Failure Analysis of a broken Centerlock Disc Brake Socket from the bushing of an Alfine-11-hub			
Type of analysis:	Failure analysis	Date:	2018-01-21
Status:	Final report	Task number	SAN-2018-001
part:	bushing, Alfine-11 hub	Manufacturer:	Shimano

1 Intention

The German subcontractor of Shimano, the company “Paul Lange”, rejected a warranty claim for a bushing of an Alfine-11 hub with a separated centerlock disc brake socket.

Ignoring its high-safety relevance the mentioned firm argued a nearly six year old part was no longer covered by warranty. A conscientious manufacturer would have carefully analyzed the root cause of the failure to improve usage safety as best he can – not so Paul Lange in cooperation with Shimano. Similarly a year ago in a claim considering slipping gears the significance of the failure was not recognized, accepting severe injury or even death of the customer.

2 Summary

After approximately 35.000 km and a bit less than 6 years in service the center-lock socket separated from the bushing of an Alfine-11 hub due to high cycle fatigue fracture. This evaluation results from an electron microscopy analysis of the fractured area as presented below. A failure due to a violent, forceful event can positively be excluded.

By means of a computer tomography a second faultless part was examined in order to understand the reasons for the failure of the first. The analysis revealed a very unfavorable design as the reason. The wall is especially thin in the transition area between the bushing and the center-lock brake disc socket coupled with a missing chamfer on the outside of the region with the highest mechanical load. It is not comprehensible why Shimano implemented unnecessarily such a predetermined breaking point in this highly safety-relevant component.

Apparently the transmission oil leaking from the developing crack reached the disc brake. This would explain the tendency of the break system to squeak towards the end of the usage period as well as the yellowish tarnish discovered inside the disc brake which must have resulted in an even higher mechanical load of the system.

3 Results

3.1 Optical inspection

The following pictures give a good impression of the visual appearance of the defect bushing and the fractured surface (Fig. 1-8). Since the center-lock socket rotated relative to the bushing after the separation had taken place large sections of the fractured surface are destroyed. Never the less enough faultless regions in indentations are left for the analysis as seen in chapter 3.3 Electron Microscopy (p.6).

Fig. 1: Bushing of the Alfine-11 hub: On the left side the socket of the centerlock disc brake is missing.

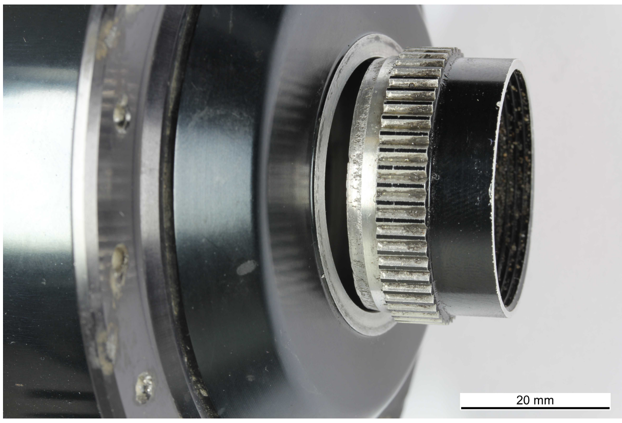


Fig. 2: The side of the bushing together with the separated centerlock disc socket

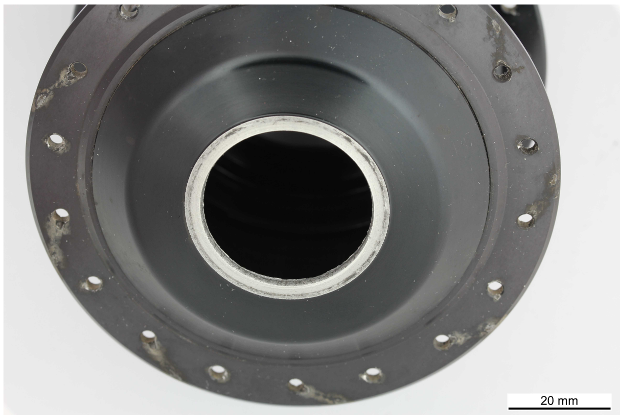


Fig. 3: Front of the bushing where the centerlock disc socket has separated

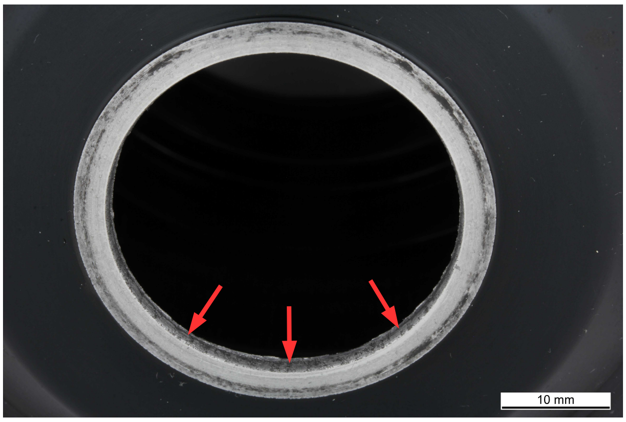


Fig. 4: Magnification of Fig. 3: The red arrows mark the fractured area.

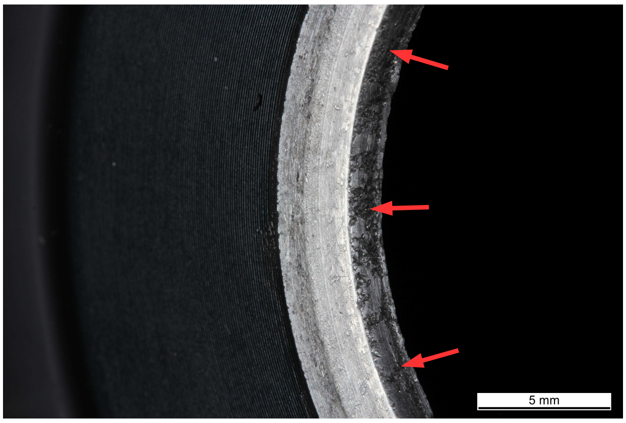


Fig. 5: Further magnification of Fig. 4 The red arrows mark the fractured area.

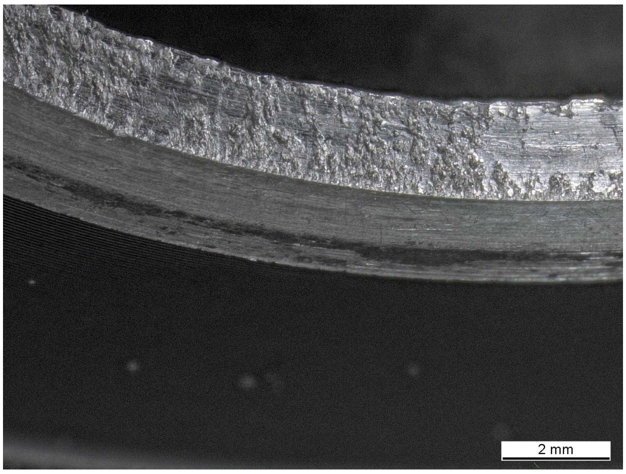


Fig. 6: Further magnification of the factured area similar to the one seen in Fig. 5.

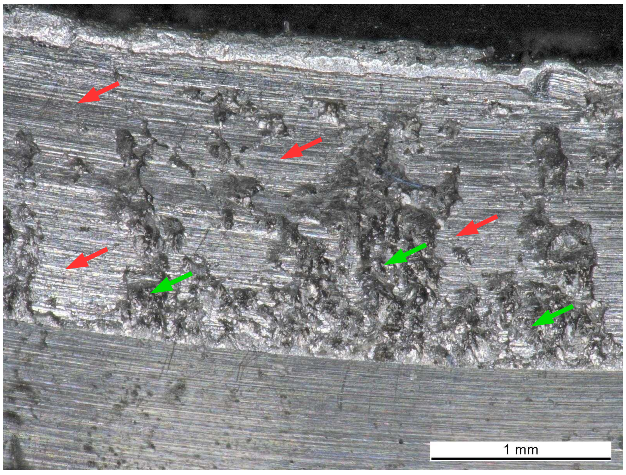


Fig. 7: Detail of the break area: The green arrows mark undamaged regions of the fractured area, whereas the red arrows mark destructed regions of the fractured area.

Fig. 8: The fractured area on the separated centerlock socket for the disc brake: The break area is destructed even more heavily on this side in comparison to the bushing side.

3.2 Computer Tomography of a comparison part

A used bushing was investigated on previous damage. This was done to insure the installation of a faultless spare part and to explore the part for weaknesses in the design of the part. Since a used part was purchased the history and production date are unknown.

The computer tomography (CT) was carried out with the pressfitted ball bearing (Fig. 9). The CT proves, that the steal bearing is correctly inserted into the press-fit. Due to the high absorption of the steal some artefacts are observed in the representation of the bushing, which falsely suggest a lower local density of the aluminum.

In the context of the failure it seems important that the center lock socket is connected to the bearing without a chamfer on the outside in the region of highest mechanical load. Moreover the transition area between the socket and the bushing has the least wall strength (1,9 mm, Fig. 9+10). It is not comprehensible why Shimano implemented unnecessarily such a predetermined breaking point in a highly safety-relevant component.

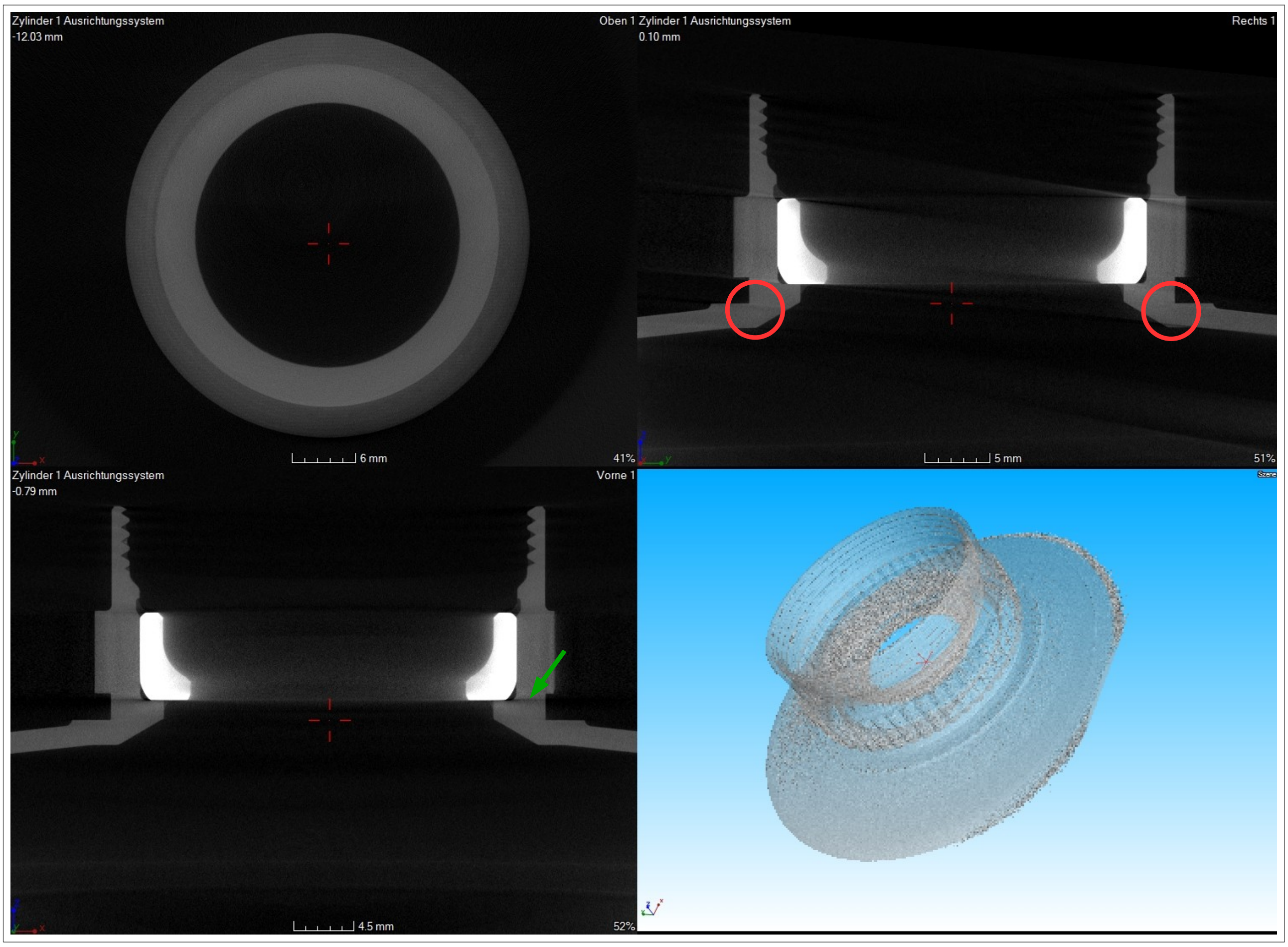


Fig. 9: Cutting plane of the faultless part from the 3D-CT for comparison:
The bearing in the press-fit shows clearly visible artefacts (green arrow, see text for details). The red circles mark the weakest spot of the component.

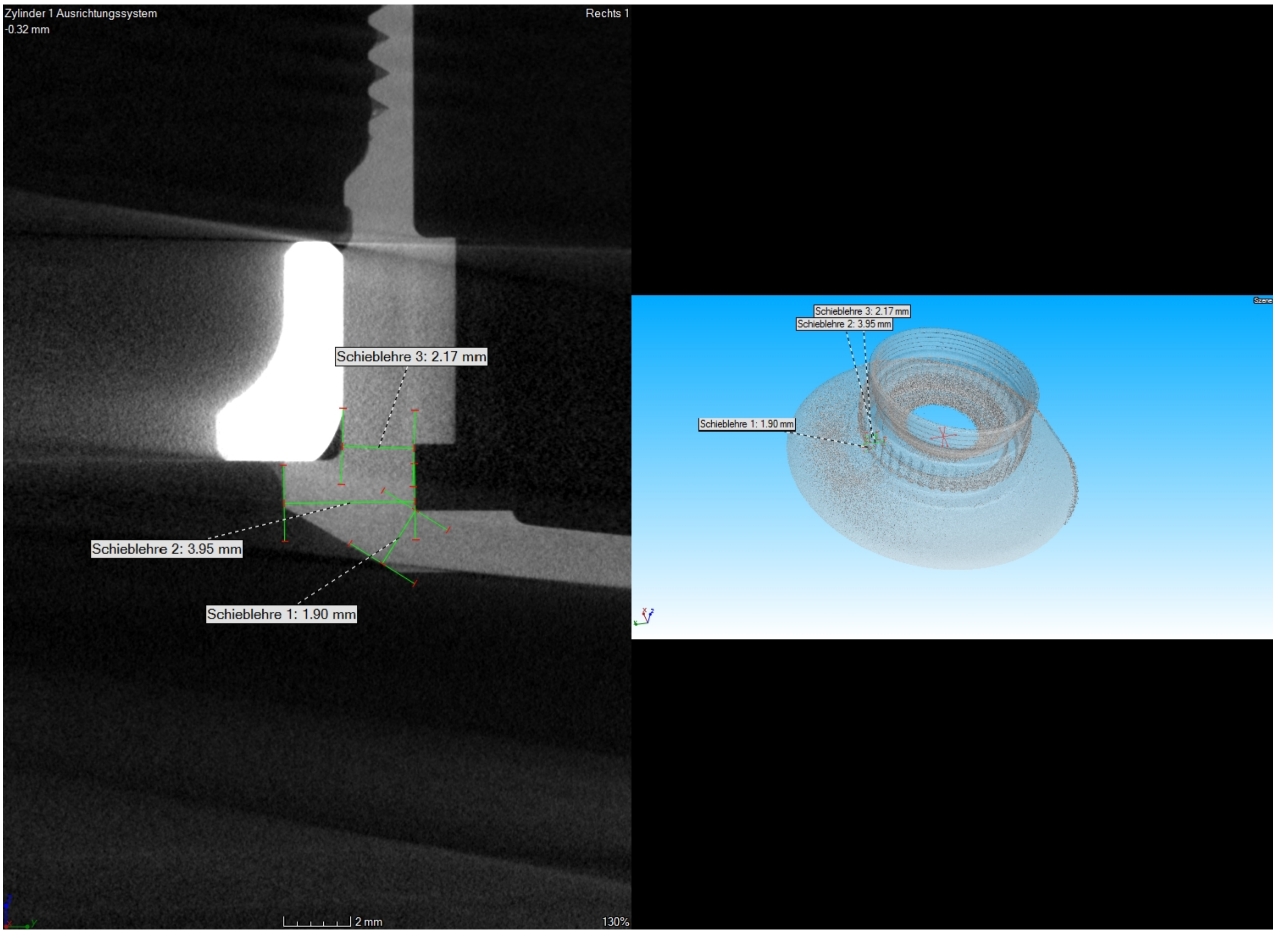


Fig. 10: Cutting plane of the faultless part from the 3D-CT for comparison: The wall thickness of the bushing was extracted from the CT. In the region of the separated center-lock disc brake socket the minimum wall thickness was less than 2 mm.

3.3 Electron Microscopy

In indentations all over the fractured surface of the remains of the bushing high cycle fatigue lines parallel to the axis of the wheel and perpendicular to the main mechanical load are found indicating that the part did not fail due to a violent, forceful event but due to an ongoing overstress leading to material wear out over a long period of time (two representative regions of the fractured surface see Fig. 11-16).

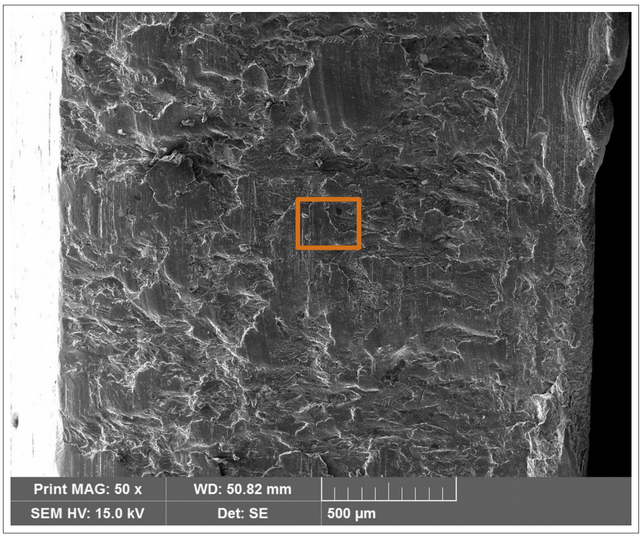


Fig. 11: Fractured surface where the brake-disc socket separated form the bushing:
left side = outer side
the colored rectangle indicates the magnified region in Fig. 12

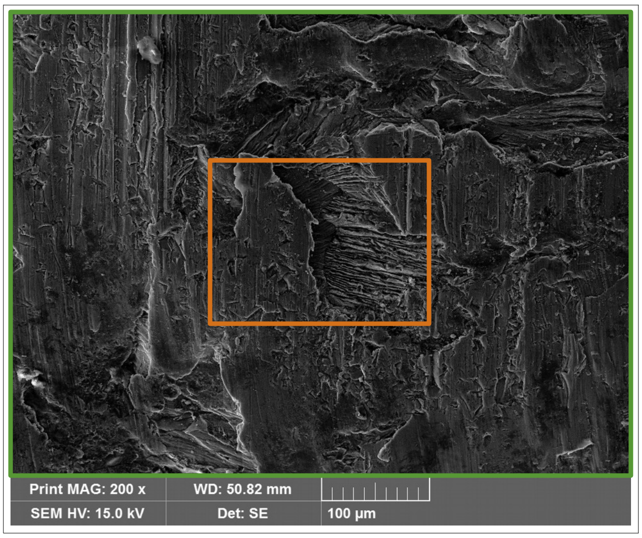
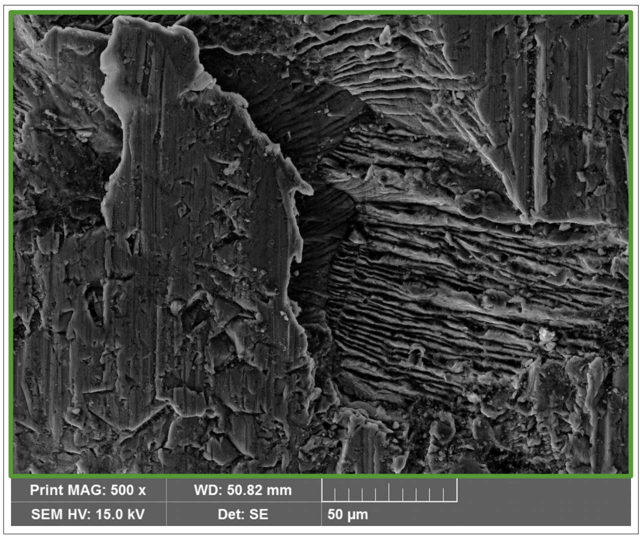


Fig. 12: Magnification from Fig. 11:
At this magnification typical lines perpendicular to the load direction become visible (compare with Fig. 13)

Fig. 13: Magnification from Fig. 12:
At this magnification the typical high cycle fatigue lines are clearly visible.



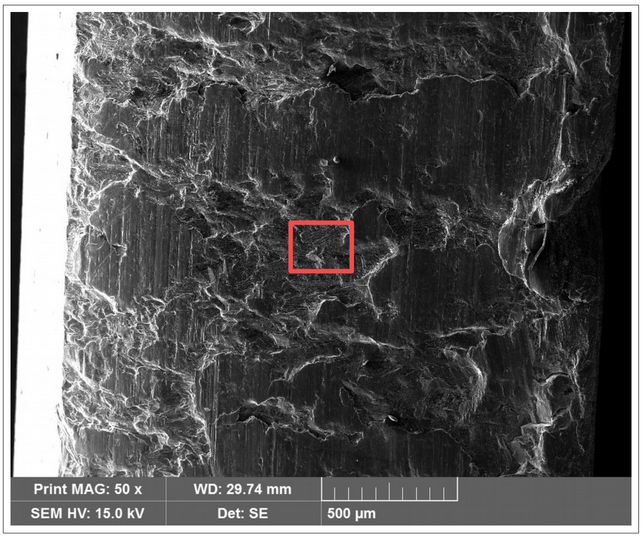


Fig. 14: A second fractured surface distant from the first on in Fig. 11:
left side = outer side
the colored rectangle indicates the magnified region in Fig. 15

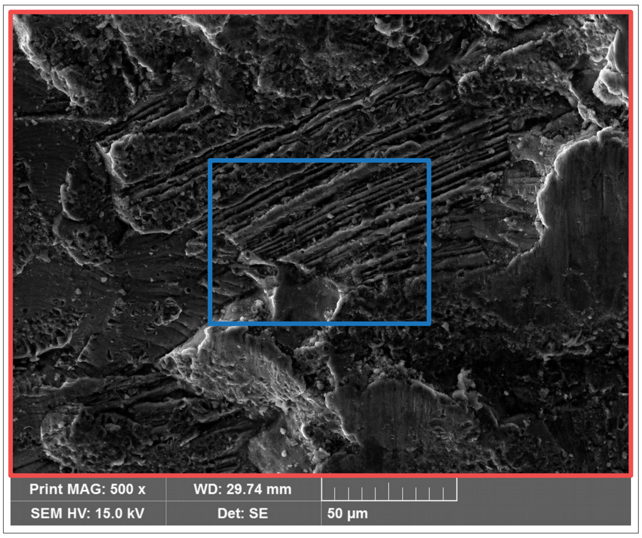


Fig. 15: Magnification from Fig. 14:
At this magnification typical lines perpendicular to the load direction become visible (compare with Fig. 16)

Fig. 16: Magnification from Fig. 15:
At this magnification the typical high cycle fatigue lines are clearly visible.