Boundary effects in physical models of simple shear

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ABSTRACT

Analogue modeling of geological structures in simple shear investigating, for example, the behavior of inclusions in a matrix or folding instabilities commonly employs a linear simple shear or general shear rig. Theoretically, a homogeneous plane strain flow is prescribed at the boundaries of such deformation rigs. However, the resulting internal deformation of the analogue material (commonly paraffin wax or silicone putties) often strongly deviates from the intended homogeneous strain field, which can easily lead to misinterpretation of analogue experiments.

We present a numerical finite element approach to quantify the influence of imperfect simple shear boundary conditions on the internal deformation of a homogeneous viscous analogue material. The results clearly demonstrate that imperfect circumferential boundary conditions in the simple shear plane (*x*-*y*-plane) do not lead to the heterogeneous strain observed in analogue experiments.

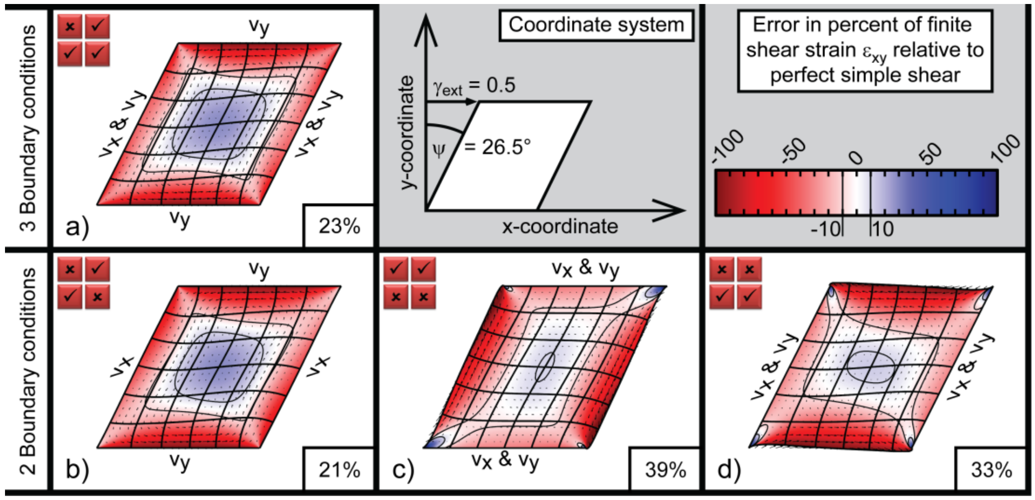
However, the analogue material commonly lies on top of a weak viscous material (e.g. vaseline) or is sandwiched between two such materials. These viscous layers are also deformed during an experiment, which leads to a viscous drag force acting on the analogue material. Therefore, they represent imperfect simple shear boundary conditions in the third dimension (*z*-direction). The numerical results identify these viscous layers to be responsible for the heterogeneous strain observed in analogue experiments. Resulting errors of the shear strain can be as high as 100%.

This study shows that great care has to be taken when the shear strain in analogue models is analized. We suggest these new findings to be considered by everyone interpreting analogue simple shear experiments.

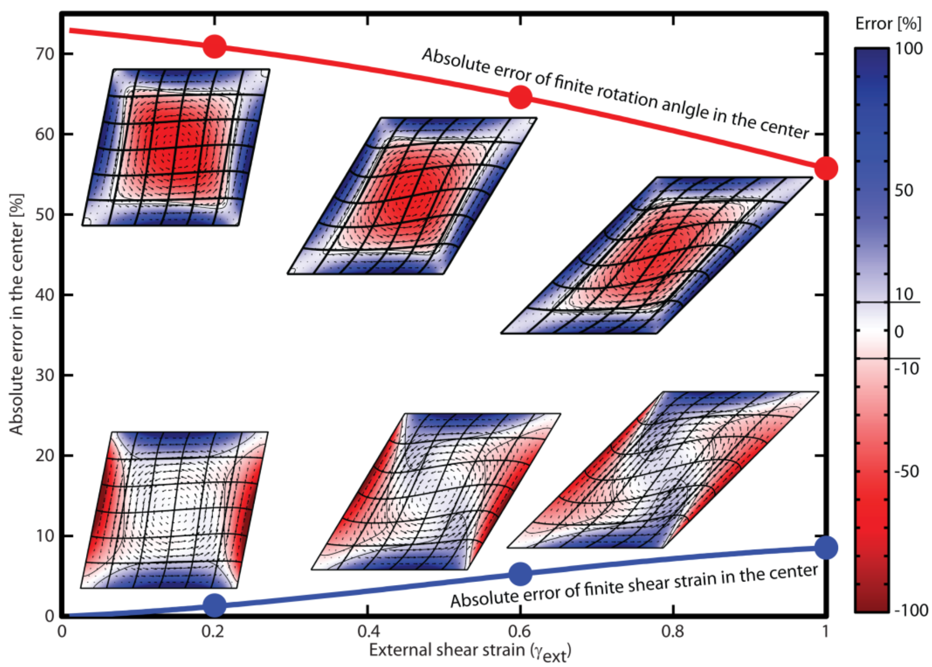
TABLES AND FIGURES

Boundary \ Condition	$v_x = \dot{\gamma}_{\text{ext}} y$	$v_y = 0$
y-boundaries	✓	✓
x-boundaries	✓	✓

The four boundary conditions for perfect simple shear in the *x*-*y*-plane. v_x and v_y are the velocities in *x*- and *y*-direction, respectively, $\dot{\gamma}_{\text{ext}}$ is the shear strain rate applied at the boundary and *y* is the coordinate in *y*-direction.



Numerically deformed homogeneous square with an applied simple shear strain γ_{ext}=0.5. In subfigures a) to d) four different combinations of imperfect boundary conditions in the *x*-*y*-plane are applied. For perfect simple shear, four boundary conditions need to be applied (Table above). In a), only three and in b) to d), only two of them are applied. The applied boundary conditions are noted at each boundary and indicated in the upper left corner of each subfigure in the same way as in the Table. Thick black lines are passive marker lines. The color represents the finite shear strain, plotted as the error in percent relative to perfect simple shear. Thin black lines are the ±10% contour lines. Numbers in the lower right corner of each subfigure represents the area of the model with an absolute error smaller than 10%. Arrows represent the finite perturbation strain, i.e. the difference between the actual deformation and perfect simple shear.



Numerically deformed homogeneous square in simple shear with increasing applied shear strain γ_{ext}. and perfect simple shear boundary conditions in the *x*-*y*-plane (Table 1). However, it contains viscous drag-boundary conditions in the third (*z*-) direction. In the inset figures, the color represents the finite shear strain (lower inset figures) and the finite rotation angle (upper inset figures), respectively, both plotted as the error in percent relative to perfect simple shear. Thin black lines are the ±10% contour lines. Thick black lines are passive marker lines. Arrows represent the finite perturbation strain. The bold blue and red line represent the finite shear strain and the finite rotation angle at the very center of the model, respectively. Big dots indicate the external shear strain η_{ext}, for which the inset figures are plotted.