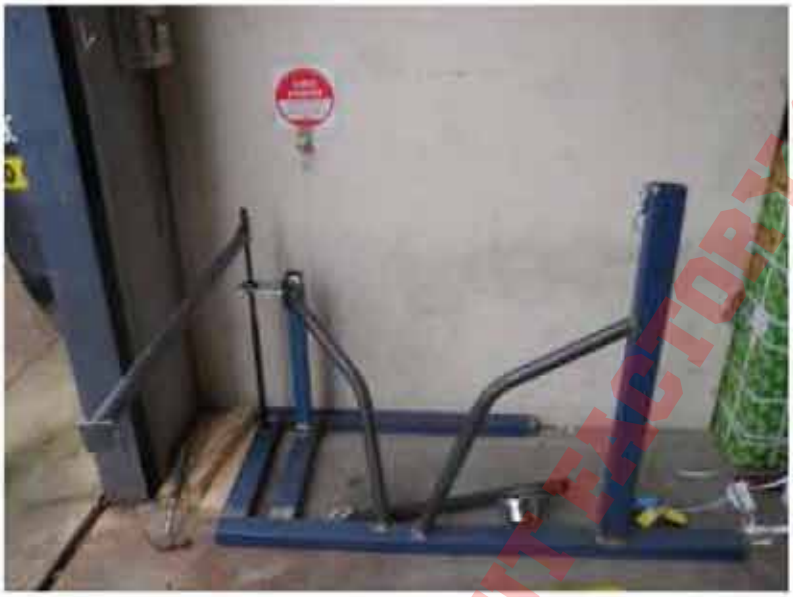
The lower shaft features an 8mm diameter hole through which passes the lower pin that mounts the polymer bush that in turn allows the tilt functionality of the steering column. The shaft is machined in this vicinity to provide clearance for the polymer bush to pivot. Examination of five Hoffman columns revealed some variation in the machining of this clearance.



Shaft Eye showing apparent irregular machining

A total of five lower column shafts were inspected and while some variation was noted the in the thickness of the material around the eye this variation was relatively small. The thickness of the material was measured at seven points around the eye on five shafts. The variation from the mean recorded was between 1.6 and 6.5%. It was also noted that photographs of the shafts appear to exaggerate the differences in the shaft ends unless the relative positions of shaft and camera are identical. There is also some variation in the chamfers on the outside of the eye which appears to contribute to this effect.

The robustness of the shaft ends was also tested by applying a similar test to that described in Section 1. Each of the five lower shafts and a genuine Ford item were installed in the test jig in turn and loaded through a revised torque arm until plastic deformation was observed.



Lower Shaft installed in test jig, note revised torque arm

Findings

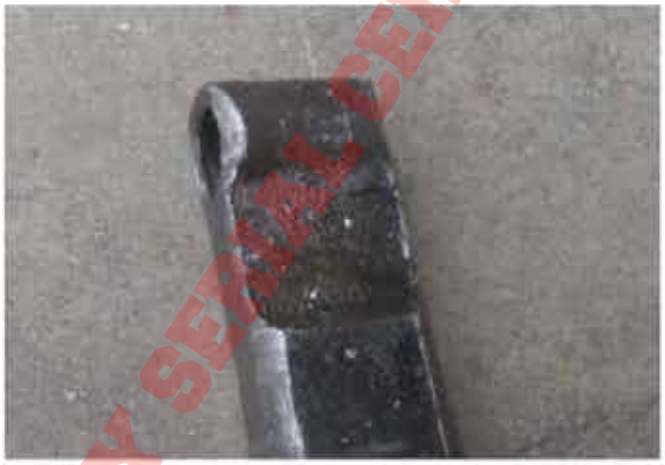
Shaft	Yield Torque
1	210Nm
2	205Nm
3	200Nm
4	210Nm
5	195Nm
Ford OEM	225Nm

Torque was increased in an attempt to determine the Ultimate tensile strength of this part of the column. No column failed at loads of up to 240Nm, plastic deformation was present in all, the only

cracking that was observed was noted in the Ford column. No sudden failure was able to be induced. Indicating that steering would not be lost through a failure at any, practically possible, load level.

In the very unlikely event of an overload leading to plastic deformation, steering would not be lost. The damage would however be obvious to the driver as the steering wheel would be offset.

Ford Column post test (crack circled)



Hoffman Column post test (note twist)

Discussion

Vehicle Standards Bulletin 14 sets the minimum standards for modified and individually constructed vehicles in Australia. This requires that the steering column be capable of sustaining a torque of 200Nm.

Measurements taken by Steve Fox (design Judge Formula SAE) of sixteen 18 to 23-year-olds of varying heights and weights showed that the maximum peak torque an individual could apply to a 254 mm diameter steering wheel was 88Nm. This is equivalent to 132 Nm through a 381 mm diameter (15 inch) steering wheel.

Mr Fox also noted in his July 2010 paper "Cockpit Control Forces" that "Production cars from the automotive OEMs have steering torque specifications of 175 Nm (130 ft.lb) yield with 240 Nm (175 ft.lb.) minimum ultimate strength."

The Helix Brand column demonstrated a yield torque of well above 175 Nm and ultimate strength of greater than 240 Nm.

It is noted that the top portion of the lower column and not the polymer universal joint is the most likely point of plastic deformation.

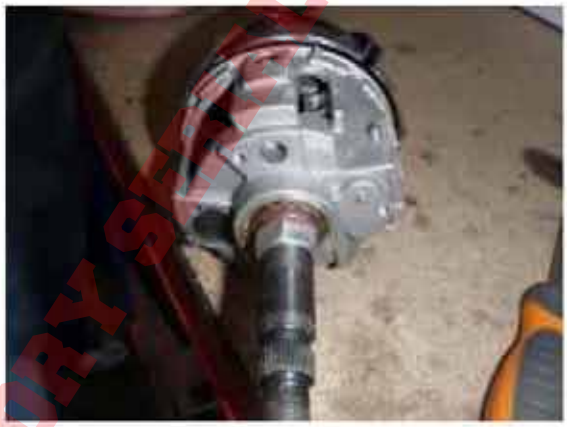
The Helix Brand column as a whole and the polymer element in the universal joint in particular has been shown to be adequate for these torque loads.

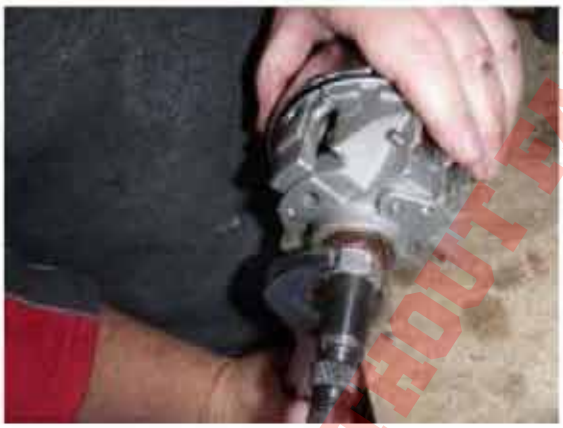
3.

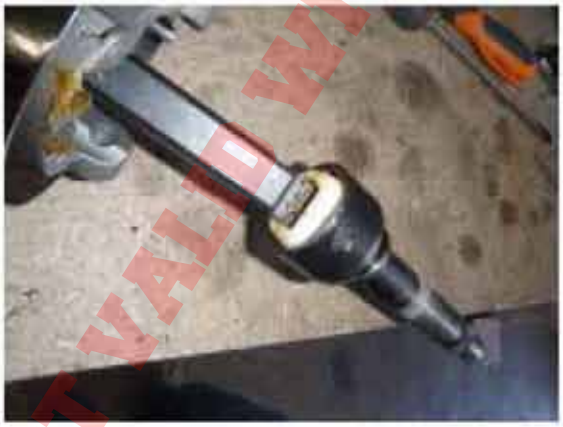
4. **Similarity to The Ford tilt Steering Column.**

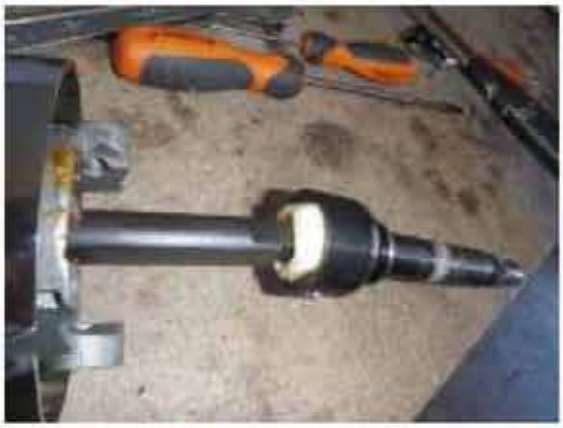
The Helix Brand steering column that had been torsionalloaded during testing was then stripped so that the universal joint that permits the tilt function could be examined along with the various pivot pins and the locking mechanism. The disassembly process was photographed.

No deformation of the polymer bush was observed.









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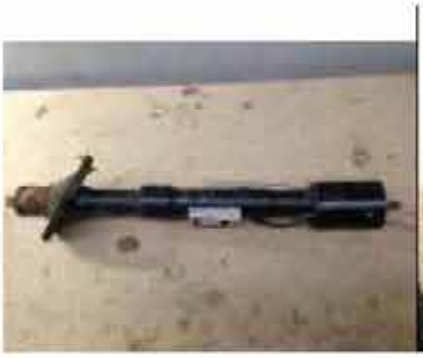
A used steering column from a 1985 forward F1 50 light truck was obtained from the USA. This unit was stripped so that the universal joint that provides the tilt function could be examined. The following photographs show the Ford column being disassembled and details of the universal joint that provides the tilt functionality.

The polymer bushes from both the Ford and Hoffman group joints were removed and sent to ExcelPlas Polymer Technology for identification. (see appendix A.) They were found to be made from the same material Polyoxymethylene (Acetal) (POM.

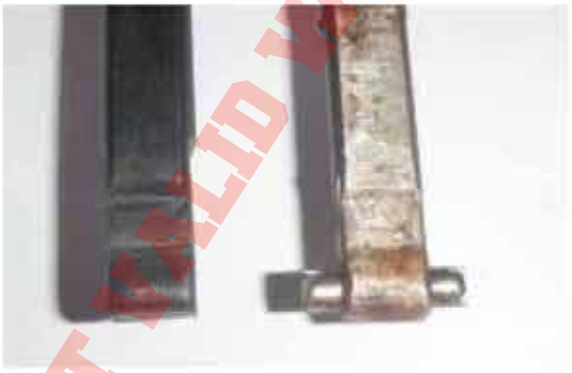


Ford OEM Complete Column

Outer Cover removed

Locking Mechanism

Ford OEM Column Universal Joint Exposed, note polymer bush and pivot pins.



Ford OEM and Hoffman Group (left) Top end of lower columns.

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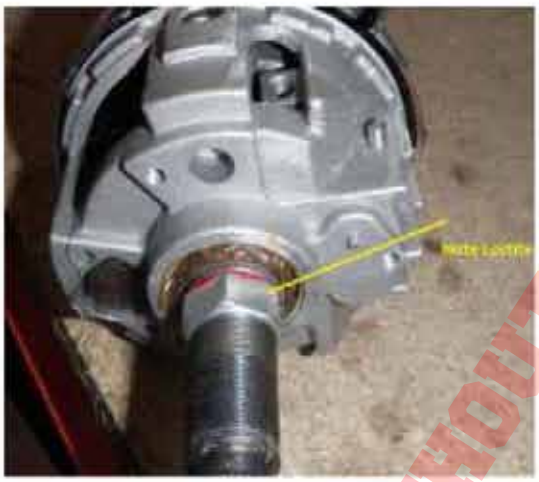
Findings

The design of the Ford and Hoffman Group tilt adjustable steering column joints are effectively the same. Pins are the same diameter (8mm), the lower and upper shaft and the joint are similarly shaped. The polymer bush is similarly shaped and manufactured from the same material.

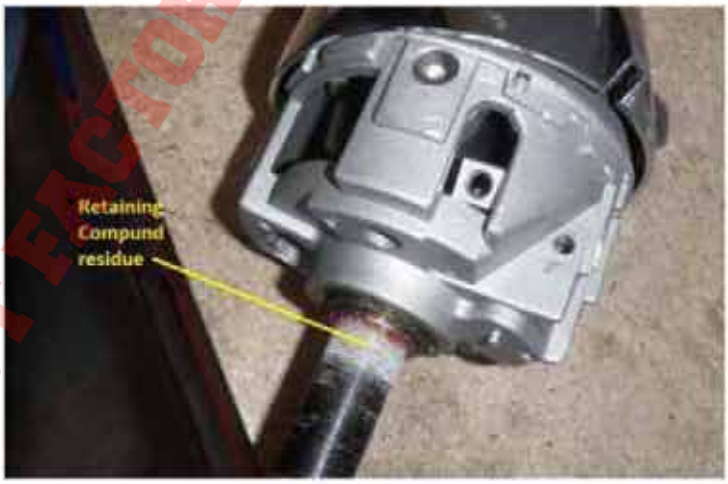
In all relevant respects the universal joint that allows tilt in the Hoffman and Ford columns are identical.

5. Retention of the Upper Column Securing Nut.

During the stripping of the Hoffman column it was observed that the securing nut had been secured with Loctite or a similar compound. The photographs below show the retaining compound evident before the nut was undone. The retaining compound residue is shown in the right-hand photograph. It was necessary to use a spanner to undo the nut along the entire length of the upper shaft, the retaining compound residue caused the thread to bind sufficiently such that the nut could not be undone without the use of tools.



Note Retaining Compound (red)



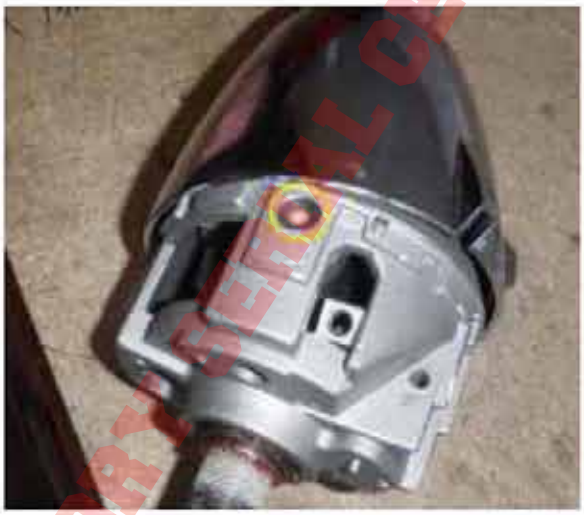
Retaining compound residue

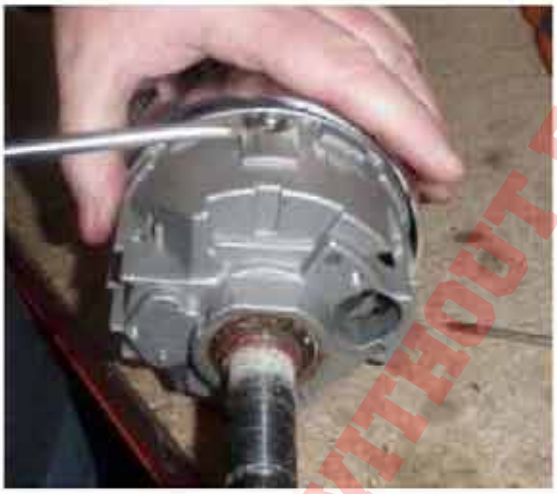
6. Retention of Upper Housing Pivot Pins

A pair of stepped pins are used to allow the Upper Housing and shaft the pivot relative to the lower column. The pins are a stepped design, the larger diameter was found to be a press fit into the Upper Housing. The photograph below shows the Hoffman pivot pin (right) with the equivalent Ford pin. Note the Ford items smaller diameter and shorter length. The photograph to the right shows the Hoffman pin in position. The Hoffman pin is removed by screwing a pan head screw into the centre of the pin and using a screwdriver to lever it from the housing.

Findings

With the outer cover installed over the upper housing these pins could not be removed as the clearance between the top of the pin and the outer housing is less than 2mm. The pin needs to be extracted by approximately 8mm before the housing is released.





7. Retention of the Tilt Lock Mechanism Pivot Pin

The tilt locking mechanism pivots on a long pivot pin, this is an easy interference fit in the upper housing. (see photograph) It can be removed with a pin punch and light hammering, it cannot be pushed from the housing without hammering. The pin is sufficiently long that it remains engaged at the required location relative to the housing even if it is driven as far as possible toward the outer cover.

Findings

With the outer cover in place the pin could not move sufficiently to allow the locking mechanism to disassemble. The end of the pivot pin would contact the inside of the cover before the pin became disengaged from the housing. The right-hand photograph below shows the pin in the position that it would contact the outer housing. The pin is still engaged in the left side of the housing. This is true also if the pin is driven in the opposite direction. The pivot pin cannot therefore work into a position that would allow the locking assembly to dissasemble the cover is in place.

It should be noted that a failure of the locking mechanism would not prevent the vehicle being steered.

8. Failsafe Design of the Column

A further test was devised to demonstrate that a cataclysmic failure of the polymer bush would not lead to the loss of steering control of the vehicle. It must be noted that as shown above a failure of this bush is extremely unlikely.

The universal joint polymer bush was removed completely from the steering column, simulating complete failure of the bush. The column was then reassembled ensuring that the relationship between the upper and lower portions of the inner column was exactly as it is when the bush is present and these two portions are connected via the pins.

The pin that normally secures the polymer bush to the lower steering shaft is sufficiently long that it is not possible for the Upper steering shaft to rotate by more than 80° without transferring rotational motion to the lower shaft .

To demonstrate this the steering column was then returned to the test jig used for the torsional test. A series of tests were conducted locking the column in each of its five tilt positions and rotating the

upper shaft via the torque arm to determine how much rotation was possible with the lower shaft secured in the jig.

Findings

At none of the five tilt positions was it possible to rotate the upper shaft by more than 80° when the lower shaft was fixed in the jig. The column was also tested at the extremities of movement of the tilt joint by leaving the locking mechanism unlatched. Again it was not possible to rotate the upper shaft by more than 80° with the lower shaft fixed. Therefore it has been shown that even in the extremely unlikely event of a catastrophic failure of the polymer bush, complete steering control is not lost.

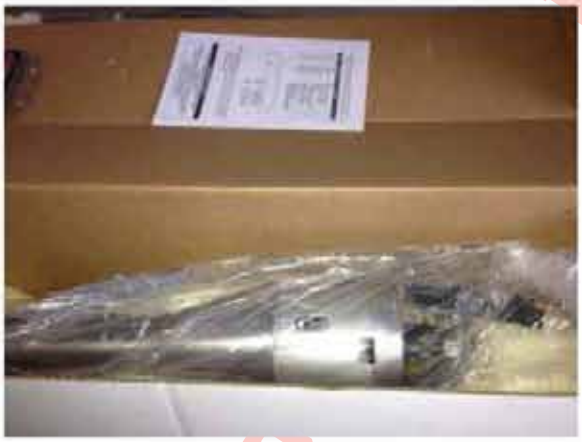
A similar test of a steering column that utilise the GM ball style of pivot universal joint revealed rotation of up to 75° when the ball was removed.

In circumstances where the polymer bush cataclysmically failed steering would be difficult but would not be lost completely. It is noted that the degree of free play in the column in this scenario is very similar to other original equipment columns that have encountered a similar failure.

In any case the similarity of the design to the Ford product means similar performance would be expected.

9. Flaming River Column Torque Test

The same test as performed on the Hoffman brand column and described above in section 1 was performed on the Flaming River FR20001 tilting Steering column.



Flaming River Column

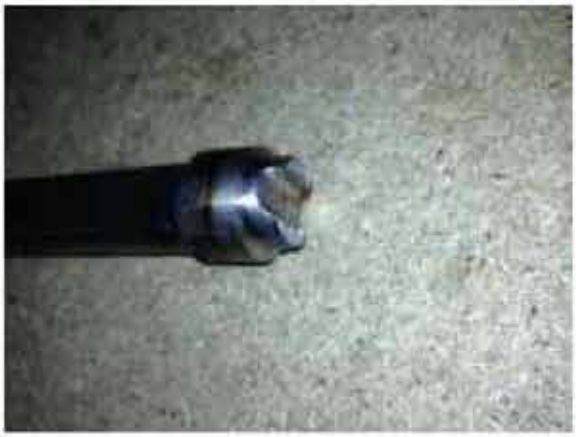
installed in jig, prior to test.

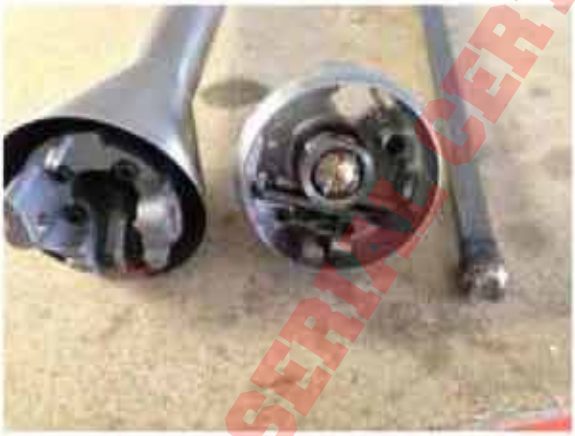
Findings

A torque of 154 Nm caused the Flaming River column to fail completely. All steering control would be lost if such a column were to fail in this way when installed in a vehicle. It is noted that this is

significantly below the 200Nm torque capacity required by VSB 14 and the column would not therefore be suitable for use in a modified vehicle that was to be certified to that standard.

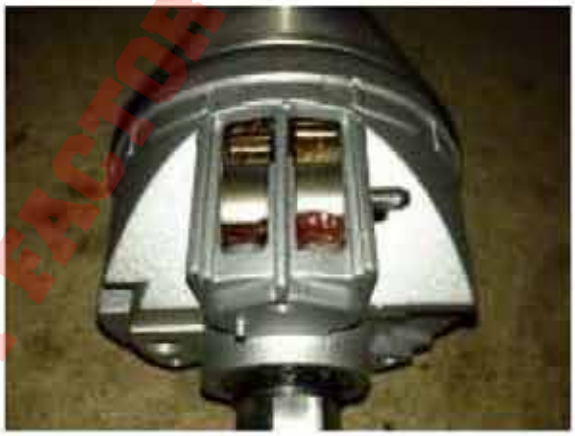
The column was stripped and it was found that the top portion of the steel lower shaft had failed.





Failed Flaming River Column

Failed Flaming River Column



Note similar locking pivot pin arrangement to Hoffman Column

Conclusions

The examination and testing of the aftermarket tilt adjustable steering column manufactured by the Hoffman group has shown that:

1. The polymer bush used in the universal joint is sufficiently robust for the usage, no plastic deformation was observed at a torque in excess of 200Nm;
2. The apparent variation in machining of the top of the lower column is small (<6.5%) and this component of the design, despite being the point in the design, most likely to deform, is satisfactory.
3. The pivot joint is of very similar design to the steering column used very widely by Ford for over 20 years;
4. The polymer bush itself is manufactured from this Acetal and is effectively identical to the item used by Ford;

5. the upper shaft retaining nut that secures the shaft in the housing is satisfactorily retained with Loctite or a similar compound;
6. The pivot pins that permit the upper housing to be adjusted for tilt cannot work loose and/or fall out of the housing with the upper steering column cover in place.
7. The pivot pin that mounts the steering column tilt locking mechanism cannot work loose such that the column pivot lock becomes disassembled; and
8. The entire steering column is of failsafe design, even a cataclysmic failure of the tilt adjustment universal joint bush will not lead to a total loss of steering.

This critical review of the steering column has found that it is well designed and will provide safe steering control of appropriately engineered modified vehicles.

It is expected that the columns will provide reliable service for a comparable period as the Ford items on which their design is based.

The Flaming River Column tested in the same manner however failed at a torque below the level required by VSB14 and failed to an unsafe condition. That is, steering control was lost completely.

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26 June 2013