Reply to Reviewers Comments

Text in *italics* are reviewers comment, normal text is our reply. The reference section only contains those references which are newly introduced into this reply, i.e. which are not already in the manuscript.

Reviewer 3

I suggest the inclusion of Hobbs (1993) within the Introduction. This is an important paper for integrating structural geology with rock mechanics (note its inclusion within Comprehensive Rock Engineering, which is probably not on the reference list for most structural geologists), focussing on fractures and joint roughness.

We agree with the reviewer that Hobbs (1993) is an important reference to include into the Introduction section of the manuscript, in particular for its review of the fractal geometry of joint surfaces.

I suggest also the inclusion of, for example, Weerasekara et al. (2013) and/or Cleary and Morrison (2016), in the discussion regarding grain size reduction. Further, Cleary (2001) describes an approach for direct inclusion of breakage in the Distinct Element Method, now implemented on a supercomputer. Different mechanisms of grain size reduction are noted, and their energy approach to size reduction in DEM could well be applied in consideration of the mechanisms active during evolution of a fracture surface.

If future work was to include the simulation of grain size reduction, the “particle replacement” approach developed by Cleary (2001) could certainly be investigated as a computationally less expensive option to the full modeling of grain fracture as described by Thornton et al. (2004) or Abe and Mair (2005), although some details how this would work in conjunction with the bonded particle model, i.e. in the situation when the fracturing particle is still bonded to another particle, are not immediately clear. Also, the method appears to depend strongly on calibration data for the grain fracture process, which might not be readily available for the high stress / low strain rate conditions relevant for the triaxial deformation tests. This would probably be particularly relevant in light of the strong stress dependence of the relative importance of different comminution mechanisms (grain splitting vs. abrasion) shown by Mair and Abe (2011) under similar conditions.

We will add the following to the “Discussion” section of the manuscript after the sentence ending in line 371: “A computationally less expensive option to include grain size reduction into the numerical models might be to adapt the empirical particle replacement approach developed by Cleary (2001) to the specific requirements of the simulation of rock fracture under triaxial loading. However, as Weerasekara et al. (2013) point out, this approach is strongly dependent on the availability of good calibration data for the grain fracture under the specific stress and strain rate conditions of the process modeled.”

A figure would be helpful in 3.1, around lines 163-196, for visualisation of the model and the boundary constraints.

The model and the boundary conditions are shown in panel (a) of Figure 1 on page 4 of the manuscript. We will add a reference to Figure 1a at line 170.

References:

Mair K. and S. Abe, 2011, Breaking Up: Comminution Mechanisms in Sheared Simulated Fault Gouge, Pure. Appl. Geophys., 168(12), 2277-2288, doi: 10.1007/s00024-011-0266-6

Thornton, C., Ciomocos, M.T. and M.J. Adams, 2004, Numerical simulations diametrical compression tests on agglomerates, Powder Technology 140, 258 – 267, doi: 10.1016/j.powtec.2004.01.022