FROM: $$f_{B3B}(\alpha,\beta,\nu)=\frac{\nu-\nu_1}{\nu_2-\nu_1}\left[c_0+\frac{c_1+c_2\alpha+c_3\alpha^2+c_4\alpha^3}{1+c_5\alpha}(1+c_6\beta)-c_7+\frac{c_8+c_9\alpha+c_{10}\alpha^2+c_{11}\alpha^3}{1+c_{12}\alpha}(1+c_{13}\beta)\right]$$ [1]

THE B3B STRENGTH TEST

Extending and simplifying stress evaluation

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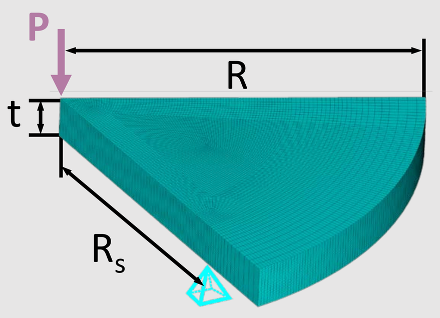
INTRODUCTION

The Ball-on-Three-Balls-Test (B3B) is a biaxial mechanical strength test with *[2]* :

- Flexible specimen size
- Easy handling and execution
- Low systematic error



$$\sigma_{max}=f_{B3B}\frac{P}{t^2}$$

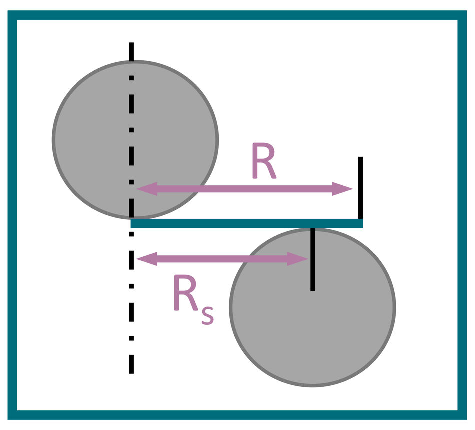
- No analytical solution
- Existing fit for f_{B3B} (top line) is unwieldy
- f_{B3B} is load-dependent at high loads

Aim

- Simplify fit for f_{B3B}
- Extend f_{B3B} to consider high loads

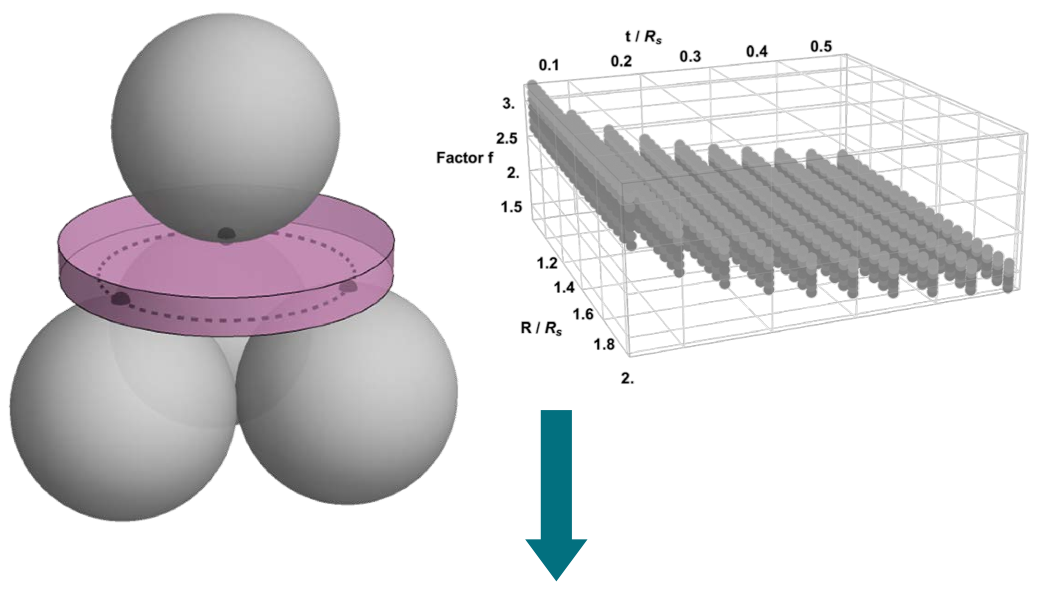
SIMPLIFICATION

$f\left(\frac{R_s}{R},\frac{t}{R},\nu\right)\rightarrow f\left(\frac{R}{R_s},\frac{t}{R_s},\nu\right)$



So far, the variables in f_{B3B} were related to R. Relating them to R_s instead greatly improved the "fitability" of FEA data since R_s governs the applied bending moment.

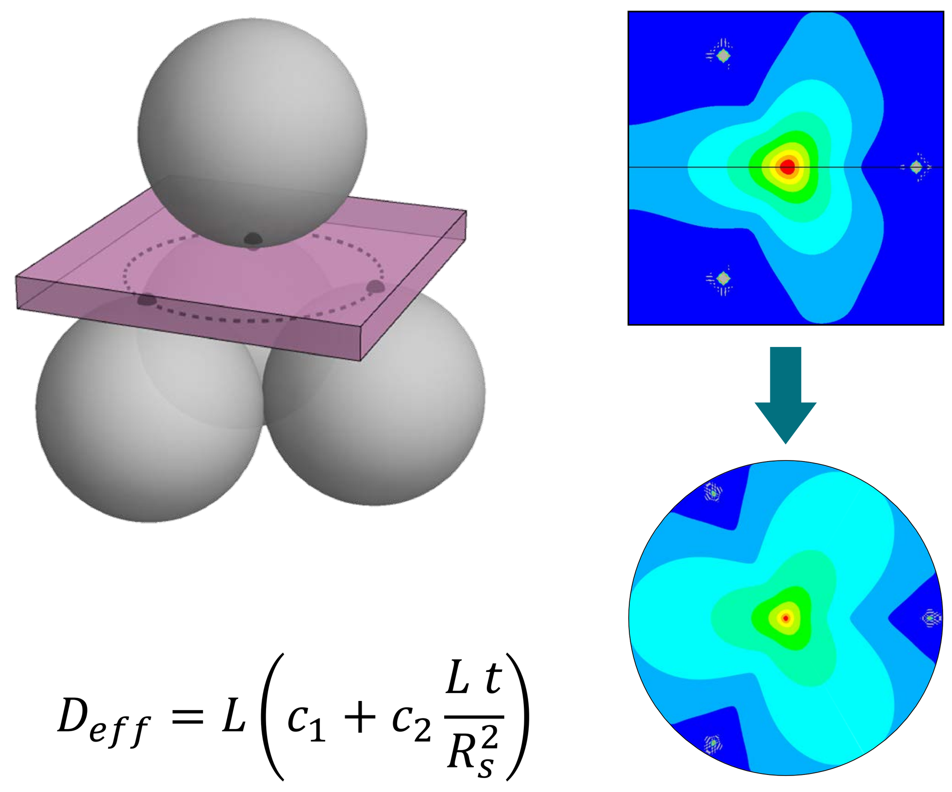
Disc specimen



$$f_{B3B}=Exp\left[c_1(1+\nu)+c_2\ln\frac{t}{R_s}+c_3\sqrt[4]{\frac{Rt^2}{R_s^3}}\right]$$ [3]

A new data-field was generated. The new fit for f_{B3B} of these results is notably shorter whilst retaining the same accuracy.

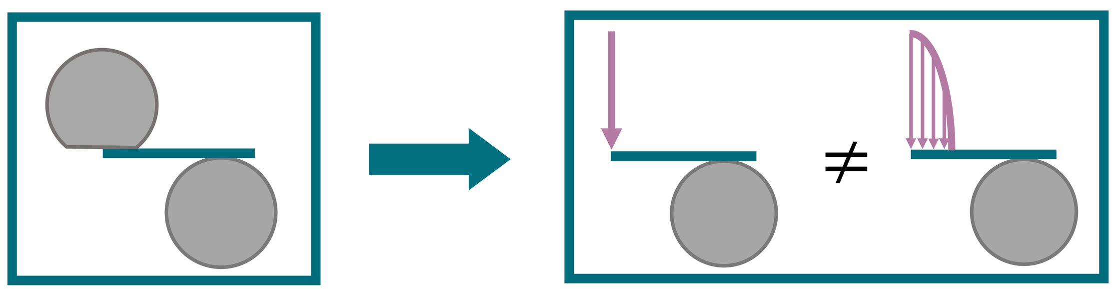
Square specimen



$$D_{eff}=L\left(c_1+c_2\frac{L\,t}{R_s^2}\right)$$

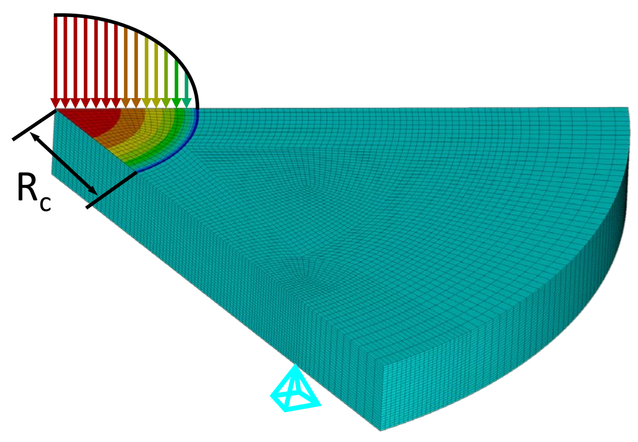
The edge length L is converted to a diameter D_{eff} of an "effective disc" to allow stress evaluation with the new fit for f_{B3B}.

Loading Ball deformation

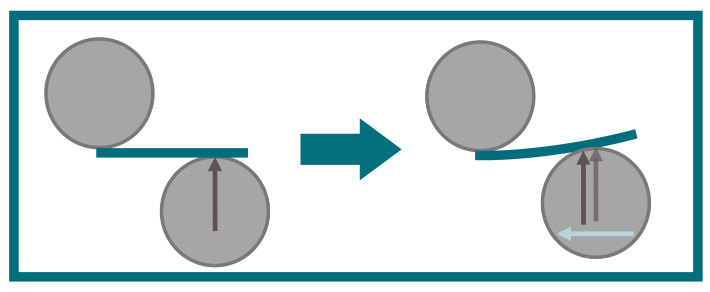


Increasing contact area reduces bending moment

Investigation through a modified FEA model and condensed to a functional expression k_1.



Specimen deflection

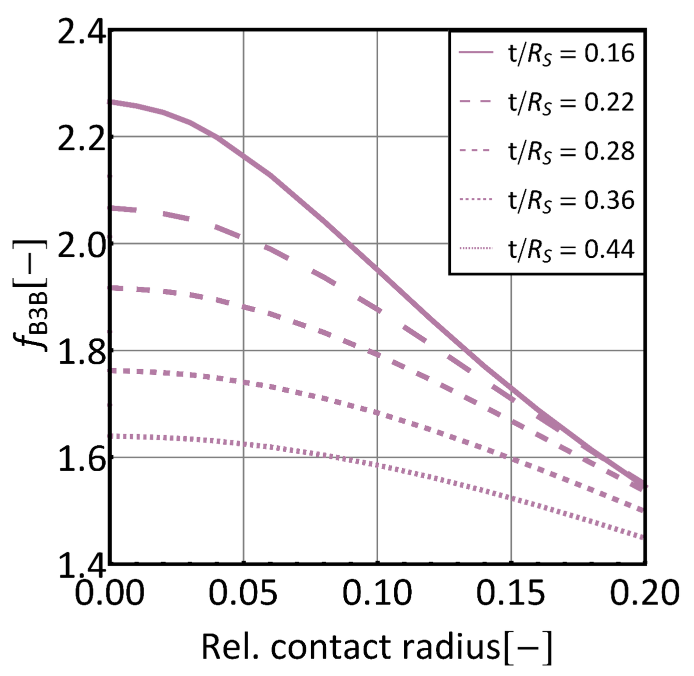


Deflection reduces bending moment

[4] gives an analytical expression for the specimen's deformation to predict the change in bending moment.

k_1 → $$f_{B3B,\,corr}=f_{B3B}\,k_1\,k_2$$ ← k_2

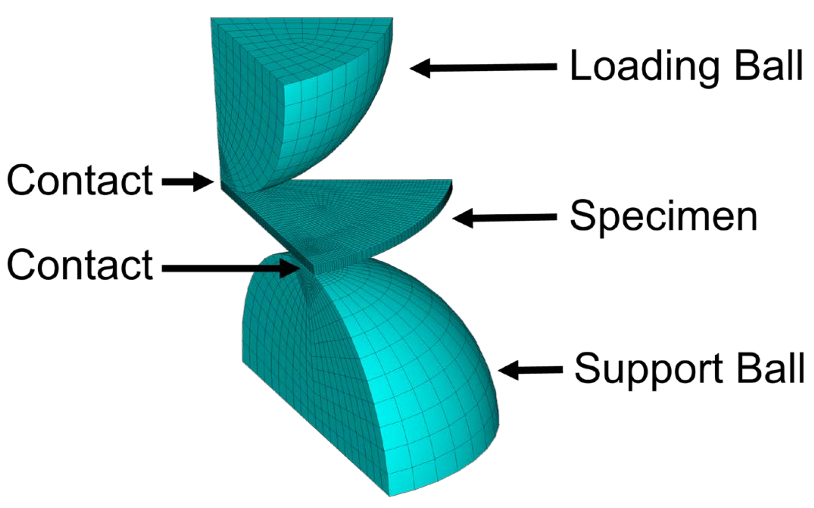
EXTENSION

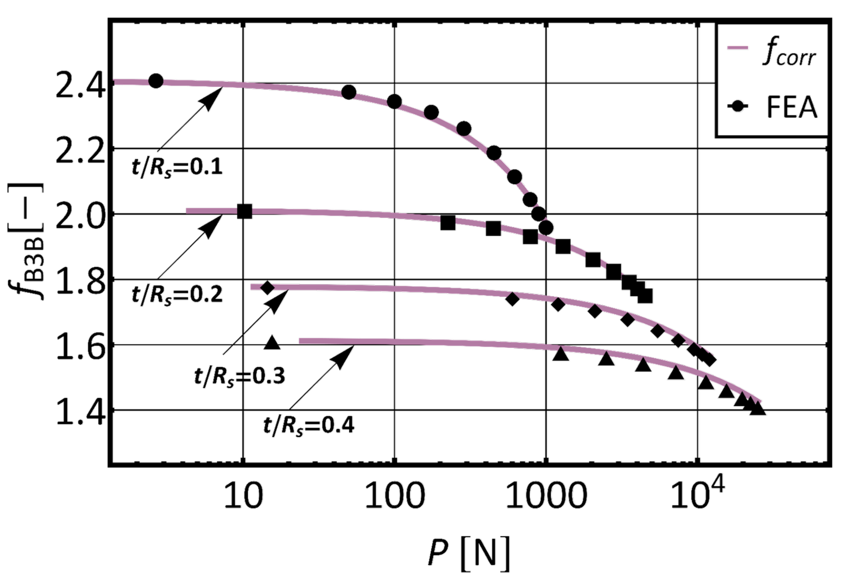


The effect of increasing contact area on f_{B3B}.

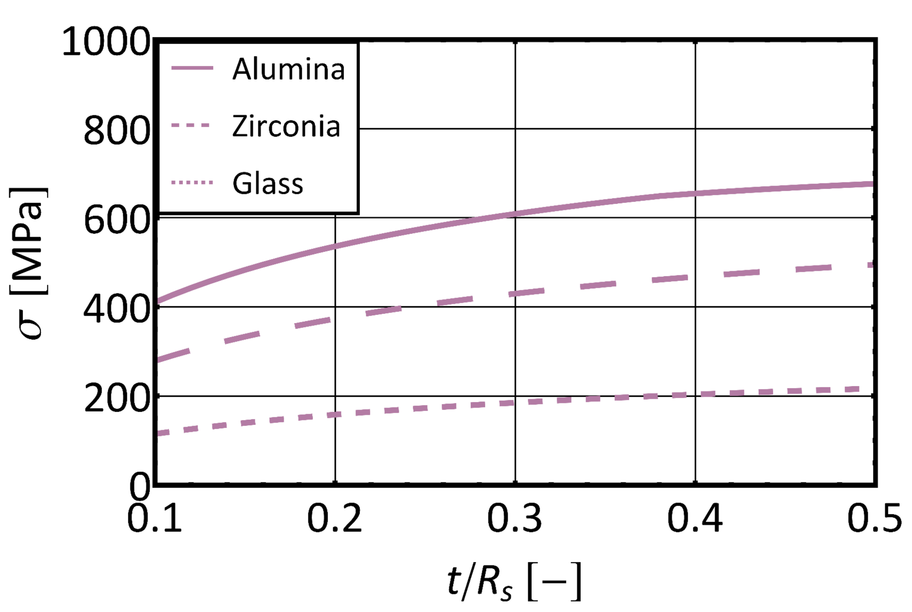
RESULTS

A comparison between f_{B3B} determined through contact-based FEA (below) and $f_{B3B,\,corr}$.





An application range for $f_{B3B,corr}$ was determined, given by the specimen's relative thickness and strength.



CONCLUSIONS & SUMMARY

The functional expression for f_{B3B} is significantly reduced in length and complexity. The same accuracy as in *[2]* is achieved.

This simplified expression is extended through a combined analytical and numerical approach by considering ball deformation & specimen deflection.

The application range of the extension k_1 & k_2 is determined and given by the specimen's strength and thickness.

References & Acknowledgments

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[3] Staudacher M. et al., J. Eur. Ceram. Soc. 43 (2023) 648–660
[4] Kirstein A. F. et al., J. Res. Natl. Inst. 70 (1966) 227-244

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TO: $$f_{B3B}(a,b,\nu)=e^{c_1(1+\nu)+c_2\ln b+c_3\sqrt[4]{ab^2}}$$

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