Rheology of viscous materials from the CNR-IGG Tectonic Modelling Laboratory at the University of Florence (Italy) (https://doi.org/10.5880/fidgeo.2020.018)

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1. Licence

2. Citation

When using the data please cite:

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Related datasets:

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3. Data Description

This dataset provides rheometric data of three viscous materials used for centrifuge experiments at the Tectonic Modelling Laboratory of CNR-IGG at the Earth Sciences Department of the University of Florence (Italy). The first material, PP45, is a mixture of a silicone (Polydimethylsiloxane or PDMS SGM36) and plasticine (Giotto Pongo). The PDMS is produced by Dow Corning and its characteristics are described by e.g. Rudolf et al. 2016a,b). Giotto Pongo is produced by FILA (Italy). Both components are mixed following a weight ratio of 100:45, and the final mixture has a density of 1520 kg m^3. The second material, SCA705 is a mixture of Dow Corning 3179 putty, mixed with fine corundum sand and oleic acid with a weight ratio of 100:70:05 and a resulting density of 1660 kg m^3.

The final material, SCA7020 consists of the same components as SCA705, but with a slightly higher oleic acid content reflected in the weight ratio of 100:70:20. The mixture's density is 1620 kg m^3. The material samples have been analyzed in the Helmholtz Laboratory for Tectonic Modelling (HelTec) at GFZ German Research Centre for Geosciences in Potsdam using an Anton Paar Physica MCR 301 rheometer in a plate-plate configuration at room temperature (20˚C). Rotational (controlled shear rate) tests with shear rates varying from 10^{-4} to 1 s^{-1} were performed. Additional temperature tests were run with shear rates between 10^{-2} to 10^{-1} s^{-1} for a temperature range between 15 and 30˚C.

According to our rheometric analysis, the materials all exhibit shear thinning behavior, with high power law exponents (n-number) for strain rates below 10^{-2} s^{-1}, while power law exponents are lower above that threshold. For PP45, therespective n-numbers are 4.8 and 2.6, for SCA705 6.7 and 1.5, and for SCA7020 9.1 and 2.0. The temperature tests show decreasing viscosities with increasing temperatures with rates of -3.8, -1.4 and -1.9% per ˚K for PP45, SCA705 and SCA7020, respectively. An application of the materials testedcan be found in Zwaan et al. (2020).

***Table 1: Sample overview** (CNR-UF = CNR-IGG lab at the University of Florence, GFZ = German Research Centre for Geosciences in Potsdam, CSR=)*

ID (CNR-UF/GFZ)	Material	Bulk density [kg m^{-3}]	Weight ratio	File name
PP45	PDMS-Pongo mixture	1520	100:45	CSR_CNR-UF_PP45.txt, TCSR_CNR-UF_PP45.txt
SCA705	Putty-corundum sand-oleic acid mixture	1660	100:70:05	CSR_CNR-UF_SCA705.txt, TCSR_CNR-UF_SCA705.txt
SCA7020	Putty-corundum sand-oleic acid mixture	1620	100:70:20	CSR_CNR-UF_SCA7020.txt, TCSR_CNR-UF_SCA7020.txt

3.1. Measurement procedure

The data presented here are derived by rheometric testing using an Anton PaarPhysica MCR 301 (e.g. http://www.ih.cas.cz/files/uploads/3_vyzkum/6_pristroje/MCR-501-brochure.pdf) at the Helmholtz Laboratory for Tectonic Modelling (HelTec) of GFZ. We used a sandblasted plate-plate configuration (PP25/S) with a 1 mm gap. A 3 mm gap was tested beforehand but yielded similar results. Tests were performed at 20°C.

Each sample has been carefully prepared by the same person to obtain a homogeneous mixture and measured consistently following a consistent test protocol. Each sample was measured in triplicates with increasing shear rates from 10^{-4} to 1 s^{-1}. After the introduction of the material into the measuring gap, the sample is allowed to relax for 360 s to remove residual stresses. The rates were increased logarithmically to obtain 4 points per decade resulting in 17 points per test and a total of 51 points per material. Following best-practices outlined by Mezger (2006) the measurement duration at each point t_{meas} is slightly larger than the inverse of the shear rate$\dot{\gamma}$:

$$t_{meas} = 1.1 \cdot \frac{1}{\dot{\gamma}}$$

This leads to logarithmically decreasing measurement durations of 11000 to 1.1 s per point. This ensures that the sample is sheared enough to prevent dilational peaks because of the rearrangement of silicone chain molecules due to shear.

For the temperature sensitivity the material is tested in a similar fashion but in a smaller interval and at increasing temperatures. Here the shear rate is increased from 10^{-2} to 10^{-1} s^{-1} with 4 points per decade to get a good estimate of viscosity over the experimental conditions. This shorter test is repeated at four temperature intervals $T = \{15, 20, 25, 30\}°C$ to estimate the change of viscosity over the usual experimental temperature range.

3.2. Analysis and visualization

Analysis of the rheometric data has been done using the RheoPlus software (version 3.4, see http://www.mate.tue.nl/~wyss/softwiki/doku.php?id=equipment:antonpaar501-rheometer for instructions) by the Anton Paar GmbH. The resulting viscosities corresponding to distinct shear stresses and rates are summarized in the file "Results_CSR.txt" and plotted in Figure 1 as a function of shear rate (also available as file "Results_CSR.png").An equivalent file with the temperature tests are provided ("Results_TCSR.txt"), and the results are presented in Figures 2-3 (also available as files "Results_TCSR_avgChange.png", "Results_TCSR_Tchange.png". Two Python scripts are provided that generate these plots from the summarizing "Results_XXX.txt". To use the scripts Python 3.x and the modules supplied in "requirements.txt" are needed. Depending on the installation of Python (conda or pip) you will need to install the requirements using *'pip install -r requirements.txt'* or *'conda installnumpymatplotlibscipy'*. The scripts then are going to ask the user to navigate to the respective file.The scripts read the data stored in the files and calculate several parameters.

3.2.1. CSR Tests

For the CSR tests the relationship of strain rate $\dot{\gamma}$and shear stress $\tau$is fit using non-linear least squares, provided by *scipy*, with a power law in the form of:

$$\tau = a \cdot \dot{\gamma}^n$$

With the consistency a and the power law index n. Because the power-law behavior changes depending on shear rate, the data is split into a slow and a fast regime. We chose the critical strain rate to be 0.01 s^{-1}, for other limits the user can set the variable 'limit' (Line 78) to a different value. The results are then plotted as can be seen in Figure 1. Errors are given as the twofold standard deviation calculated from the covariance of the fits:

$$2\sigma = \sqrt{Cov_{Fit}}$$

The power law exponents are in rheometric notation and to convert them into the typical geological notation where strain rate is expressed as a function of shear stress (e.g. Bürgmann and Dresen, 2008) the inverse $m = \frac{1}{n}$ has to be taken. Accordingly, the materials exhibit shear thinning behavior, with very high power law exponents $m > 5$(n-number) for lower strain rates, whereas power law exponents decrease to $m < 2.5$when strain rates increase.

3.2.2. TCSR Tests

The change of viscosity with increasing temperature is defined by the average change of viscosity at each shear rate. For this the script calculates the difference in viscosity at each shear rate for each temperature step. This results in 15 values per material, which are then plotted into a boxplot to visualize the median and standard deviation (Figure 3).

4. File description

For each sample the original "CSR_CNR-UF_xx.txt" (standard rheology test) and "TCSR_CNR-UF_xx.txt" (temperature test) files as exported from the RheoPlus software are provided (see Table 1). These data files include a header with relevant measurement information and a table with tab-separated columns:

- Meas. Pts.: Measurement interval (number)
- Shear Rate: Mean shear rate (s^{-1})
- Shear Stress: Mean shear stress (Pa)
- Viscosity: Mean viscosity (Pa s)
- Speed: Number of revolutions (min^{-1})[2]
- Torque: Mean torque (µNm)
- Status: Device status

Shear stresses and viscosities for corresponding shear rates are summarized in the file “Results_CSR.txt” which is organized as a matrix with the first three rows describing the samples according to the header in the first column (see Table 2). An equivalent file “Results_TCSR.txt” is provided for the temperature tests (see Table 3)

An overview of all files of the data set is given in the **List of Files.**

Table 2: *Structure of file “Results_CSR.txt”*

%ID	PP45		SCA705		SCA7020	
%Material	PP45		SCA705		SCA7020	
%						
%Shear rate	Shearstress	Viscosity	Shearstress	Viscosity	Shearstress	Viscosity
%s-1	Pa	Pa s	Pa	Pa s	…	…
0.0001	1721	17210000		…	…	…
0.0001779	1847	…	…	…	…	…
…	…	…	…	…	…	…

Table 3: *Structure of file “Results_TCSR.txt”*

%ID		PP45		SCA705		SCA7020	
%Material		PP45		SCA705		SCA7020	
%							
%Tempera- ture	%Shear rate	Shear- stress	Viscosity	Shear- stress	Viscosi- ty	Shear- stress	Viscosi- ty
%˚C	%s-1	Pa	Pa s	Pa	Pa s	…	…
15	0.0001	1721	17210000		…	…	…
15	0.00017 9	1847	…	…	…	…	…
…	…	…	…	…	…	…	…

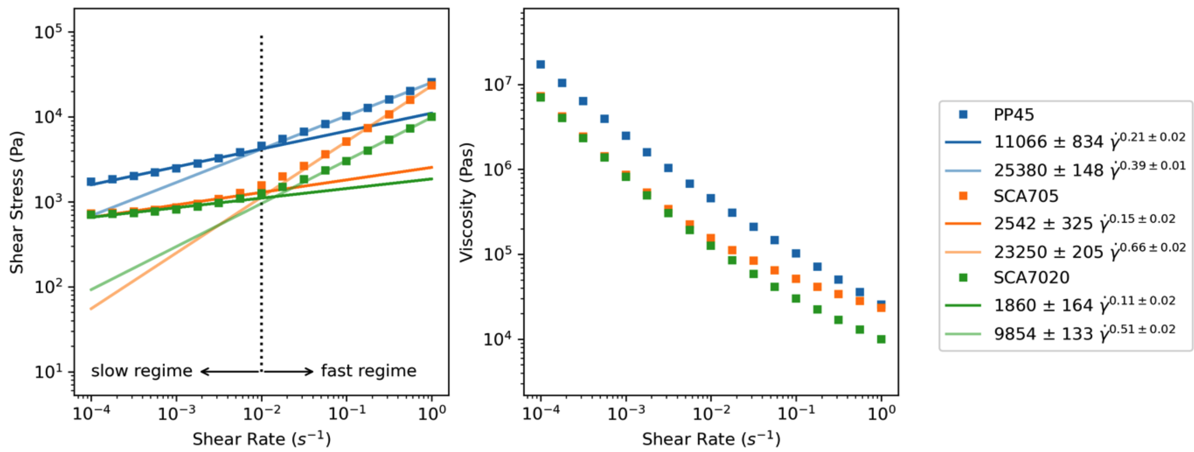

Figure 1: *Shear stress and viscosity as a function of shear rate for CNR-UF samples (T=20˚C). The materials have a different behavior above and below a shear rate of $10^{-2}s^{-1}$. Power law exponents (n-numbers) are given "rheometer style", the reciprocal of which is the "geological standard".*

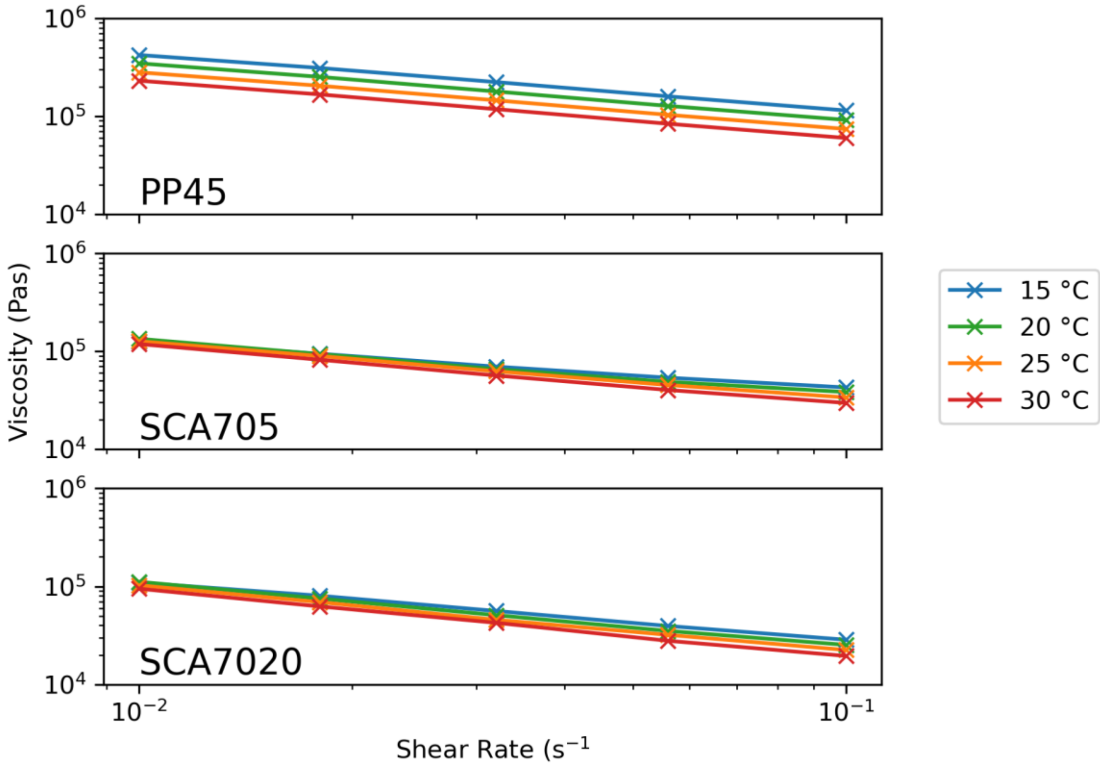

Figure 2: *Viscosity vs. shear rate for different temperatures (15, 20, 25 and 30˚C) for CNR-UF samples.*

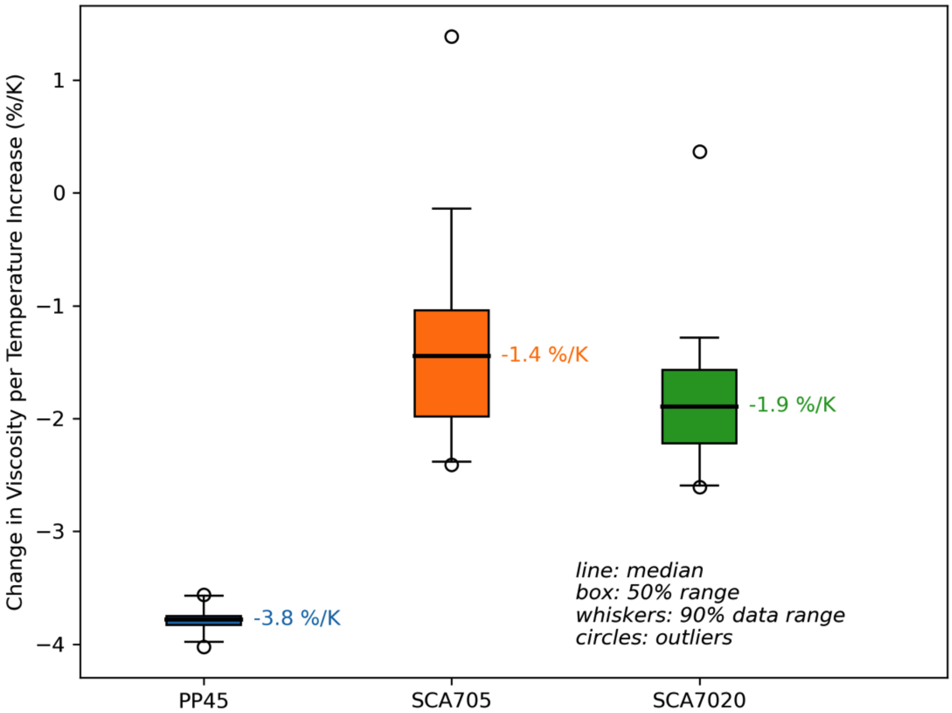

Figure 3: *Average change of viscosity for increasing temperatures (CNR-UF samples).*

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