

TASK 4: VISCOELASTICITY

Fabian Roth

TUTORIAL MACHINE LEARNING IN SOLID MECHANICS

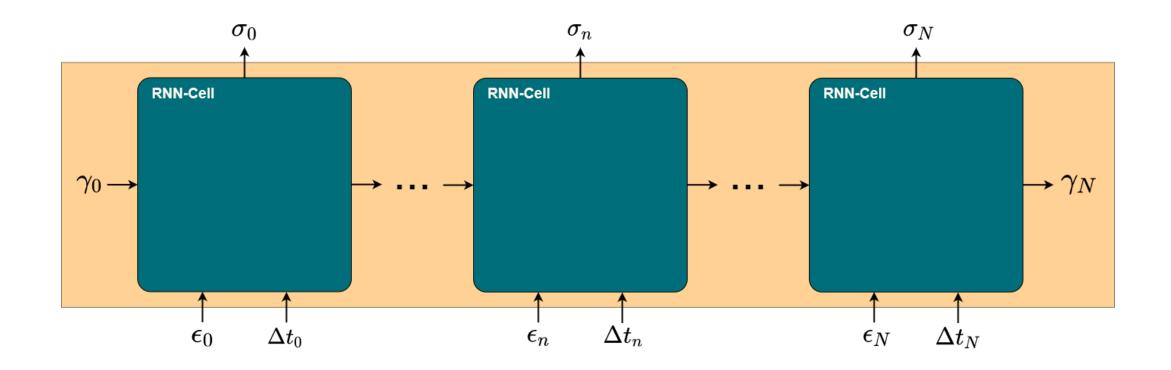
SECTIONS



- 4.1 Simple RNN
- 4.2 Maxwell model
- 4.3 FFNN Maxwell model
- 4.4 GSM model

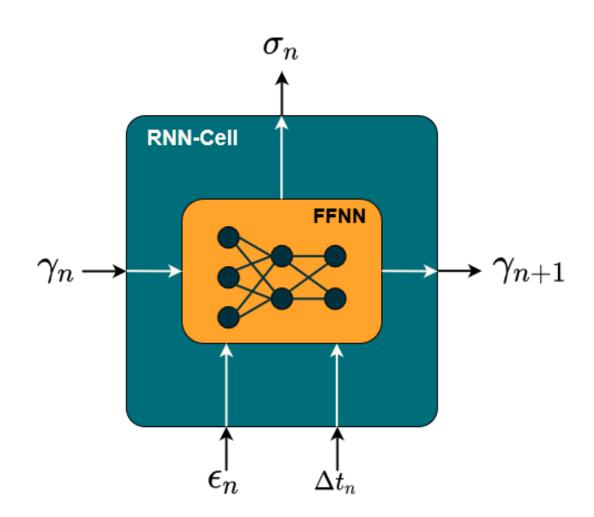
RNN ARCHITECTURE





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SIMPLE RNN



Physical Knowledge:

- Thermodynamics
- Equilibrium stiffness
- Non equilibrium stiffness
- Relaxation behavior

SIMPLE RNN

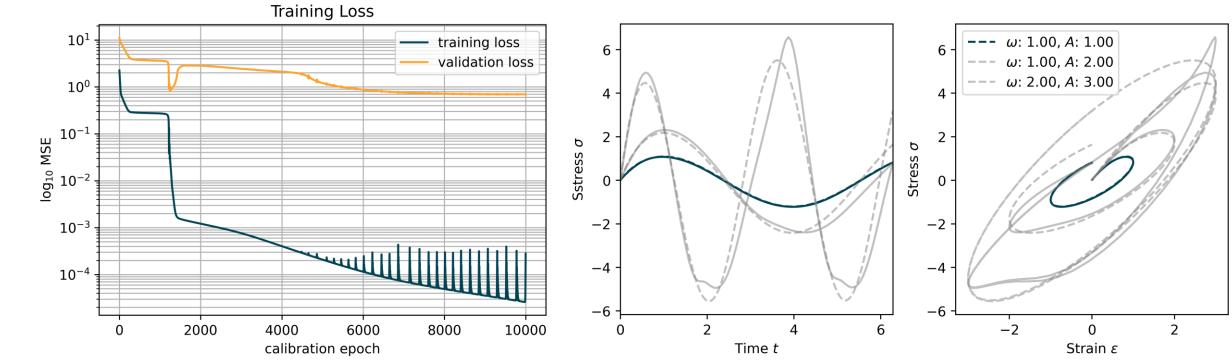
Trained on $\omega = 1$, A = 1



Epochs: 10,000

L. Rate: 0.001

Layers: 32,2



SIMPLE RNN

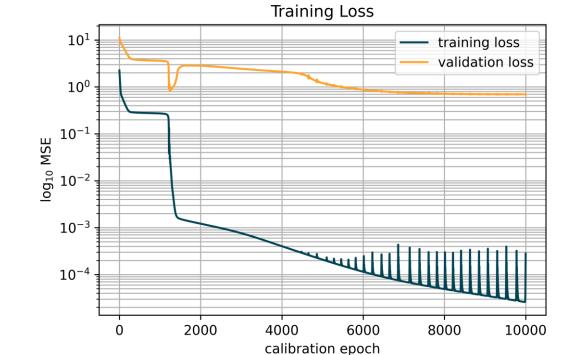
Trained on $\omega = 1, A = 1$

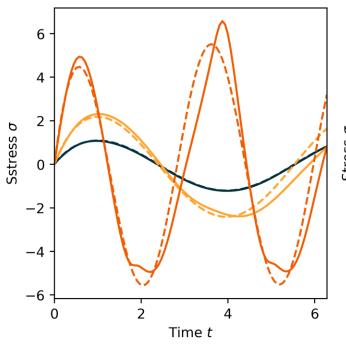


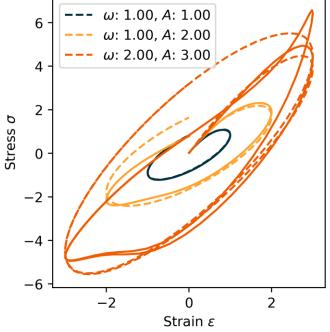
Epochs: 10,000

L. Rate: 0.001

Layers: 32,2







SIMPLE RNN

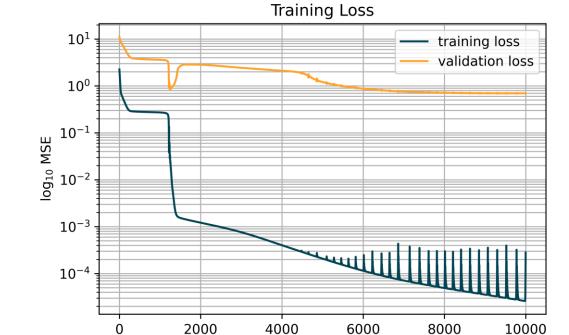
Trained on $\omega = 1$, A = 1



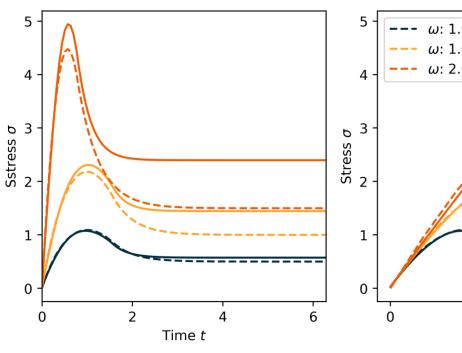
Epochs: 10,000

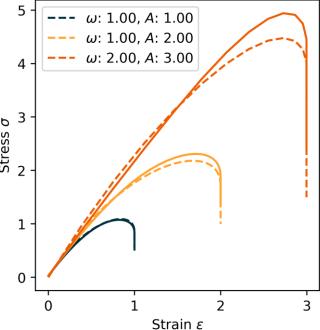
L. Rate: 0.001

Layers: 32,2



calibration epoch

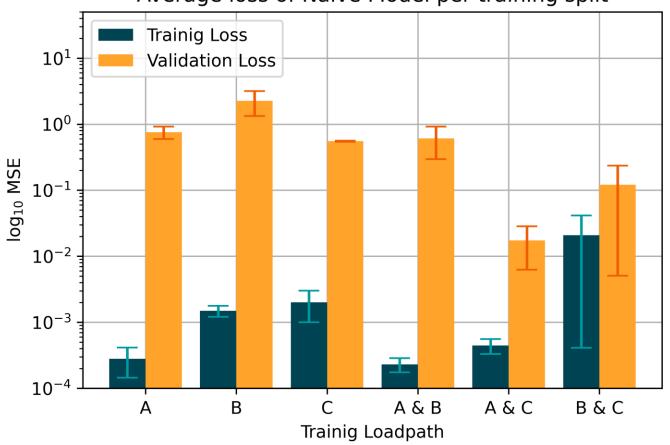




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SIMPLE RNN





A:
$$\omega = 1, A = 1$$

B: $\omega = 1, A = 2$
C: $\omega = 2, A = 3$

Epochs: 4000 L. Rate: 0.001 Layers: 32,2 Instances: 2

SIMPLE RNN

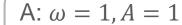


Epochs: 4000

L. Rate: 0.001

Layers: 32,2

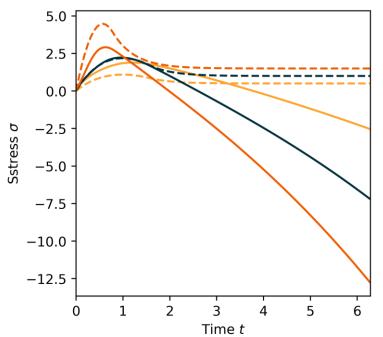
Instances: 2

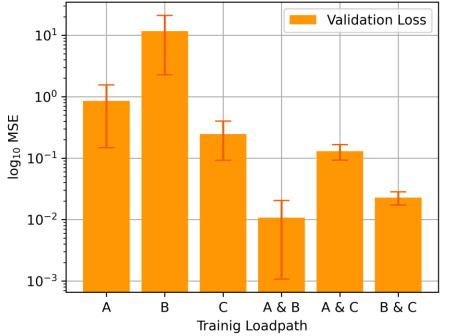


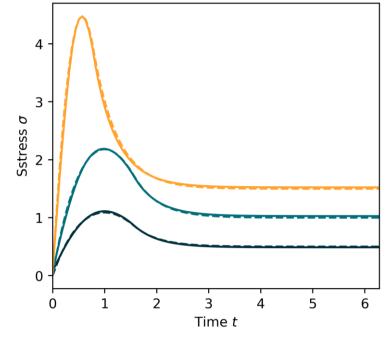
B:
$$\omega = 1, A = 2$$

C:
$$\omega = 2, A = 3$$

Average loss of Naive Model on relaxation data per training split

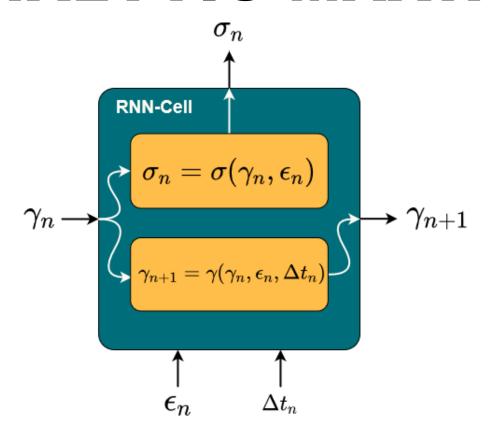




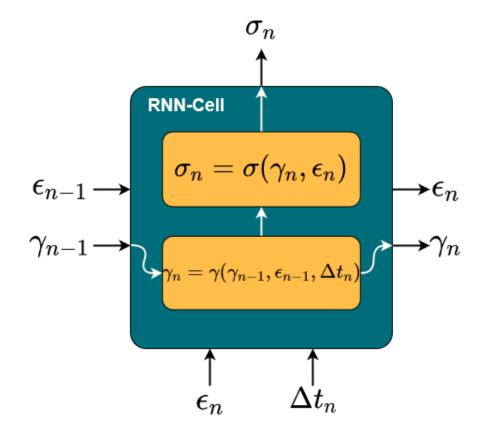




ANALYTIC MAXWELL MODEL



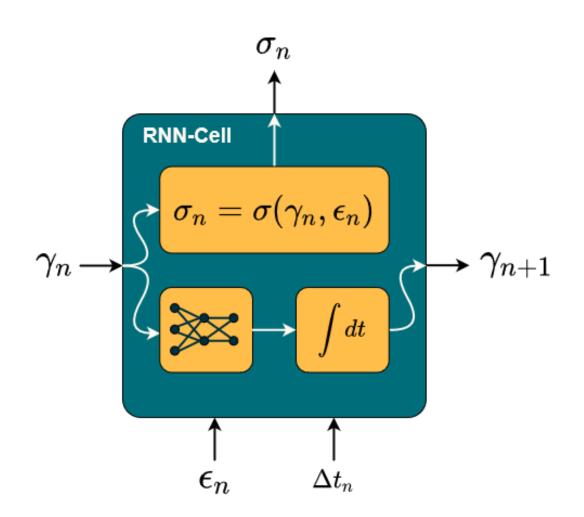
$$\Delta t_n = t_{n+1} - t_n$$



$$\Delta t_n = t_n - t_{n-1}$$

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FFNN MAXWELL MODEL



Physical Knowledge:

- ▼ Thermodynamics*
- Equilibrium stiffness
- Non equilibrium stiffness
- Relaxation behavior

*For exact integration

FFNN MAXWELL MODEL

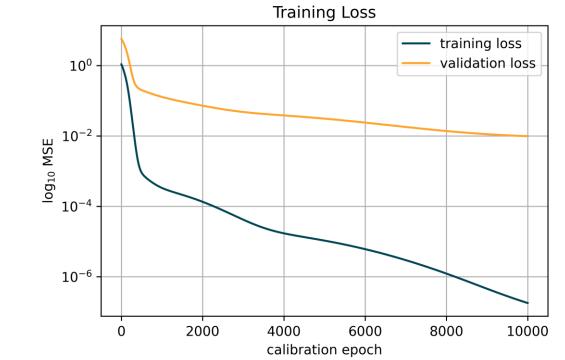


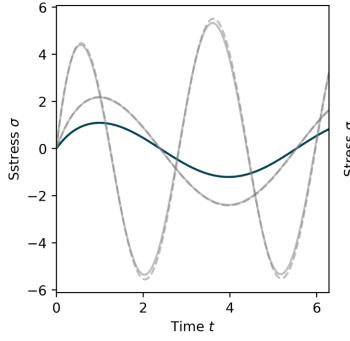
Epochs: 10,000

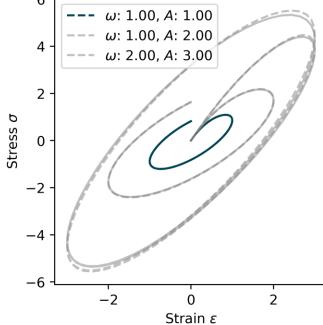
L. Rate: 0.001

Layers: 8, 8, 1









FFNN MAXWELL MODEL

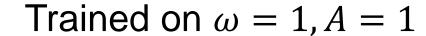


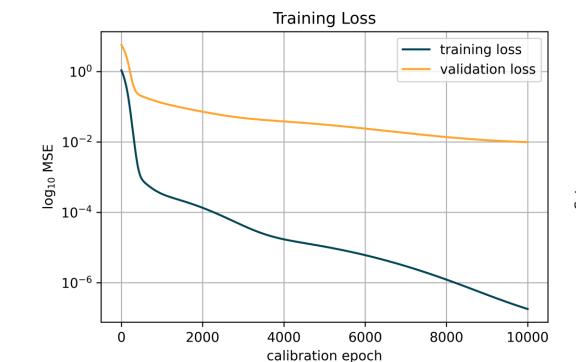
Epochs: 10,000

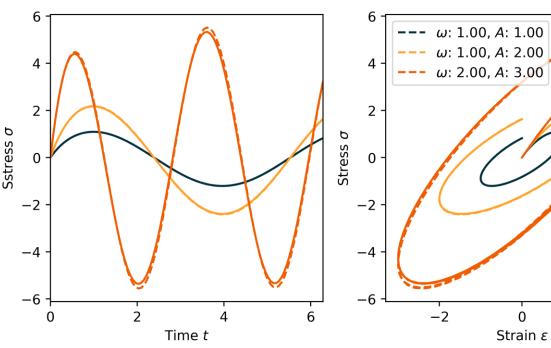
L. Rate: 0.001

Layers: 8, 8, 1

0







Model Prediction



2

FFNN MAXWELL MODEL



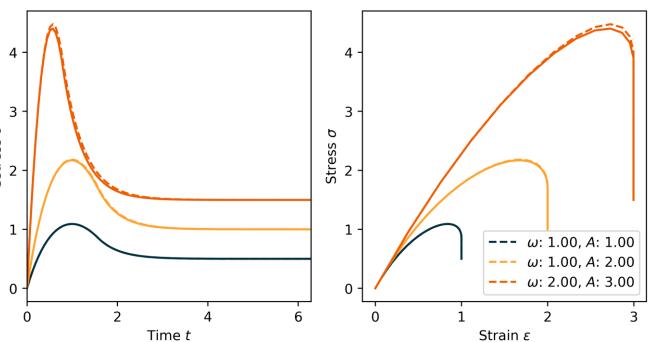
Epochs: 10,000

L. Rate: 0.001

Layers: 8, 8, 1



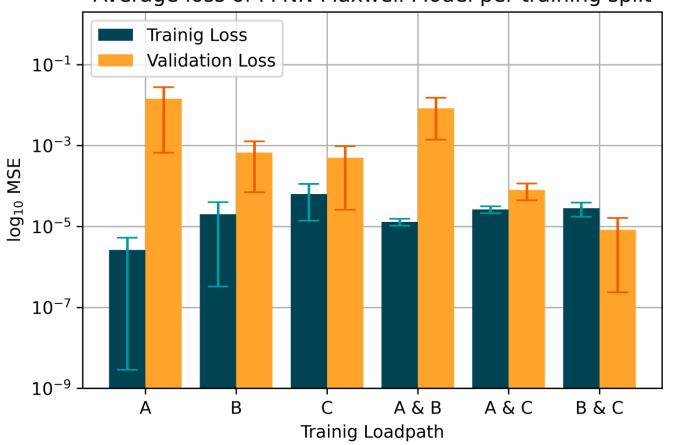




FFNN MAXWELL MODEL







A:
$$\omega = 1, A = 1$$

B: $\omega = 1, A = 2$

C:
$$\omega = 2$$
, $A = 3$

Epochs: 4000 L. Rate: 0.001 Layers: 8,8,1 Instances: 2

FFNN MAXWELL MODEL



Epochs: 3,000

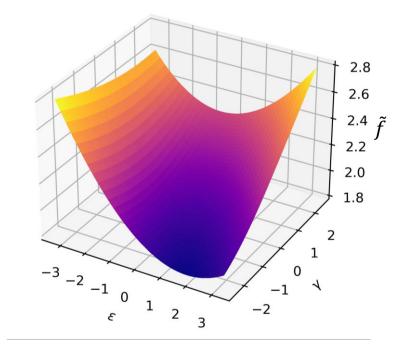
L. Rate: 0.001

Layers: 8, 8, 1

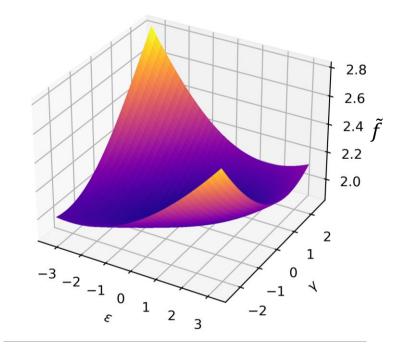
Evolution Equation: $\dot{\gamma} = \tilde{f}(\varepsilon, \gamma)(\varepsilon - \gamma)$

Model: $\tilde{f} = FFNN(\varepsilon, \gamma)$, Data: $\tilde{f} = \frac{E}{n} = 2$

Trained on A



Trained on C



FFNN MAXWELL MODEL



Epochs: 3,000

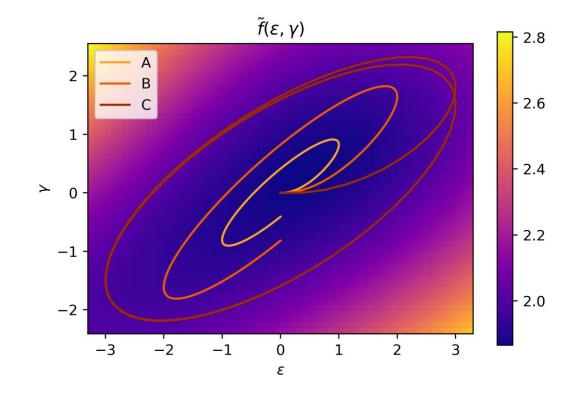
L. Rate: 0.001

Layers: 8, 8, 1

Trained on A

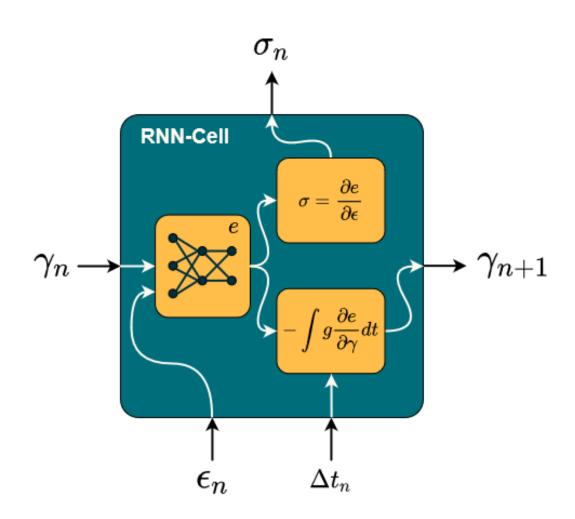
$\tilde{f}(\varepsilon, \gamma)$ 2.8 - 2.6 2.4 > - 2.2 -1- 2.0 -2

Trained on C



GSM MODEL





Physical Knowledge:

- ▼ Thermodynamics*
- Equilibrium stiffness
- Non equilibrium stiffness
- Relaxation behavior

*For exact integration

GSM MODEL

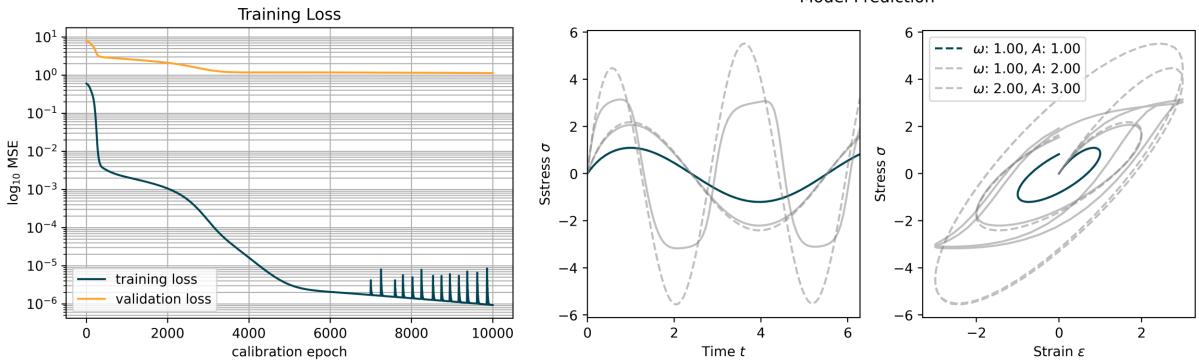
Trained on $\omega = 1$, A = 1



Epochs: 10,000

L. Rate: 0.001

Layers: 8, 8, 1



GSM MODEL

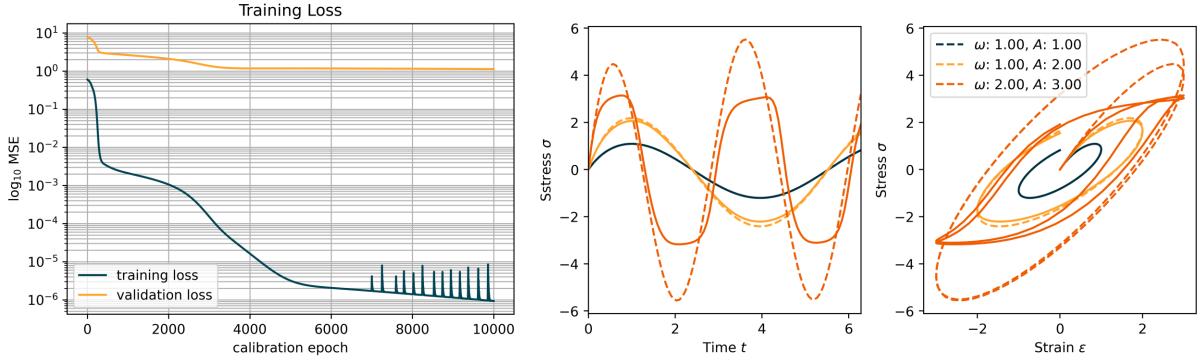
Trained on $\omega = 1$, A = 1



Epochs: 10,000

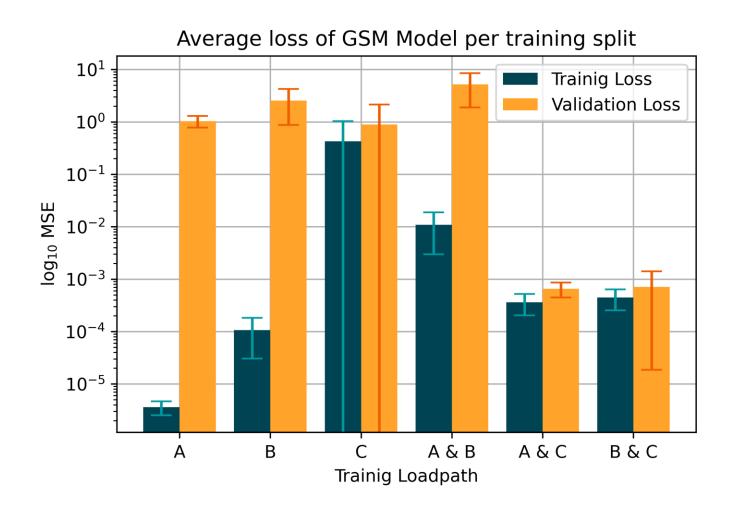
L. Rate: 0.001

Layers: 8, 8, 1



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GSM MODEL



A:
$$\omega = 1, A = 1$$

B: $\omega = 1, A = 2$
C: $\omega = 2, A = 3$

Epochs: 6000 L. Rate: 0.001 Layers: 8,8,1 Instances: 3



DISCUSSION

SIMPLE RNN

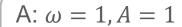


Epochs: 4000

L. Rate: 0.001

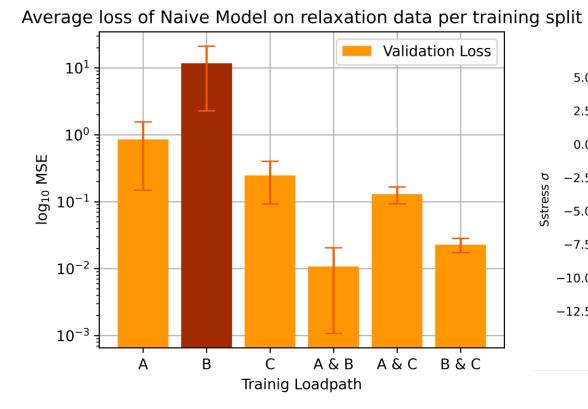
Layers: 32,2

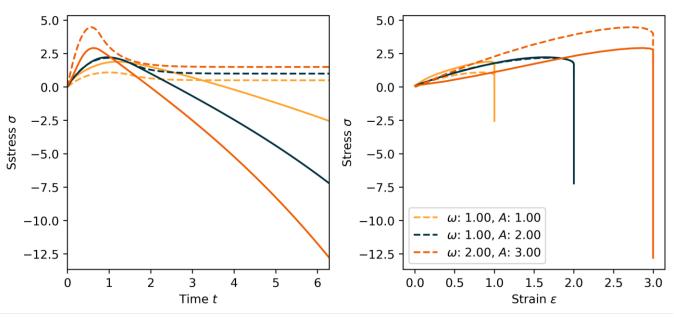
Instances: 2



B:
$$\omega = 1, A = 2$$

C:
$$\omega = 2, A = 3$$





SIMPLE RNN

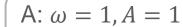


Epochs: 4000

L. Rate: 0.001

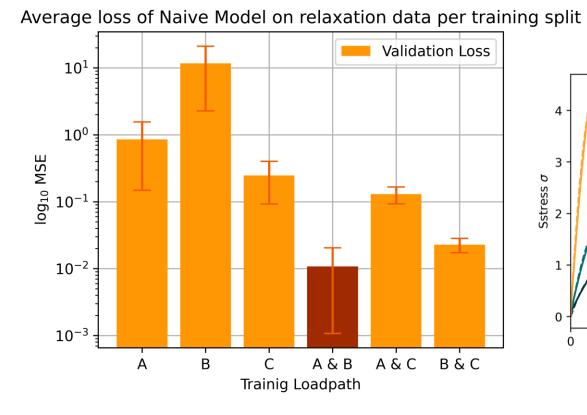
Layers: 32,2

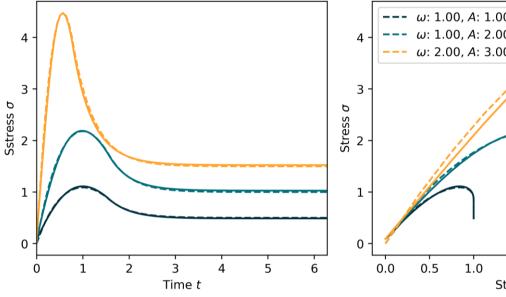
Instances: 2

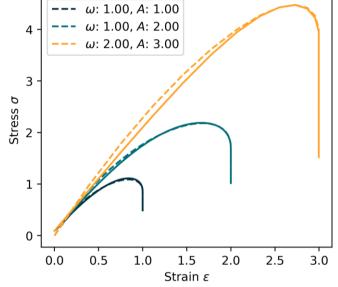


B:
$$\omega = 1, A = 2$$

C:
$$\omega = 2, A = 3$$

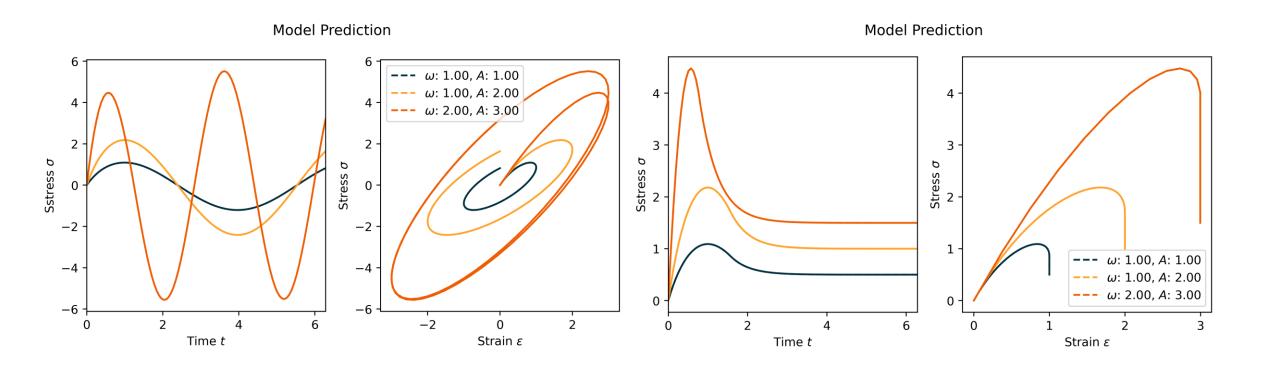






ANALYTIC MAXWELL MODEL





GSM MODEL

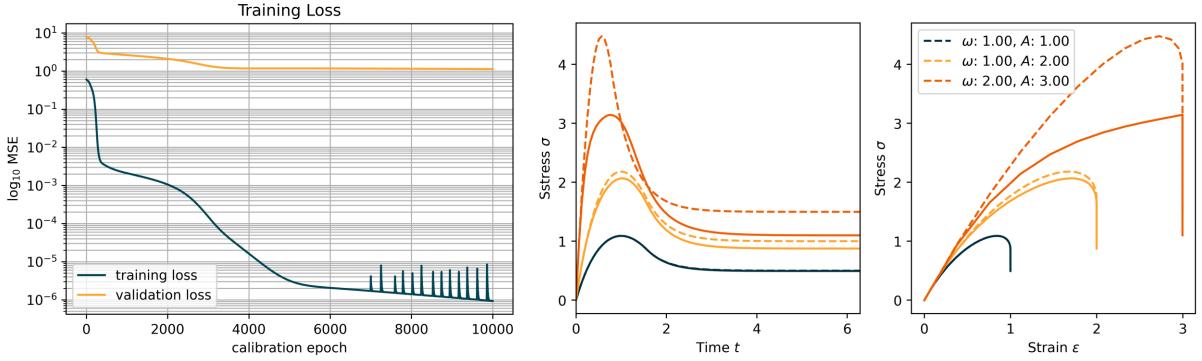
Trained on $\omega = 1$, A = 1



Epochs: 10,000

L. Rate: 0.001

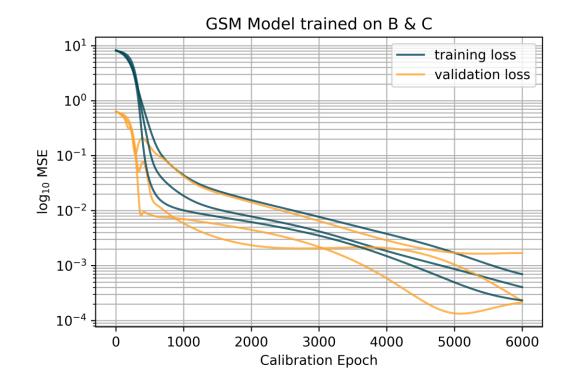
Layers: 8, 8, 1



4 - 2-4

GSM MODEL

Trained on B & C



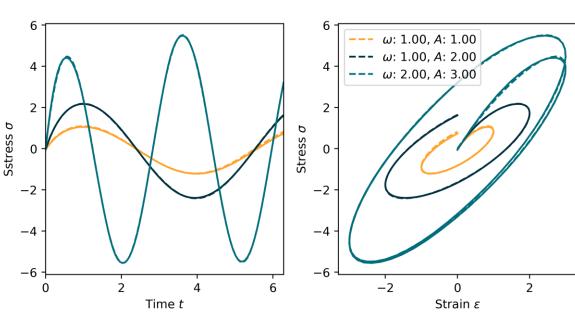
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Epochs: 6,000

L. Rate: 0.001

Layers: 8, 8, 1

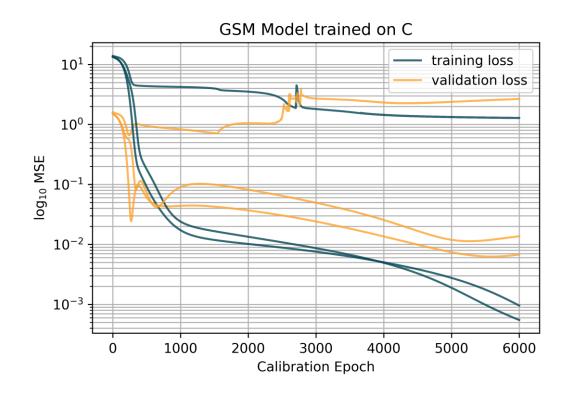
Prediction of GSM Model trained on B & C



4 - 2-4

GSM MODEL

Trained on C



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Epochs: 6,000

L. Rate: 0.001

Layers: 8, 8, 1

Prediction of GSM Model trained on C

