The not-so-simple effects of boundary conditions on models of simple shear

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Analogue modeling of geological structures, such as the behavior of inclusions in a matrix or folding instabilities commonly employs a linear simple shear or general shear rig. In theory, a homogeneous plane strain flow is prescribed at the boundaries of such deformation rigs, but, in practice, the resulting internal deformation of the analogue material (commonly paraffin wax or silicone putties) often strongly deviates from the intended homogeneous strain field. This can easily lead to misinterpretation of such 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 (Figure 1) demonstrate that imperfect circumferential boundary conditions in the simple shear plane (*x*-*y*-plane) lead to the heterogeneous strain observed in some analogue experiments (Price and Torok, 1989; Sengupta and Koyi, 2001), depending on their design.

However, in other experiments, the analogue material lies on top of a weak lubricating material (e.g. Vaseline) or is sandwiched between two such materials (Ildefonse and Mancktelow, 1993; Grujic and Mancktelow, 1995). These layers lead to a viscous drag force acting on the surface of the analogue material that represents imperfect simple shear boundary conditions in the third dimension (*z*-direction). For this experimental configuration, the numerical results (Figure 2) show that the lubricating layers are responsible for the heterogeneous strain observed in analogue models.

The resulting errors in internal strain can be as high as 100% and these important boundary effects, which are difficult to avoid, must be considered when interpreting analogue simple shear experiments.

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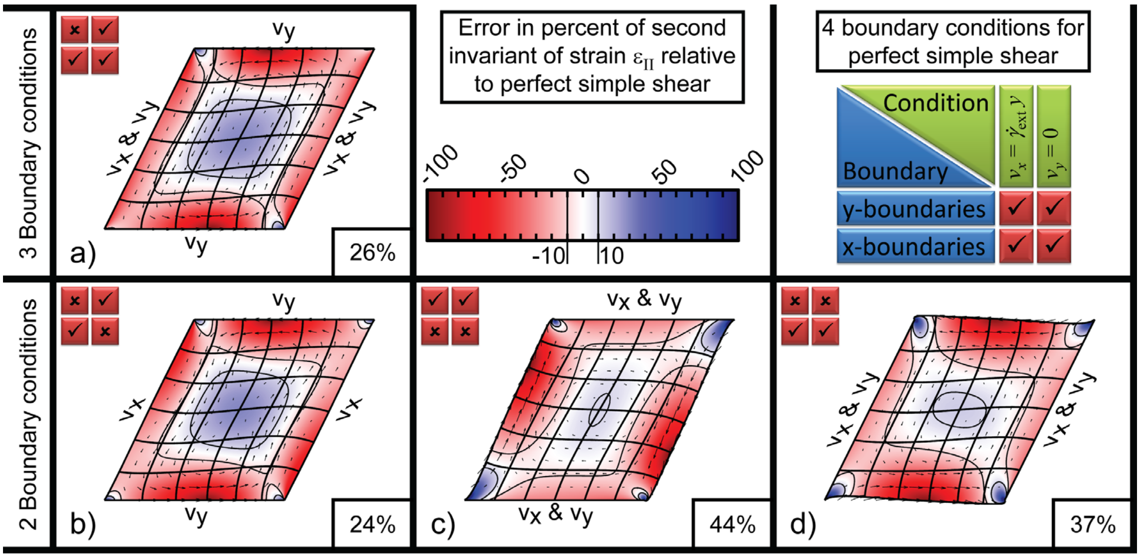

Figure 1. Numerically deformed homogeneous square with an applied simple shear strain γ_{ext}=0.5. The for boundary conditions for perfect simple shear are given in the table. In a), only three and in b) to d), only two of them are applied. The applied boundary conditions are noted at each boundary. Thick black lines are passive marker lines. The color represents the second invariant of finite strain, plotted as the error in percent relative to perfect simple shear. Thin black lines are the ±10% contour lines. The area with an absolute error smaller than 10% is given in the lower right corner of each subfigure. Arrows represent the finite perturbation strain.

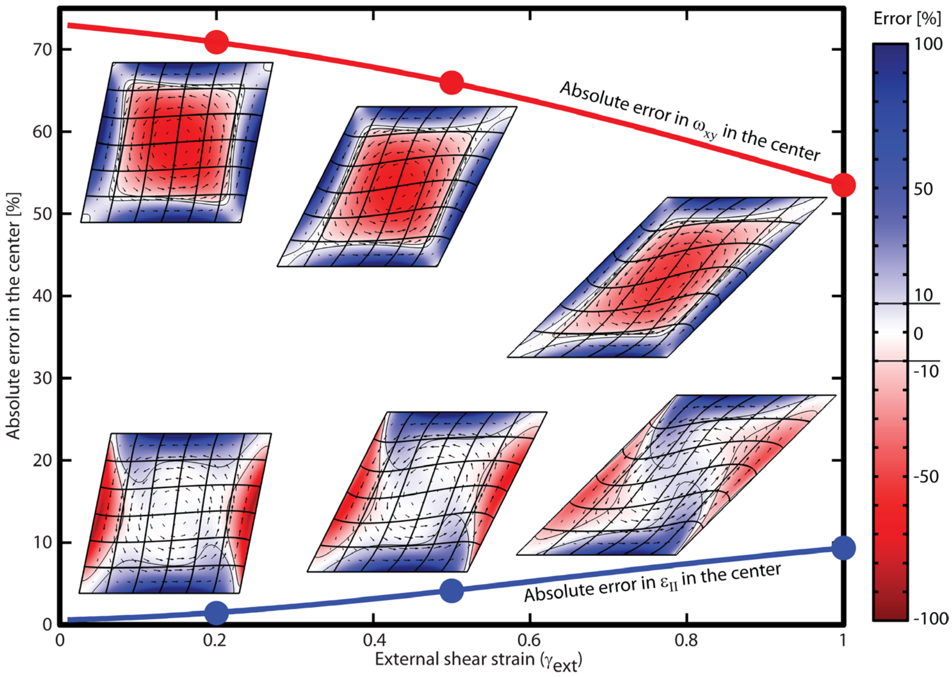

Figure 2. Numerically deformed homogeneous square with increasing applied simple shear strain γ_{ext}, perfect simple shear boundary conditions in the *x*-*y*-plane and viscous drag-boundary conditions in the third (*z*-) direction. The color represents the finite shear strain (lower inset figures) and the finite rotation angle (upper inset figures), respectively, both plotted as the error in percent relative to perfect simple shear. Thin and think black lines and arrows are the same as in Figure 1. The bold blue and red line represent the finite shear strain and the finite rotation angle at the very center of the model, respectively.