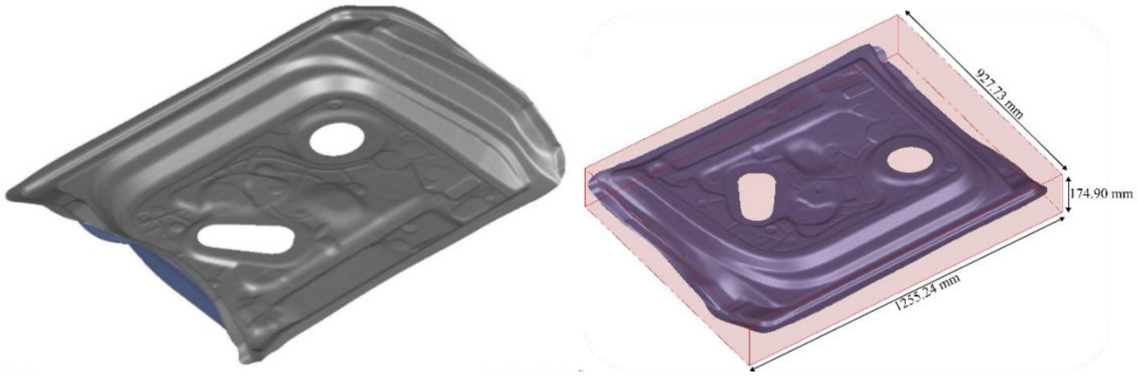
MPT coursework: manufacturing for sustainability

The manufacturing sector has placed great emphasis on low-carbon development, i.e., it has been committed to building a green supply chain covering the full lifecycle of products.
With the product development concept of “manufacturing for sustainability” in mind, this MPT coursework (including task 1, 2 and 3) will develop sustainable manufacturing process(es) to produce a ‘door inner panel (CAD file will be released in task 3)’, at low-cost, and low-carbon emission.



MPT coursework: A ‘Door Inner’ to be produced for an EV manufacturing company

Task 2, a Pre-FE task: developing a material card for the FE simulation of a sustainable manufacturing process

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Key learning outcomes of task 2:

- Essential skills for sustainable digital manufacturing, e.g., data processing and material modelling.
- Development of a material card to be used in a widely used commercial FE software: AutoForm (training to be provided in CW3)

Instructions

The aim of this task is to develop a ‘material card’ for the FE simulation of a high temperature sheet metal forming process. An experimental data set will be provided which was obtained by using uniaxial tensile tests of sheet aluminium alloys at various temperatures and strain rates. Process the raw data for material modelling.

Find appropriate constants for a series of constitutive equations used to model experimental data. As a part of the task, you are expected to solve these equations through MATLAB (or Excel or Python) by using a numerical integration method of your choice. Manual fitting is also possible.

The typical procedure for determining the equation constants is to first plot the constitutive equations with initial estimated values for the constants (following their physical meanings) and adjust the constants in order to represent the experimental data as closely as possible. This can be performed either manually or through an algorithmic optimisation method.

The equation constants to be fitted should enable an accurate representation of the experimental data for strain rate and temperature conditions. An example set of experimental data for a particular aluminium alloy is shown in Appendix 1. The two graphs provided show stress-strain results for strain rates of 0.1s^{-1}, 1s^{-1} and 5s^{-1} at a temperature of 500°C, as well as at temperatures of 350°C, 400°C, 450°C, 500°C and 535°C at a strain rate of 1s^{-1}. For this task, all the groups will be provided with a set of experimental data (which will be uploaded to Blackboard).

You are required to work in **groups** and carry out the numerical integrations outlined below, submit the MATLAB/Python scripts (or Excel) and supplementary paperwork (optional) and peer assessments *no later than* **12pm on Friday 30th Jan. 2026 on Blackboard. Present your results on 3rd Feb. 2026 between 2 and 5 pm.**

Equations

The experimental results show that the material's mechanical properties are both strain rate and temperature dependent. Therefore, the viscoplastic flow of the material can be modelled using the following constitutive equations:

$$\dot{\varepsilon}_p = \left(\frac{\overline{\sigma} - R - k}{K}\right)^{n_1} \quad (1)$$

$$\dot{R} = 0.5B\overline{\rho}^{-0.5}\dot{\overline{\rho}} \quad (2)$$

$$\dot{\overline{\rho}} = A(1-\overline{\rho})\dot{\varepsilon}_p - C\overline{\rho}^{n_2} \quad (3)$$

$$\overline{\sigma} = E\left(\varepsilon_T - \varepsilon_p\right) \quad (4)$$

Where Equation 1 is the viscoplastic flow rule, Equation 2 represents isotropic hardening, Equation 3 represents the rate of change of the normalized dislocation density, and Equation 4 represents the flow stress. This set of equations does not capture the later stages of deformation (and subsequent failure of the material), and hence can only be used to model yielding and hardening or softening.

The temperature dependency for the constants *K*, *k*, n_1, *B*, *A*, *C*, and *E* in Equations 1 to 4 can be modelled using Arrhenius relationships as shown in Equations 5 - 11 below. Note that the constant n_2 (Equation 3) is temperature independent.

$$K = K_0 \exp\left(\frac{Q_K}{R_{gas}T}\right) \quad (5)$$

$$k = k_0 \exp\left(\frac{Q_k}{R_{gas}T}\right) \quad (6)$$

$$n_1 = n_0 \exp\left(\frac{Q_n}{R_{gas}T}\right) \quad (7)$$

$$B = B_0 exp\left(\frac{Q_B}{R_{gas}T}\right) \quad (8)$$

$$A = A_0 exp\left(\frac{Q_A}{R_{gas}T}\right) \tag{9}$$

$$C = C_0 exp\left(\frac{-Q_C}{R_{gas}T}\right) \tag{10}$$

$$E = E_0 \exp\left(\frac{Q_E}{R_{gas}T}\right) \tag{11}$$

Where: K_o , k_o , n_o , B_o , A_o , C_o , E_o , Q_K , Q_k , Q_n Q_B , Q_A , Q_C , and Q_E are temperature independent constants. T is the temperature in Kelvin and R_g is the universal gas constant 8.31J/mol.K.

It is important to remember that whilst there can be different temperature dependent constants to represent each of the experimental test conditions, there can only be a single set of temperature independent constants that is unique to each material.

Tasks

- Work in groups
- Use a manual or numerical method to integrate the set of unified constitutive equations. Use the Excel template code provided as a guide for the model fitting procedures.
- Determine the temperature independent constants ($K_o, k_o, n_o, B_o, A_o, C_o, E_o, Q_K, Q_k, Q_n$ $Q_B, Q_A, Q_C,$ Q_E and n_2) for the best fit. This fitting can be performed manually.

Assessment (pitch on 3rd Feb. 2026):

- Present your results of task 2 for up to 10 min + 5 min Q&A per group.
- Each group member should present individual contributions.
- Feedback and comments will be provided by 'customers' (course-leaders and GTAs).
- MATLAB/Python scripts (or Excel) and supplementary paperwork (optional) should be submitted as separate files to Blackboard. They will be reviewed for plagiarism purposes.
- Improvements should be made by following the feedback and comments, leading to high-quality results in task 3.
- Submit peer assessment on Blackboard.

Assessment criteria for your pitch

Topic/item examined	**Typical poor result**						**Typical excellent result**
Aim & Objectives	*Scattered/uninformative*	E	D	C	B	A	*Clear, good understanding*
Style & timekeeping	*inaudible/untimely*	E	D	C	B	A	*audible/punctual*
Quality of slides	*illegible/confused/unhelpful*	E	D	C	B	A	*legible/clear/helpful*
Quantity of work done	*very little*	E	D	C	B	A	*a great deal*
Discussion	*Inadequate, shallow*	E	D	C	B	A	*Balanced, professional*
Conclusions	*None/trivial/misleading*	E	D	C	B	A	*Clear/concise/accurate*
Audience questions	*not answered*	E	D	C	B	A	*handled expertly*

In the presentation and optional supplementary paperwork, the following sections could be included:

(0) **Title page and abstract.**

(1) **Aim and background.** Clearly explain the motivation of the work. Provide comprehensive discussions of the physical mechanisms of the constitutive material model.

Scant, trivial E D C B A Comprehensive, publishable

(2) **Numerical integration method.** Clearly explain the numerical integration method developed and implemented in this coursework. A flow chart should be presented.

Lack of understanding E D C B A Comprehensive, thoughtful, professional quality

(4) **Results and discussion (accuracy analysis).** Present graphical evidence of the optimised model parameters ($K_o, k_o, n_o, B_o, A_o, C_o, E_o, Q_K, Q_k, Q_n\ \ Q_B, Q_A, Q_C, Q_E$ and n_2) being fitted to the experimental uniaxial tensile test results. Discuss the achieved fit and any errors between the two. Include remarks on how a better fit could be achieved by considering the provided data and model equations.

Lack of understanding	E	D	C	B	A	Comprehensive, thoughtful, professional quality

(6) **Sustainability analysis.**

High carbon footprint of proposed solution	E	D	C	B	A	Low carbon footprint of proposed solution

(7) **Cost analysis.**

High cost of proposed solution	E	D	C	B	A	Low cost of proposed solution

(8) **Conclusions.** Summarise the findings obtained in this coursework.

None/trivial/misleading	E	D	C	B	A	Clear/concise/accurate

(9) **MATLAB/Python/Excel scripts.**

None/trivial/misleading	E	D	C	B	A	Clear/commented/accurate

Appendix 1:

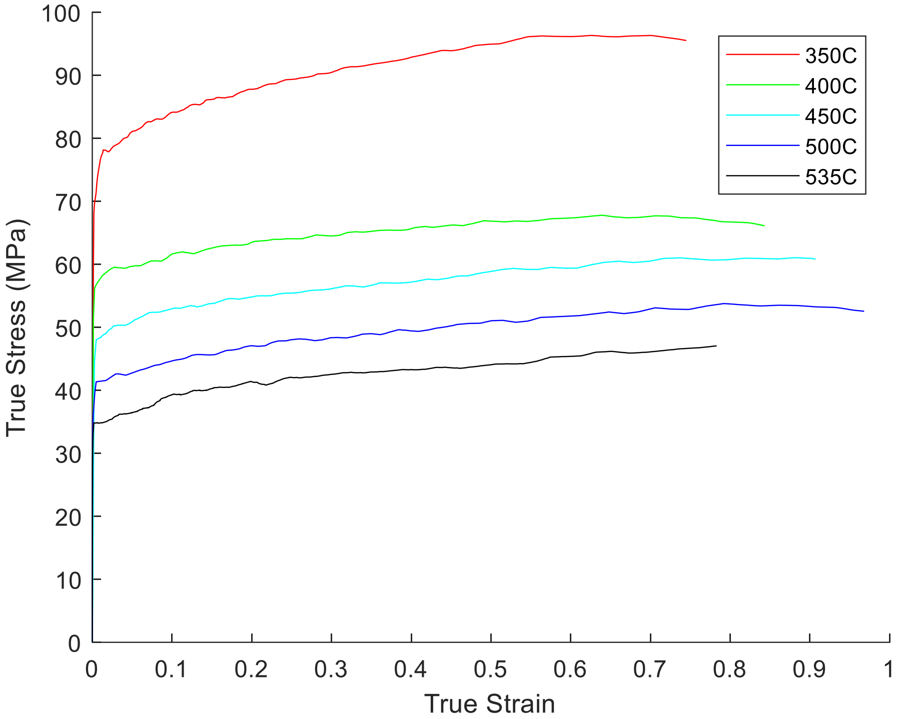

Figure 1: Flow stress data at different temperatures for a strain rate of 1/s

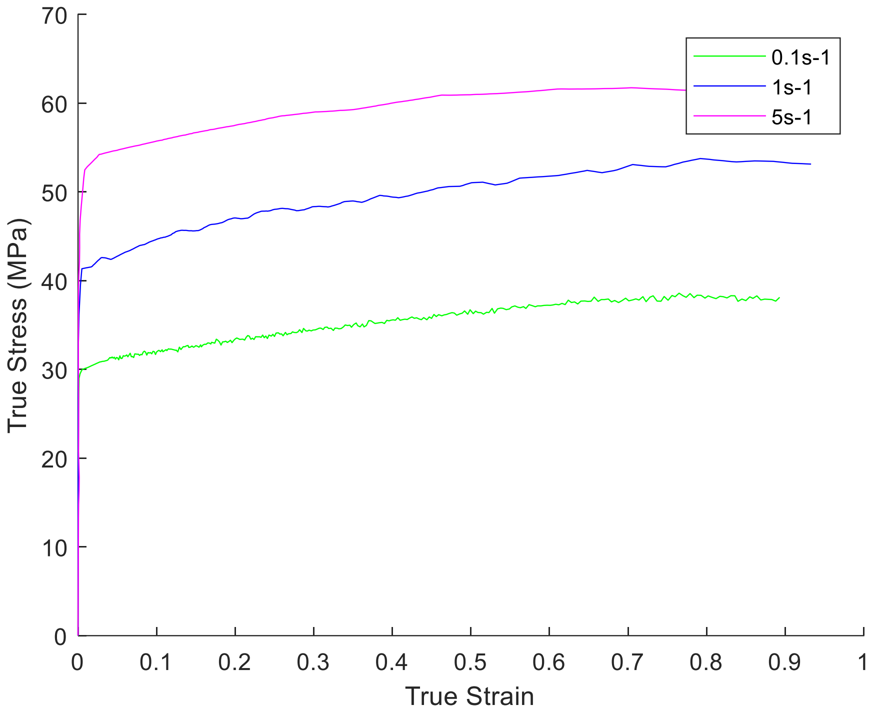

Figure 2: Flow stress data at different strain rates for a temperature of 500°C