



## Sceptre Application Notes Automotive Drive Line Components

Competitive pressures for greater efficiency and higher automotive performance have led to a dramatic tightening of tolerances and more sophisticated designs within the drive-line of the modern automobile.

Transferring rotational energy from the transmission to the wheels is a very complex task and a primary source of lost energy. In the current front wheel drive automobile the motor axis is more or less parallel to the front wheel axis when the wheels are pointing straight ahead. Once the front wheels are steered off of front center or the suspension exercised, then this misalignment increases and efficiency decreases.

The CV (constant velocity) joint allows for the misalignment of these two axes by turning of the rotational torque force from one axis to the other via spherical set ball raceways.



**Figure 1 Pictures of a typical CV constant velocity joint**

The complex geometry and required levels of precision have made this an interesting application, which takes advantage of several unique measuring and evaluation modes of the Sceptre system.

## Machine Configuration

The part was measured on a standard, three linear axes CMM without the need for a rotary table. Multiple components could be inspected on a pallet fixture where many parts are fixtured up to the volumetric capacity of the CMM.

Although a rotary table could have been used, there is a cost and efficiency savings to using a standard, three linear axis CMM. If the part was to be inspected centered on the rotary table, then this set up does not lend itself to unmanned pallet operation.

## External Contoured Profiles

The external contour of the CV joint is an engineered shape that is dimensions as a series of arcs and lines. That nominal shape is defined on a CAD drawing / file. Standard CMM evaluations (i.e. best-fit circles and lines) are poor tools for the analysis of these complex contours and tend to lead to poor repeatability and accuracy. Partial arcs and short relief angles do not lend themselves to deductive reasoning. (See Application Note)

A scanning CMM will scan the section the part and then have the system mathematically compare the measured section directly to the nominal CAD file. This process is similar to taking a mylare overlay chart on an optical comparator and seeing if the actual contour lies within a tolerance band

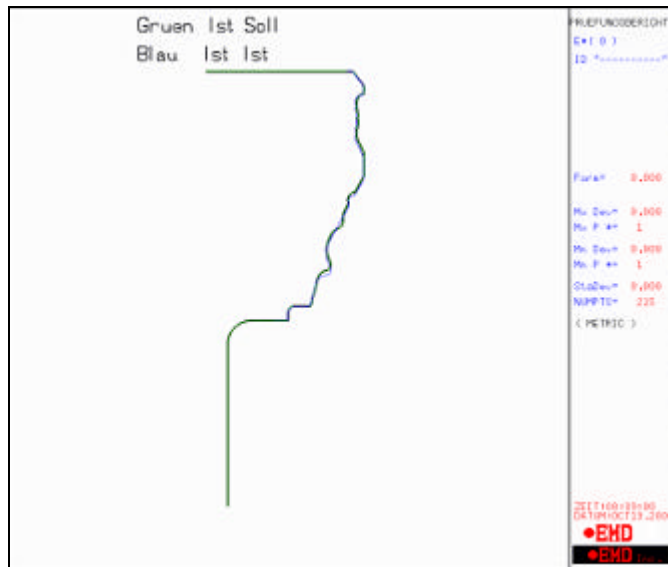


Figure 2 Exterior Scan using 1.0 mm stylus tip at 2mm/sec

## High Precision Working Surfaces

The interior geometry consists of a spherical surface which is interrupted by the six ball races that are equally spaced every 60 degrees. The part was inspected with a single stylus in an Omni directional-measuring mode. The stylus was an 18mm Ceramic Ball tip that was necessary to do the functional analysis of the raceway. This same tip was used on the ID spherical surface since it has ample shank to ball clearance.

Six scan sections were taken in the normal scan mode (planar cross sections) at a scan speed of 5.0mm per second and with a data point spacing of 50um. A best-fit sphere was calculated from all of the data and the following report was generated.

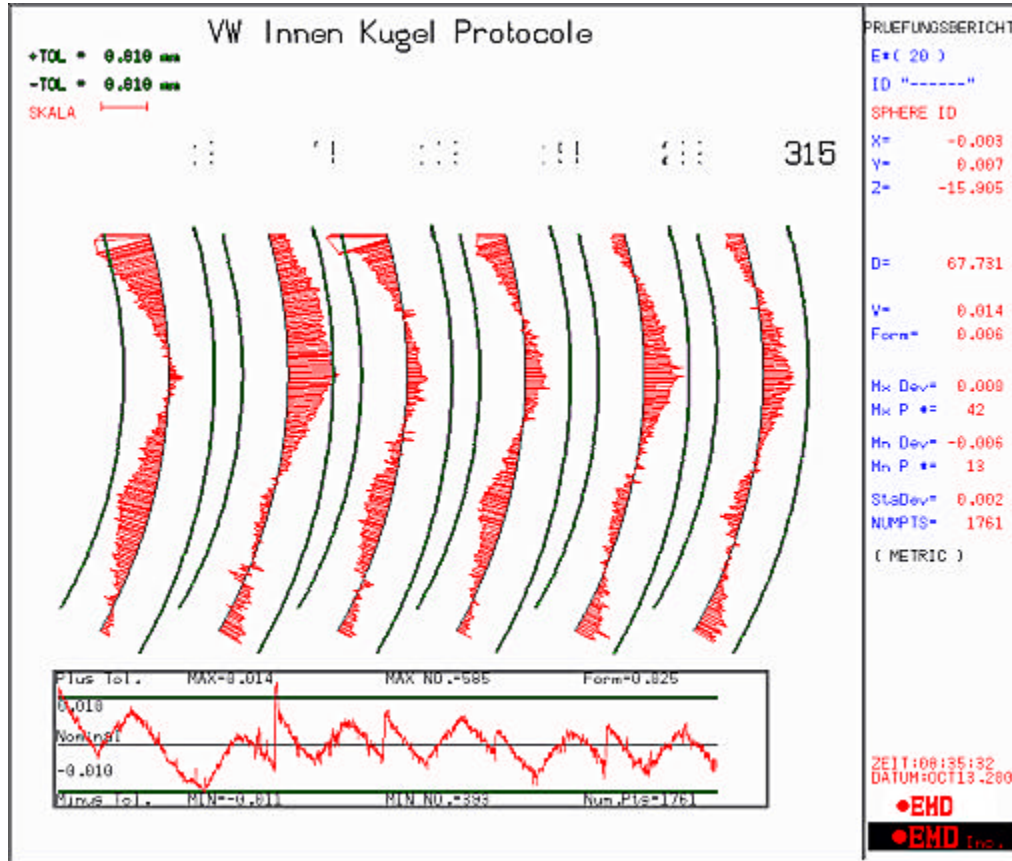


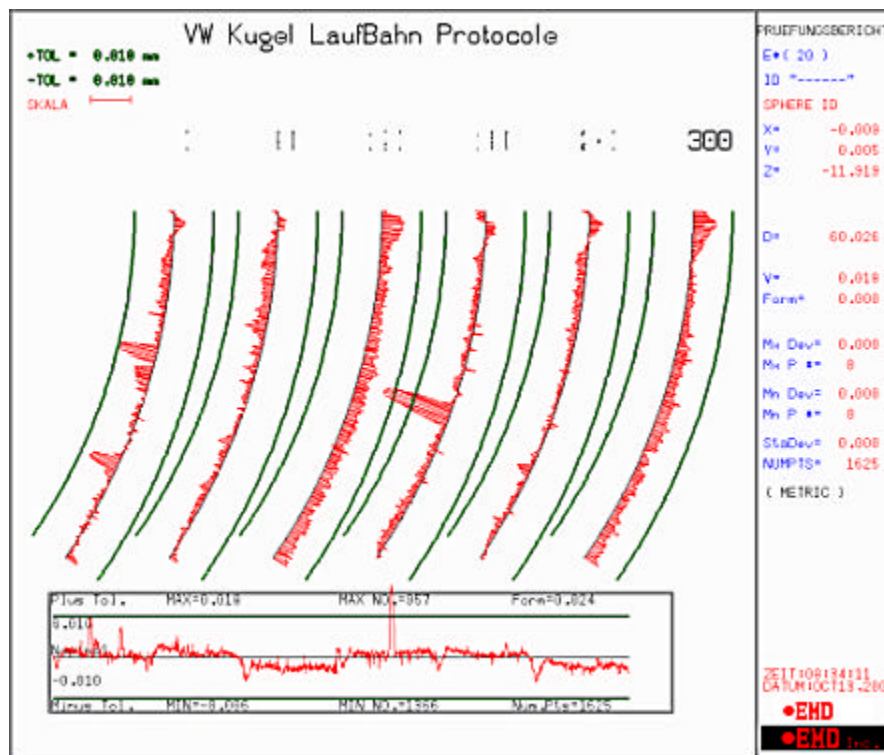
Figure 3 Spherical Evaluation of six cross sections

## Functional Analysis of Ball Race Ways

The ball races were inspected with a stylus ball tip that was the identical diameter as the intended balls of the completed final assembly. The self-centering scan mode was employed that essentially seated the stylus ball in the groove.

This yielded the functional path that the ball in the assembly would take when the joint is exercised.

The self centering mode is a complex sensor driven motion control mode that determines the motion path so that a constant contact force is maintained against the part while the forces acting on the stylus normal to the sectioning plane are driven to zero. Essentially finding the lowest path through the raceway.

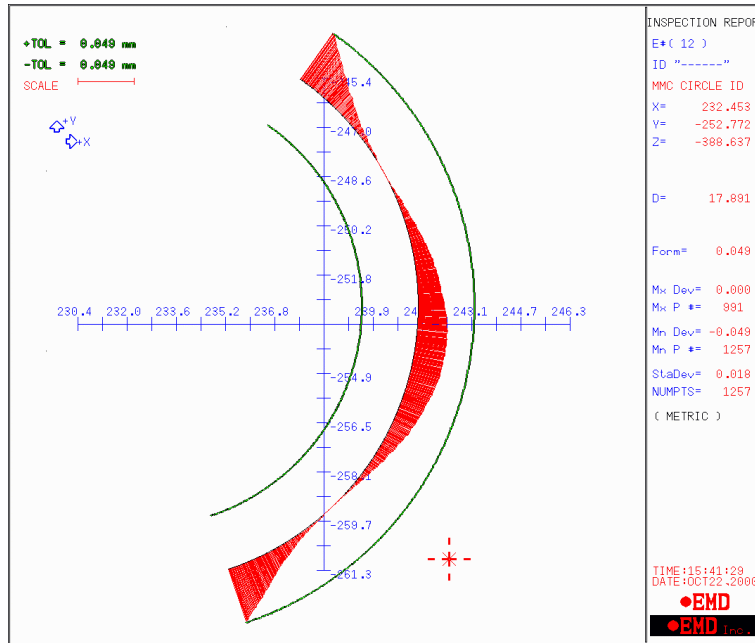


**Figure 4 Spherical Evaluation of the six ball races simulating the functional path of the balls in the joint assembly.**

### Profile Shape of the raceway (in the plane normal to the ball travel)

The raceway itself is a contour that has been engineered to maximize support of the balls at the 45-degree points essentially trapping the ball every 90 degrees. The relief's are engineered so that the lubricant has a place to be stored during operation. Under stress the raceway deflects maximizing the load-bearing surface.

We analyzed the raceway against a ball of a fixed diameter using (MMC) Maximum Material Criteria. This leads to the following analysis showing where the two contact points define the location of the fixed diameter. The remainder of the contour is in minus material variation.



**Figure 5 Shape of the raceway itself Evaluated against an 18mm Ball diameter to MMC or Functional location**

The contact or pressure angle (angle between the center of the ball and contact point on the raceway) is a critical dimension which effects the efficiency and life expectancy of the device.

### Surface Finish and Waviness

The performance of the joint is also greatly effected by surface finish and waviness of the ball race. As the ball rolls through the raceway, friction and roller bounce can cause early fatigue fractures and degradation of efficiency.

Measuring surface finish with conventional instrumentation is a difficult if not impossible task on this complex intricate internal geometry. Most surface roughness instruments can be used on only linear straight surfaces or on round surfaces centered on a rotary table. The gauging head usually requires plenty of access space, which is not readily available inside the CV joint.

The above profile data was taken with a high data point spacing of 10.0um while using a small ball stylus of 0.3mm radius. The same data that was used to determine geometry and profile can be processed, using appropriate filtering, to determine profile, waviness and surface roughness.

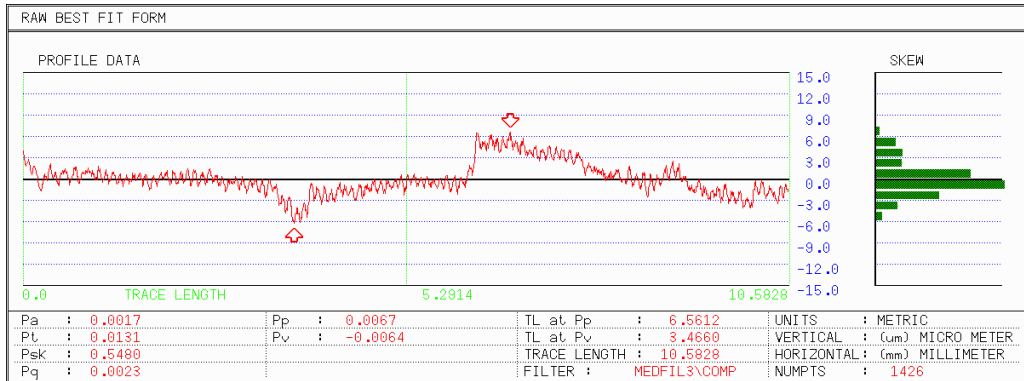


Figure 6 Raw Profile Data - Geometry and surface finish superimposed

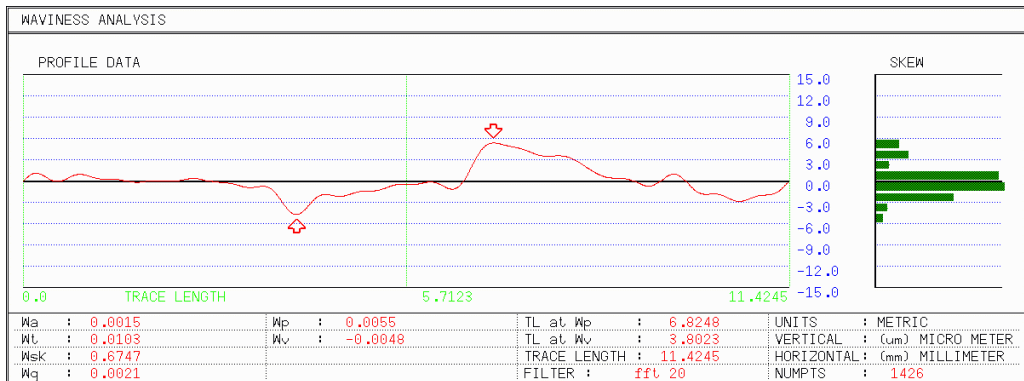


Figure 7 Waviness Analysis – Removed High Frequency Surface Finish

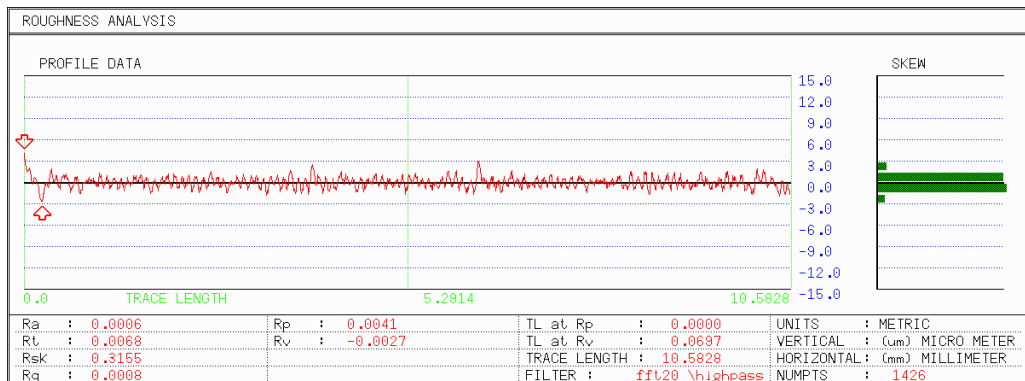


Figure 8 Surface Finish Analysis – Removed Low Frequency Geometry