Supplementary materials

1 Materials and methods

1.1 Structural rheological models

1.1.1 Burgers model

Under constant strain rate conditions which are expressed by the Cauchy problem (;), the stress-strain relationship is given by [27]:

where parameters a and b are defined as follows:

For stress relaxation under applied constant strain ε₀, the Burgers model solution (; ) is given by [13]:

where

1.1.2 Maxwell model

The creep process is described by the solution of the constitutive equation at σ=σ₀=const according to the initial condition set (; ) [30]:

where

Stress relaxation is described by the solution of the equation at ε=ε₀=const expressed by the Cauchy problem (; ) [31, 32]:

Where

All of the aforementioned and further listed mathematical operations were implemented using the Wolfram Mathematica 11.2 (Wolfram Research, USA) computational software package.

1.2 Procedure for identification of Viscoelastic Parameters

To derive a unified viscoelastic parameter set from creep tests describing material’s behavior across three different stress levels (10%, 20% and 30% of maximum stress) a least-squares method was implemented. For a single strain-time curve the objective function is defined as follows:

where are the modeled strain functions dependent on time and viscoelastic parameters at the i-th stress level, defined according to Eqs. (3), (7), and (11); are the experimental values obtained at the *i*-th stress level.

Parameter set was then retrieved as the solution of the following optimization problem:

where F is the objective function comprising both analytical descriptions and creep test data across 10%, 20% and 30% stress and i corresponds to a specific stress level.

The minimization of the sum of squared residuals was carried out using the standard TPE Sampler method. Unlike random or grid search, the TPE algorithm models the probabilities of hyperparameters based on information from previous trials. This allows it to learn from the history of evaluations and direct the search towards the most promising regions of the hyperparameter space, efficiently converging to the optimal values. To ensure on the validity of acquired lumped parameter values, the initial guess for parameter E0 in the SLS and GM models were taken as the tangent elastic modulus obtained from tests at 0.12 mm/min, while parameter E1 in the BURG model was taken from tests at 120 mm/min.

To ensure the robustness and independence of the obtained lumped parameters from the initial guess, a sensitivity analysis was performed. Across all models the optimization procedure was repeated with several initial values comprising constants derived from cyclic compression (a), creep parameters (b), mean values between compression and creep for corresponding parameters (с) and 15% deviation from mean for both moduli and viscosity coefficients (d-g) with overall result of 7 initial point sets. Initial point numeric values are presented in Tables S1-S3 for each rheological model.

**Table S1:** Initial Points (SLS model)

|  |  |  |  |
| --- | --- | --- | --- |
| **Initial Point Set** | **Zener model (SLS)** | | |
| **E0,MPa** | **E1,MPa** | **η₁,MPa\*s** |
| Cyclic compression (a) | 31.1 | 16.7 | 109.5 |
| Creep (b) | 25.9 | 10.1 | 1378 |
| Mean (c) | 28.5 | 13.4 | 743.8 |
| +15% for (d) | 32.8 | 15.4 | 743.8 |
| -15% for (e) | 24.2 | 11.4 | 743.8 |
| +15% for (f) | 28.5 | 13.4 | 855.4 |
| -15% for (g) | 28.5 | 13.4 | 632.2 |

**Table S2:** Initial Points (Burgers model)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Initial Point set** | **Burgers model (BURG)** | | | |
| **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Cyclic compression (a) | 48.4 | 123.9 | 169800 | 645.5 |
| Creep (b) | 42.9 | 86.6 | 1.37·106 | 8947 |
| Mean (c) | 45.7 | 105.4 | 769900 | 4810 |
| +15% for (d) | 52.6 | 121.2 | 769900 | 4810 |
| -15% for (e) | 38.8 | 89.6 | 769900 | 4810 |
| +15% for (f) | 45.7 | 105.4 | 885400 | 5530 |
| -15% for (g) | 45.7 | 105.4 | 654400 | 4090 |

**Table S3:** Initial Points (GM model)

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| --- | --- | --- | --- | --- | --- |
| **Initial Point Set** | **Generalized Maxwell model (GM)** | | | | |
| **E0,MPa** | **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Cyclic compression (a) | 30.6 | 8.51 | 17.4 | 559.9 | 9.68 |
| Creep (b) | 25.9 | 7.31 | 18.8 | 1291 | 53.9 |
| Mean (c) | 28.3 | 7.91 | 17.9 | 925.5 | 31.8 |
| +15% for (d) | 32.5 | 9.10 | 20.6 | 925.5 | 31.8 |
| -15% for (e) | 24.1 | 6.72 | 17.9 | 925.5 | 31.8 |
| +15% for (f) | 28.3 | 7.91 | 17.9 | 1064 | 36.6 |
| -15% for (g) | 28.3 | 7.91 | 17.9 | 786.7 | 27.0 |

Sensitivity Analysis was carried out in Wolfram Mathematica for cyclic compression solution and in Python with the use of Optuna framework for creep process according to the provided optimization procedure description (Section 2.3). For all the parameters retrieved mean, standard deviation (std) and coefficient of variation (cv) values were calculated.

1.3 Study of elastic-hysteretic characteristics

To obtain the theoretical loading-unloading law, the differential equations of the models Eqs. (1), (5), and (9) were used with the determined parameters and constant strain rate. The differential equation of the SLS model:

For = const, the governing equation for the Burgers model took the form:

The differential equation of the generalized Maxwell model under constant strain rate:

In the listed above expressions are stress-time relations, as which experimental stress-time data from first cycle, which are shown in Figure S1, were taken.

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| **Figure S1**: Experimental stress-time data from the first cycle (cyclic compression tests) |

To minimize errors in the numerical solution procedure of the differential equations for each strain rate, prior to substitution the experimental curves were approximated by piecewise linear functions, as illustrated in Figure S2 (the blue curve represents the experimental data, while the red line shows the linear approximation).

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| **Figure S2**: Linear approximation of experimental stress-time data |

For all models and strain rates, the solution of the differential equation with respect to ε was split into loading and unloading stages. During the loading phase, an initial value (Cauchy) problem was solved for all models. For the SLS model across all strain rates, the following condition was set on the strain value at the point corresponding to the start of the first cycle ():

For the Burgers and GM models across all strain rates, conditions were set on the initial strain value and the initial strain rate, respectively:

On the loading phase the solutions of the differential equations for the models were obtained numerically in the Wolfram Mathematica 11.2 package using the built-in Adams option comprising explicit Adams-Bashfourth and implicit Adams-Moulton methods with orders varying from 1 to 12.

During the unloading phase for the SLS model across all of the strain rates used, an initial value (Cauchy) problem was solved, with the following continuity condition imposed at the peak strain time point with the corresponding strain value derived from the loading phase solution:

For the Burgers and GM models at strain rates of 0.12 and 1.2 mm/min, continuity conditions were specified for both strain and strain rate at the maximum strain point:

where negative strain rate denotes the unloading process

At higher strain rates (12, 60, and 120 mm/min) boundary value problems were solved for the Burgers and Maxwell models, with conditions set on strain values at both the peak point () and the endpoint of the second cycle ():

An example of the solution for the SLS model at 12 mm/min is presented in Figure S3. During unloading stage solutions for initial value problems were obtained numerically with the use of Adams option incorporated in Wolfram Mathematica 11.2 software package, switching to Finite Element method in boundary value formulations for all models and specified strain rates, respectively.

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| **Figure S3**: Obtained strain-time functions on both loading and unloading stages |

To establish the constitutive relationship from the computed solutions, the following post-processing procedure was implemented. After obtaining the numerical solution of the differential equations that generated strain-time data consistent with the experimental stress-time measurements, the corresponding stress-strain pairs were tabulated. These discrete data points were subsequently transformed into a continuous stress-strain interpolated function with the use of 3rd order polynomials for further analysis. An example for derived theoretical loading-unloading curves is shown in Figure S4 for SLS-model and 12 mm/min strain rate.

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| **Figure S4**: Obtained strain-time functions on both loading and unloading stages |

1.4 Inverse Finite Element Modeling of Creep and Stress Relaxation

There are several models for predicting long-term deformation of polymer materials that account for both viscous and elastic components. This work examines two approaches to describing viscoelastic material behavior. Common finite element (FE) analysis software packages (ANSYS, etc.) use the Prony series linear viscoelastic model based on exponential functions to describe the stress relaxation process (for a more complete formulation see section 2.5 in Supplementary Materials).

The FE analysis employed a third-order Mooney-Rivlin material model, which is the minimum-order model capable of capturing the infection points on experimental creep and stress relaxation curves, alongside with incompressibility assumption, which is consistent for modelling polyurethane behavior. The strain energy density function is thus expressed as:

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|  | (15) |

where – material constants, – are invariants of the modified deformation gradient tensor [33].

Within the framework of small strain theory, the constitutive equation for an isotropic viscoelastic material is written as follows:

where – Cauchy stress, *e* – deviatoric part of the strain, – volumetric part of the strain, *G(t)* – shear relaxation kernel function, *K(t)* – bulk relaxation kernel function, *t* – current time,  – past time, *I* – unit tensor.

The kernel represented in the Prony series form:

where  – shear elastic moduli,  – bulk elastic moduli,  – relaxation times for each Prony component.

To account for viscoelastic behavior, a first-order Prony Shear Relaxation model was implemented. For fully incompressible case, the volumetric viscoelastic response was consequently neglected, and only the deviatoric (shear) component was characterized using the Prony series formulation (see Eq. (S14)). The numerical simulation employed boundary conditions shown in Fig. 2: the bottom surface of the specimen had constrained vertical displacements, while the top surface was subjected to loading - a constant prescribed displacement for stress relaxation modeling and pressure loading for creep modeling. The mesh was constructed using 8-node PLANE183 finite elements with 1 mm size, determined through convergence testing. The final model comprised 320 elements and 399 nodes.

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| **Figure S5:** Schematic representation of boundary conditions |

Both values of Mooney-Rivlin model as well as relaxation time and relative modulus of Prony series were derived as the solution of the reverse engineering problem for creep process in ANSYS Workbench software package. Namely, 3rd Mooney-Rivlin and 1st order Prony series material constants were taken as input parameters during material definition and FEA strain was considered as output parameter after the solution processed. Experimental creep strain-time curves at three levels of maximum stress (10%, 20%, 30%) were used as target values. An iterative solution process was then performed aiming to minimize the discrepancy between FEA-predicted and experimental strains by varying the input parameter values with the use of in-built direct optimization module with the Advanced-Multiple Objective option set as optimization method for parameter definition. The correctness of derived parameter values was controlled by initial shear modulus condition for fully incompressible case:

where is initial shear modulus, and are elastic modulus determined as the initial slope of experimental stress-strain curve during loading phase and Poisson’s ratio, respectively.

The second approach involved numerical determination of Prony series coefficients for the generalized Maxwell model's mechanical properties which is defined according to Eq. (16):

where is instantaneous modulus and ,  are Prony coefficients.

Creep material behavior (σ (0) = σ₀ = const) is thus derived as:

Stress relaxation description (ε=ε₀=const) comprising Prony series takes the form:

The assessment of Prony series coefficients was performed with the least squares method utilizing data from creep tests at three different stress levels (10%, 20%, 30%). Similarly to Eqs. (S5) and (S6), the optimization problem is presented as:

where are the modeled strain functions dependent on time, instantaneous modulus and Prony series coefficients at the i-th stress level, defined according to Eq. S(13); are the experimental strain values obtained at the *i*-th stress level.

The sum of squared discrepancies was minimized using the standard TPE Sampler method, which works based on probability modeling. hyperparameters, using information from previous tests. To appropriately determine possible solution space, an instantaneous modulus value was set to , where E0, E1 and E2 are spring moduli in the Generalized Maxwell model (E₀=25.9 MPa, E₁=7.3 MPa, E₂=18.8 MPa). Experimental verification of derived coefficients was subsequently conducted on stress-time functions defined by Eq. (S18) by plotting them against stress relaxation test data.

2 Results and discussion

2.1 Samples Fabrication and Mechanical testing

The uniaxial compression tests yielded stress-strain diagrams for the entire range of strain rates during the first loading cycle (shown in Fig. S6a), as well as hysteresis curves corresponding to the first cycle (presented in Fig. S6b).

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|  | |
| (a) | (b) |
| **Figure S6:** Uniaxial compression testing: (a) first loading cycle, (b) loading-unloading behavior of the material. | |

The dependence of the tangent elastic modulus (mean and standard deviation values) on strain rate is presented in Table S1.

**Table S1:** Elastic moduli at different testing rates.

|  |  |
| --- | --- |
| **Testing speed, mm/min** | **Tangent modulus, MPa** |
| 120 | 49.6±1.7 |
| 60 | 45.4±0.6 |
| 12 | 41.7±1.7 |
| 1.2 | 37.5±1.7 |
| 0.12 | 33.4±1.3 |

2.2 Procedure for identification of Viscoelastic Parameters

Fig. S7 presents the comparison between experimental and theoretical stress-strain relationships during the first loading cycle.

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| **Figure S7:** Comparison of experimental and theoretical curves during the first loading cycle |

Results of sensitivity analysis for compression case parameter derivation procedure in regards to SLS model are presented in Tables S4, S5 and in Figure S8.

**Table S4:** Optimization Results for cyclic compression (SLS model)

|  |  |  |  |
| --- | --- | --- | --- |
| **Initial Point Set** | **Derived parameters (SLS-model)** | | |
| **E0,MPa** | **E1,MPa** | **η₁,MPa\*s** |
| Cyclic compression (a) | 31.1 | 16.7 | 109.5 |
| Creep (b) | 31.1 | 16.7 | 109.5 |
| Mean (c) | 31.1 | 16.7 | 109.5 |
| +15% for (d) | 31.1 | 16.7 | 109.5 |
| -15% for (e) | 31.1 | 16.7 | 109.5 |
| +15% for (f) | 31.1 | 16.7 | 109.5 |
| -15% for (g) | 31.1 | 16.7 | 109.5 |

**Table S5:** Compression solution statistics (SLS model)

|  |  |  |  |
| --- | --- | --- | --- |
| Quantity | SLS model | | |
| **E0,MPa** | **E1,MPa** | **η₁,MPa\*s** |
| Mean, MPa | 31.1 | 16.7 | 109.5 |
| Std, MPa | 1.2·10-8 | 2.2·10-8 | 3.3·10-8 |
| CV, % | 3.9·10-8 | 1.6·10-8 | 3.0·10-7 |
|  | | | |
| **Figure S8:** Sensitivity analysis for compression solution (SLS model) | | | |

Results of sensitivity analysis for creep parameter determination in regards to SLS model are presented in Tables S6, S7 and in Figure S9.

**Table S6:** Optimization Results for creep process (SLS model)

|  |  |  |  |
| --- | --- | --- | --- |
| **Initial Point Set** | **Derived parameters (SLS-model)** | | |
| **E0,MPa** | **E1,MPa** | **η₁,MPa\*s** |
| Cyclic compression (a) | 25.9 | 10.1 | 1380 |
| Creep (b) | 25.9 | 10.1 | 1378 |
| Mean (c) | 25.9 | 10.1 | 1378 |
| +15% for (d) | 25.9 | 10.1 | 1380 |
| -15% for (e) | 24.3 | 11.4 | 743.8 |
| +15% for (f) | 25.9 | 10.1 | 1383 |
| -15% for (g) | 25.9 | 10.1 | 1379 |

**Table S7:** Creep solution statistics (SLS model)

|  |  |  |  |
| --- | --- | --- | --- |
| Quantity | SLS model | | |
| **E0,MPa** | **E1,MPa** | **η₁,MPa\*s** |
| Mean, MPa | 25.7 | 10.2 | 1289 |
| Std, MPa | 0.59 | 0.48 | 222.8 |
| CV, % | 2.3 | 4.7 | 17.3 |
|  | | | |
| **Figure S9:** Sensitivity analysis for creep solution (SLS model) | | | |

In the SLS model, the standard deviation for compression solution was negligible (2.2·10⁻⁸ MPa), with a coefficient of variation (CV) 4·10⁻⁸%, confirming the uniqueness of the solution for the compression case. A minor deviation was observed at point 5 during creep fitting for the SLS model leading to a slight increase in CV (2.3% for E0 and 4.7% for E1 in SLS). This is attributed to the inherent coupling between parameters in the constitutive equations and the fact that dynamic viscosity coefficients are lumped parameters without direct experimental analogs. Their values are more sensitive to the initial guess as they primarily serve to shape the transient response between the well-defined instantaneous and equilibrium elastic states. Therefore, the algorithm may find a local minimum where slightly different combinations of moduli and viscosities yield a similarly good fit to the creep data. However, it is of crucial importance that both numerical procedures for SLS model (the conjugate gradient method and the TPE Sampler) converged to the same moduli values with variations of less than 5%, confirming the uniqueness and reliability of the identified viscoelastic parameters. Additionally, there is a strong correlation between derived equilibrium (Eeq) and instantaneous (Einst) moduli either between both parameter values themselves or in their estimation against tangent moduli at 0.12 mm/min and 120 mm/min experimental data which emphasizes the consistency and correctness of derived results for creep and cyclic compression sets of material constants.

Results of sensitivity analysis for compression case parameter derivation procedure in regards to Burgers model are presented in Tables S8, S9 and in Figure S10.

**Table S8:** Optimization Results for compression process (Burgers model)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Initial Point set** | **Derived parameters (Burgers model)** | | | |
| **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Cyclic compression (a) | 48.4 | 123.9 | 169800 | 645.5 |
| Creep (b) | 47.1 | 101.5 | 216400 | 1547 |
| Mean (c) | 48.3 | 120.5 | 197700 | 684.0 |
| +15% for (d) | 45.9 | 110.2 | 658500 | 1877 |
| -15% for (e) | 47.9 | 106.9 | 586900 | 838.8 |
| +15% for (f) | 44.6 | 112.8 | 569700 | 3550 |
| -15% for (g) | 45.7 | 105.4 | 654400 | 845.0 |

**Table S9:** Compression solution statistics (Burgers model)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Quantity | Burgers model | | | |
| **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Mean, MPa | 47.2 | 111.8 | 433400 | 1427 |
| Std, MPa | 1.42 | 8.02 | 225700 | 1047 |
| CV, % | 3.0 | 7.20 | 52.1 | 73.4 |

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| |  | | --- | | **Figure S10:** Sensitivity analysis for compression solution (Burgers model) | |

Results of sensitivity analysis for creep parameter determination in regards to Burgers model are presented in Tables S10, S11 and in Figure S11.

**Table S10:** Optimization Results for creep process (Burgers model)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Initial Point set** | **Derived parameters (Burgers model)** | | | |
| **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Cyclic compression (a) | 48.4 | 123.9 | 169800 | 645.5 |
| Creep (b) | 42.9 | 86.6 | 1.37·106 | 8947 |
| Mean (c) | 45.7 | 105.3 | 769900 | 4796 |
| +15% for (d) | 43.0 | 86.6 | 1.37·106 | 8947 |
| -15% for (e) | 38.8 | 89.5 | 769900 | 4796 |
| +15% for (f) | 43.0 | 86.6 | 1.37·106 | 8948 |
| -15% for (g) | 45.7 | 105.3 | 654400 | 4077 |

**Table S11:** Creep solution statistics (Burgers model)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Quantity | Burgers model | | | |
| **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Mean, MPa | 43.9 | 97.7 | 924900 | 5880 |
| Std, MPa | 2.80 | 13.3 | 428600 | 2958 |
| CV, % | 6.40 | 13.6 | 46.3 | 50.3 |

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| **Figure S10:** Sensitivity analysis for creep solution (Burgers model) |

The sensitivity analysis for the Burgers model revealed an expectedly more complex picture compared to the SLS model, which is associated with a larger number of optimized parameters. The elastic moduli E₁ and E₂ demonstrate satisfactory stability for both the compression (CV ~3-7%) and creep (CV ~6-14%) problems, confirming their adequate identification. As anticipated, the dynamic viscosity coefficients η₁ and η₂ showed significant scatter (CV > 50%), which is also owed to the initial large discrepancy between corresponding viscosities from different sets themselves affecting the values of initial guesses. This is a direct consequence of their nature as lumped parameters, whose function is to describe the shape of the transient response between two well-defined elastic states. Furthermore, for more complex models with relatively larger parameter amount different combinations of viscosities and moduli can yield a similarly close fit to the experimental curves within the parameter space, which is also known as “valley” region. Within it these parameters can compensate each other, while giving a very similar result due to their inherent coupling and mathematical description of rheological model. Nevertheless, the key result is that, despite the variability in individual viscosity values, all parameter sets provide a correct description of the material's macroscopic behavior, and the instantaneous modulus (E₁) remains physically meaningful and consistent with high strain-rate experiments. Results of sensitivity analysis for compression parameter determination in regards to GM model are presented in Tables S6, S7 and in Figure S9.

**Table S12:** Optimization Results for compression process (GM model)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Initial Point Set** | **Generalized Maxwell model (GM)** | | | | |
| **E0,MPa** | **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Cyclic compression (a) | 30.6 | 8.51 | 17.4 | 559.9 | 9.68 |
| Creep (b) | 30.4 | 5.63 | 12.6 | 958.5 | 31.2 |
| Mean (c) | 30.4 | 6.61 | 12.5 | 750.1 | 22.7 |
| +15% for (d) | 29.2 | 8.56 | 10.5 | 766.4 | 24.9 |
| -15% for (e) | 30.6 | 8.48 | 17.4 | 560.0 | 9.67 |
| +15% for (f) | 30.7 | 7.53 | 13.5 | 793.2 | 14.0 |
| -15% for (g) | 30.6 | 8.48 | 17.4 | 560.0 | 9.68 |

**Table S13:** Compression solution statistics (GM model)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Quantity | GM model | | | | |
| **E0,MPa** | **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Mean, MPa | 30.3 | 7.68 | 14.5 | 706.9 | 17.4 |
| Std, MPa | 0.52 | 1.16 | 2.86 | 153.3 | 8.80 |
| CV, % | 1.70 | 15.1 | 19.8 | 21.7 | 50.6 |

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| **Figure S11:** Sensitivity analysis for compression solution (GM model) |

Results of sensitivity analysis for compression parameter determination in regards to GM model are presented in Tables S14, S15 and in Figure S12.

**Table S14:** Optimization Results for creep process (GM model)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Initial Point Set** | **Generalized Maxwell model (GM)** | | | | |
| **E0,MPa** | **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Cyclic compression (a) | 25.9 | 7.83 | 19.8 | 1293 | 53.9 |
| Creep (b) | 25.9 | 7.30 | 18.8 | 1291 | 53.9 |
| Mean (c) | 25.9 | 7.80 | 19.4 | 1297 | 54.1 |
| +15% for (d) | 25.9 | 7.81 | 19.9 | 1299 | 54.2 |
| -15% for (e) | 24.0 | 6.72 | 15.4 | 925.5 | 31.8 |
| +15% for (f) | 25.9 | 7.80 | 19.4 | 1297 | 54.1 |
| -15% for (g) | 25.9 | 8.01 | 19.5 | 1299 | 53.5 |

**Table S15:** Creep solution statistics (GM model)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Quantity | GM model | | | | |
| **E0,MPa** | **E1,MPa** | **E2,MPa** | **η₁,MPa\*s** | **η2,MPa\*s** |
| Mean, MPa | 25.6 | 7.61 | 18.9 | 1243 | 50.8 |
| Std, MPa | 0.66 | 0.42 | 1.46 | 129.8 | 7.81 |
| CV, % | 2.60 | 5.50 | 7.81 | 10.4 | 15.3 |

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| **Figure S12:** Sensitivity analysis for creep solution (GM model) |

For the Generalized Maxwell model, the sensitivity analysis shows stable determination of the equilibrium modulus E₀ across all test conditions. The observed variability in individual moduli E₁ and E₂ (CV ~15-20% for compression, ~6-8% for creep) is characteristic of models with parallel Maxwell arms, where the optimization algorithm can redistribute contributions between parallel branches while maintaining overall stiffness characteristics and relaxation behavior. The viscosity parameters demonstrate expected variability consistent with their role as lumped parameters. Furthermore, the experimental stress-strain curve from cyclic compression in the 0-15% strain range has a shape that is close to linear. In the five-dimensional Generalized Maxwell parameter space an attempt to describe such relatively simple diagram will result in different parameter combinations (especially the parameters in the decaying exponential functions) yielding an almost identical and accurate fit to the experiment. Importantly, despite the scatter in individual parameters, the derived equilibrium (E₀) and instantaneous (E₀+E₁+E₂) moduli show strong correlation with experimental values, which is of considerable emphasis on the correctness and physical justification

All of the above mentioned confirms that the identification methodology provides representative parameter sets suitable for describing the material's viscoelastic behavior within the chosen structural model framework.