Problem 2

- Perform a Rainflow counting for the following load history (see Figure 1)

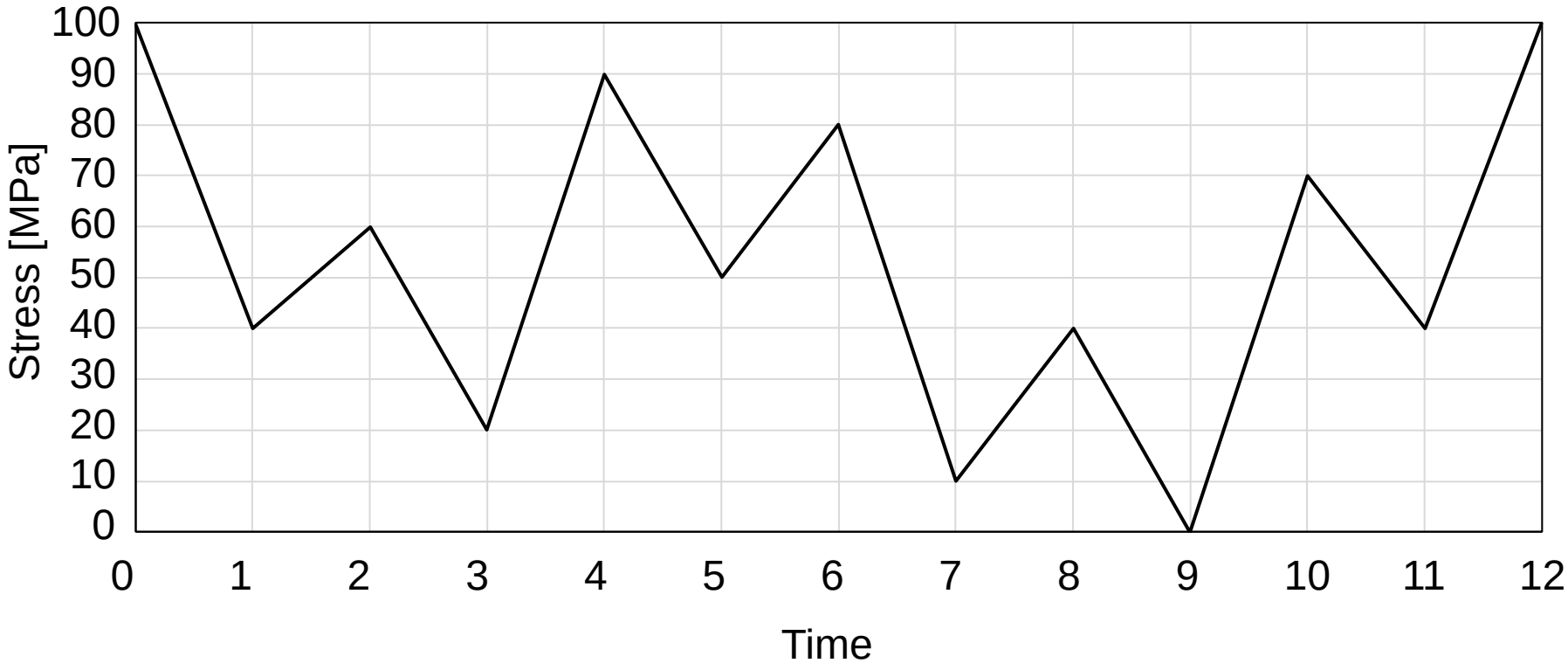
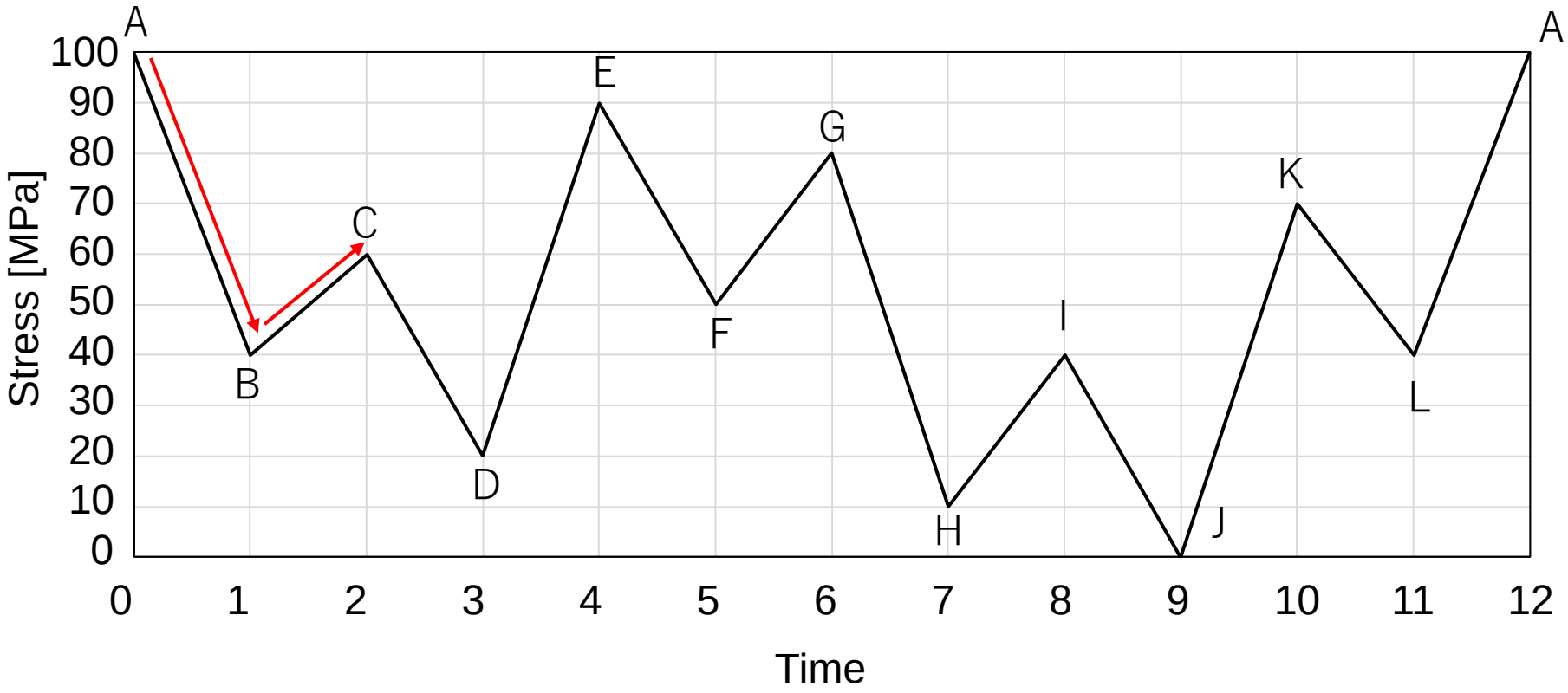


Figure 1 Load history for one repetition

Step 1

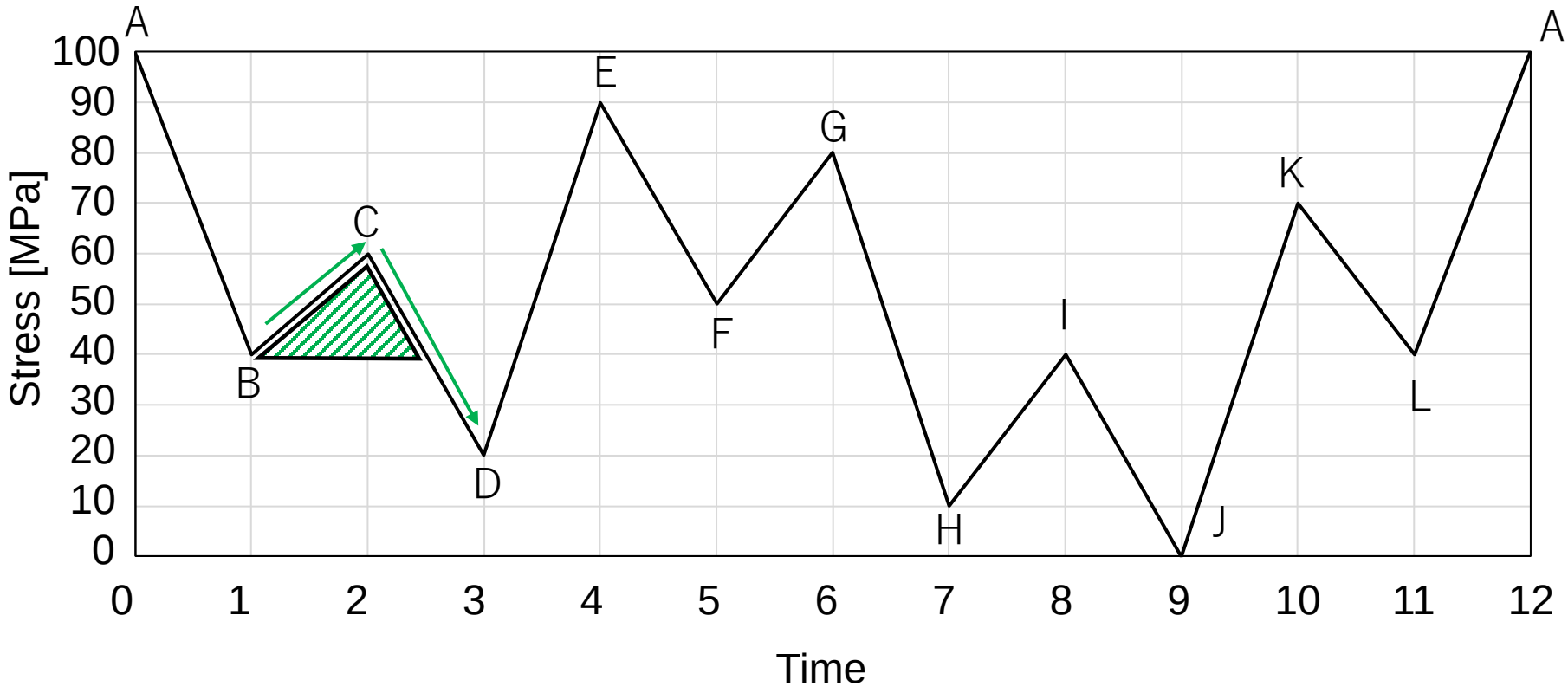
Stress range **AB** > **BC**
→then move to the next segment

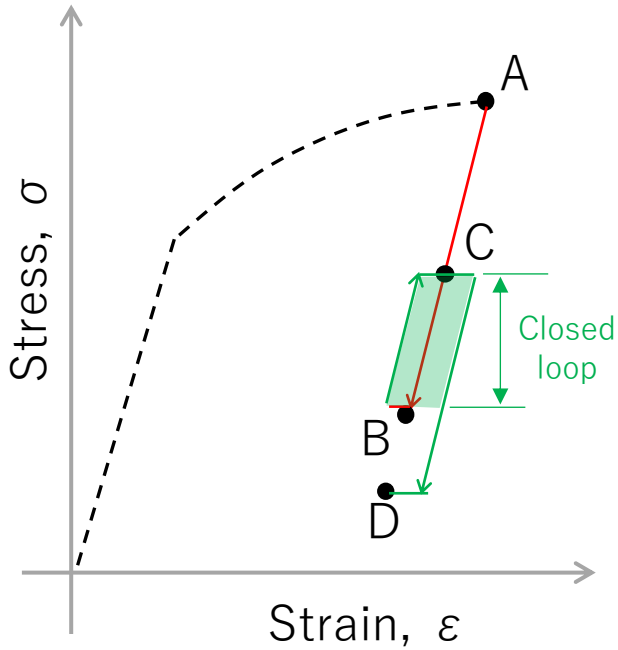


Step 1

Stress range **BC** < **CD**
→then count a cycle

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa





Step 2

Stress range **AD** > **DE**
→then move to the next segment

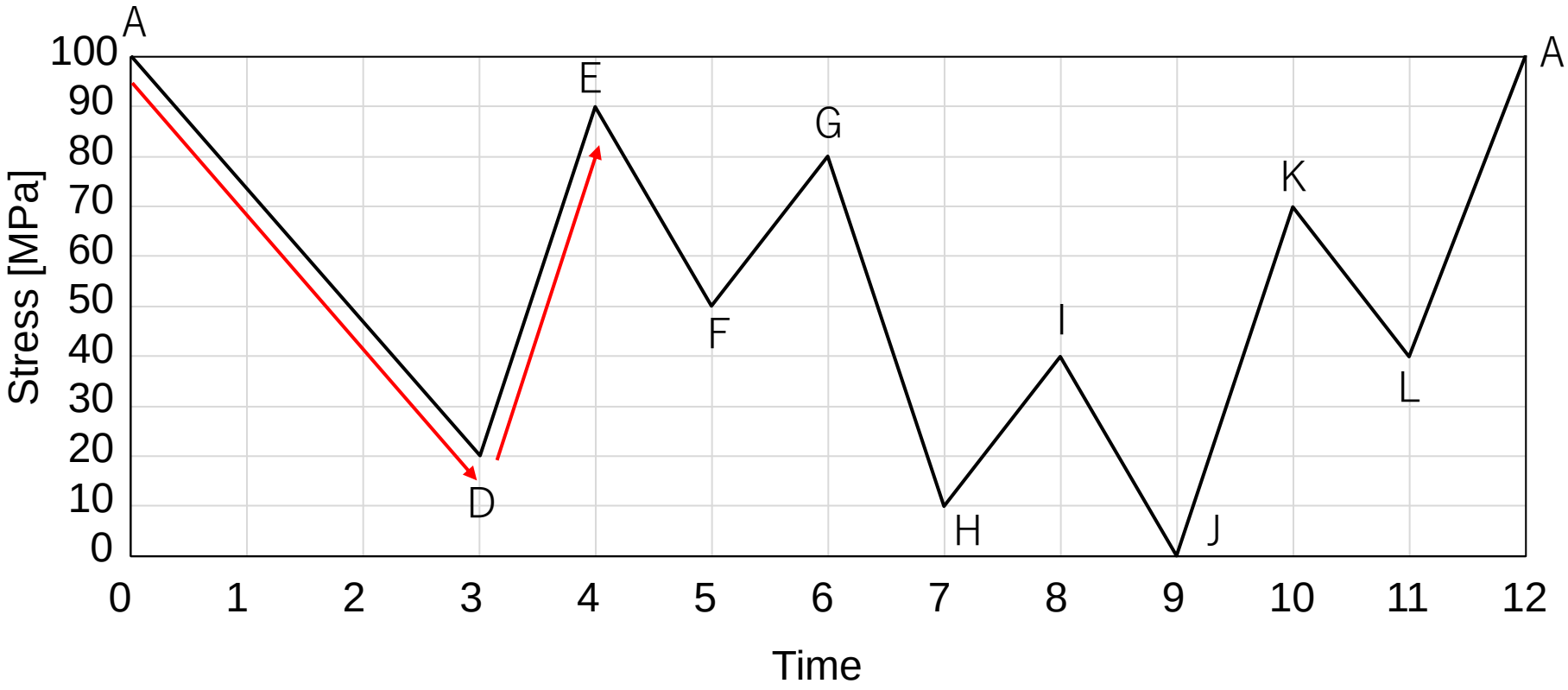


Figure 1 Load history for one repetition

Step 2

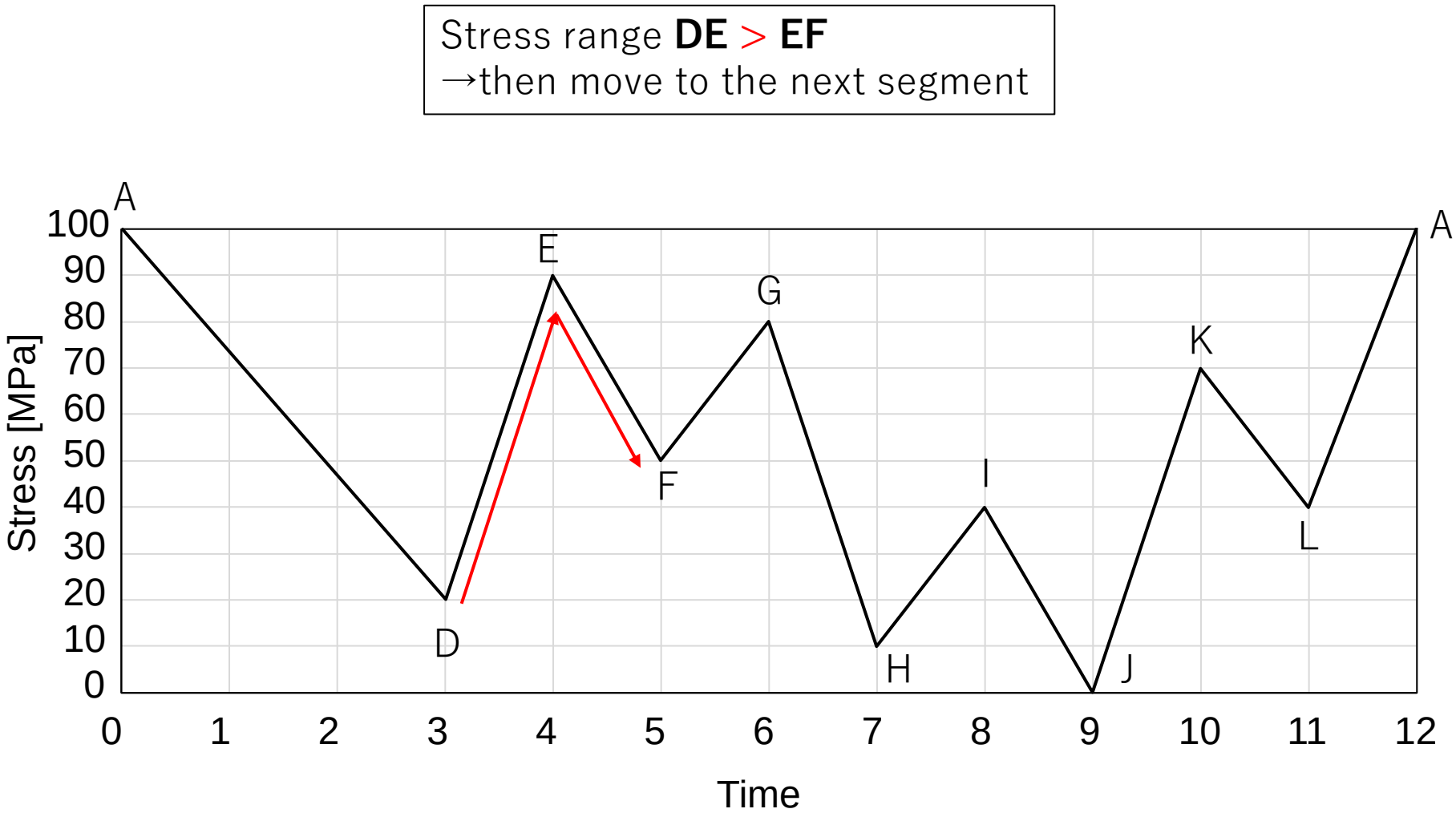


Figure 1 Load history for one repetition

Step 2

Stress range **EF** > **FG**
→then move to the next segment

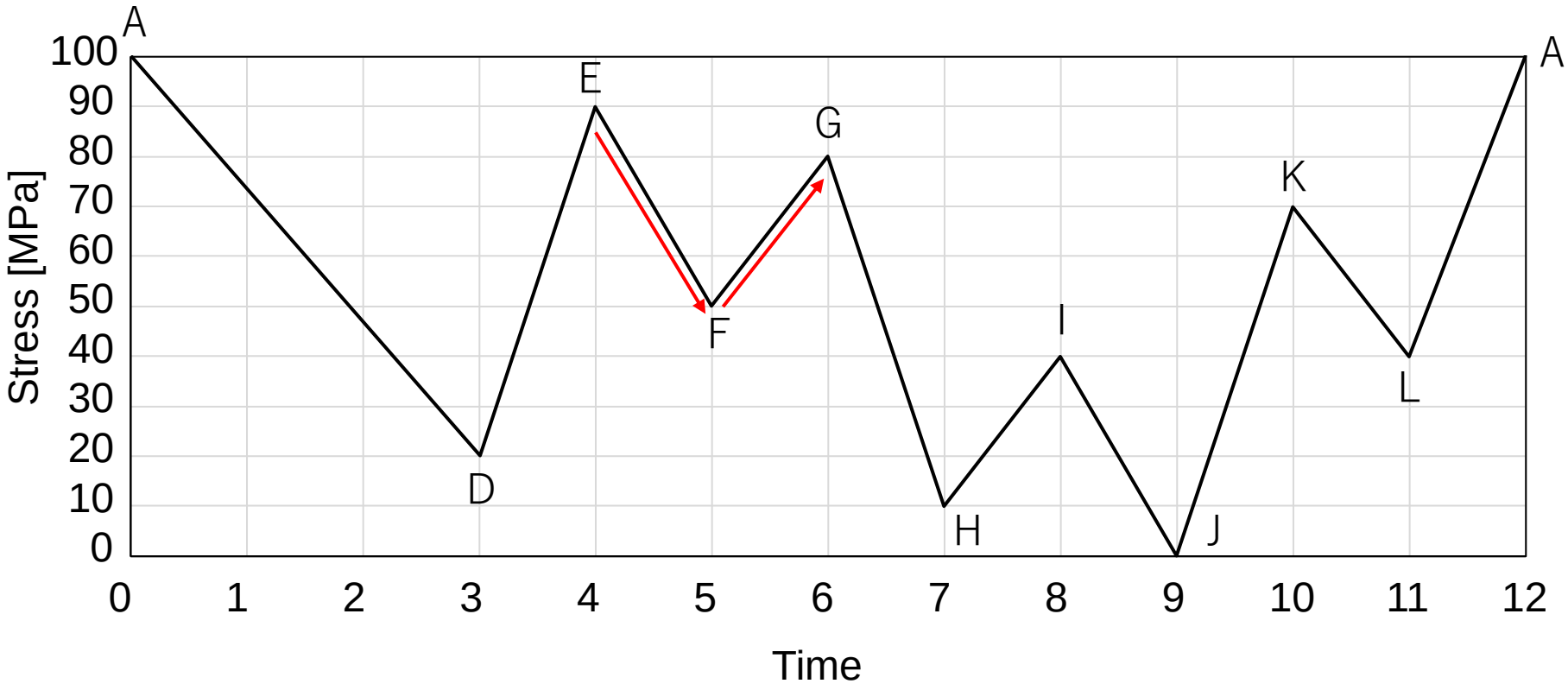


Figure 1 Load history for one repetition

Step 2

Stress range **FG** < **GH**
→then count a cycle

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa
F-G	30 MPa	65 MPa

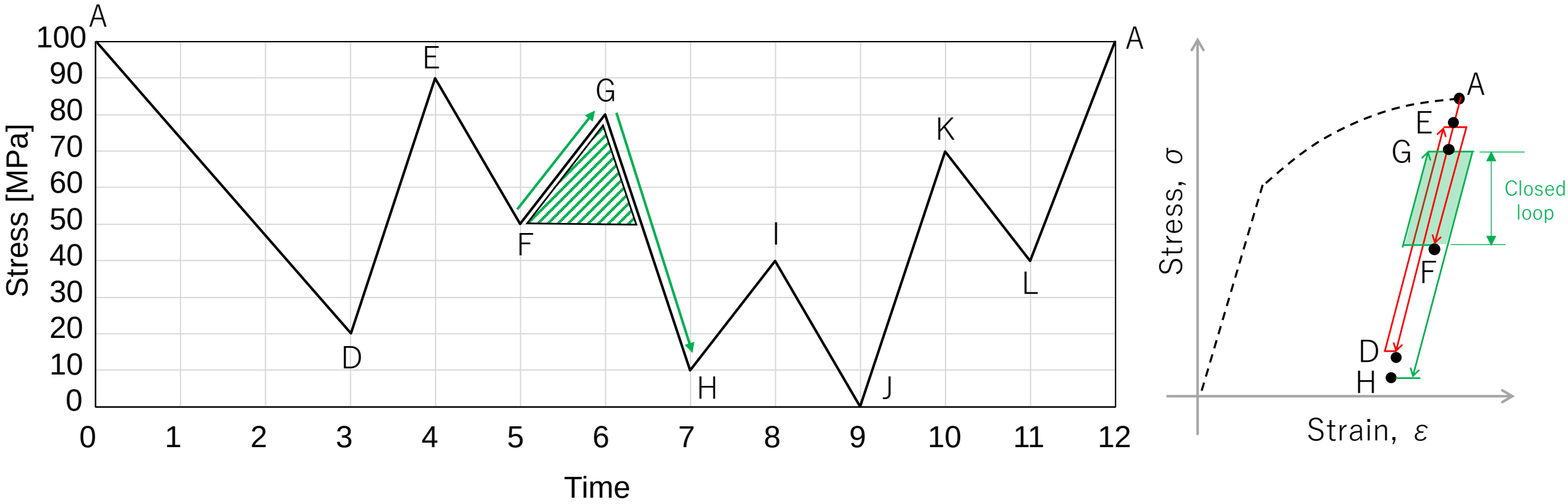


Figure 1 Load history for one repetition

Step 3

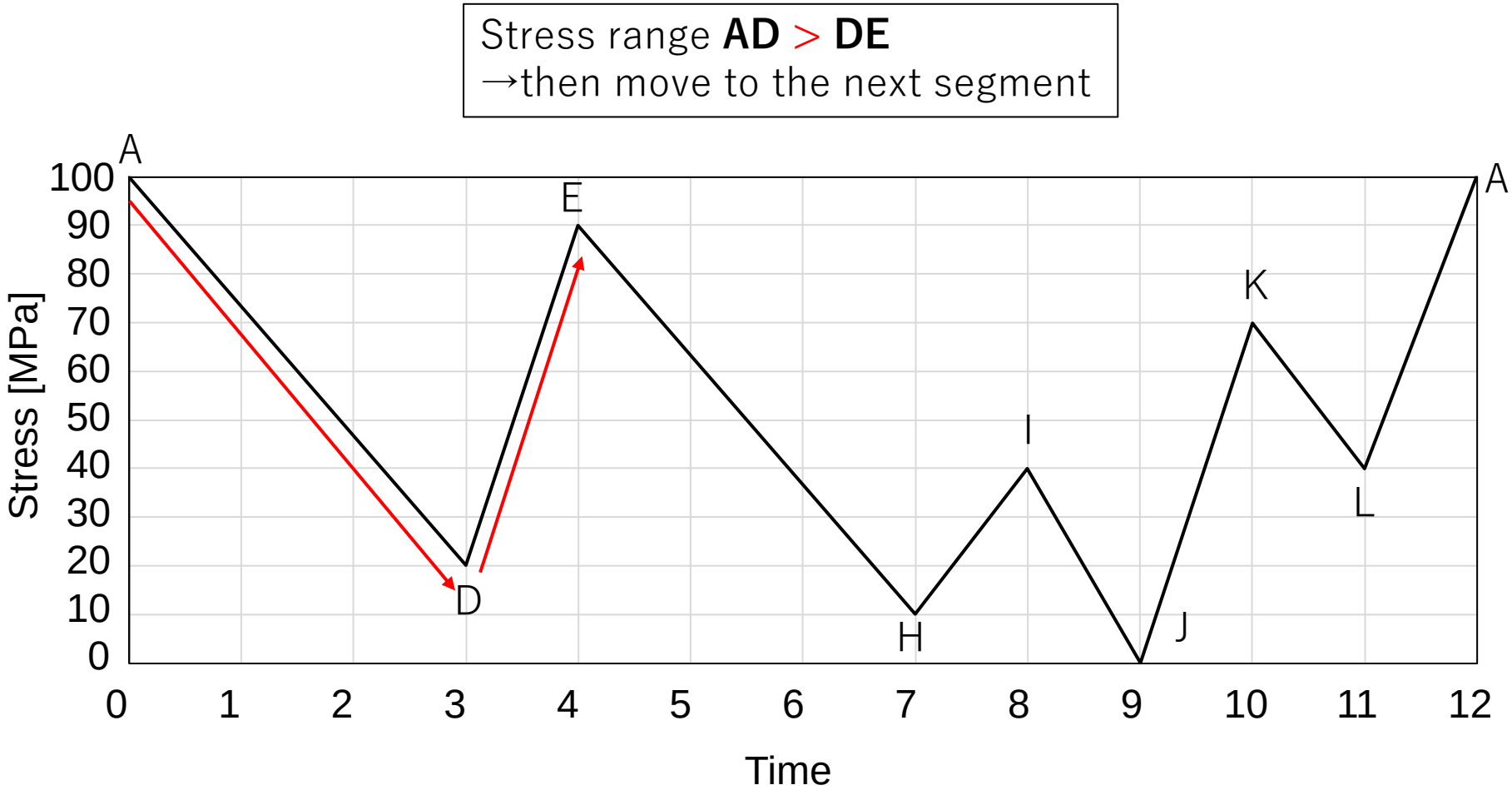
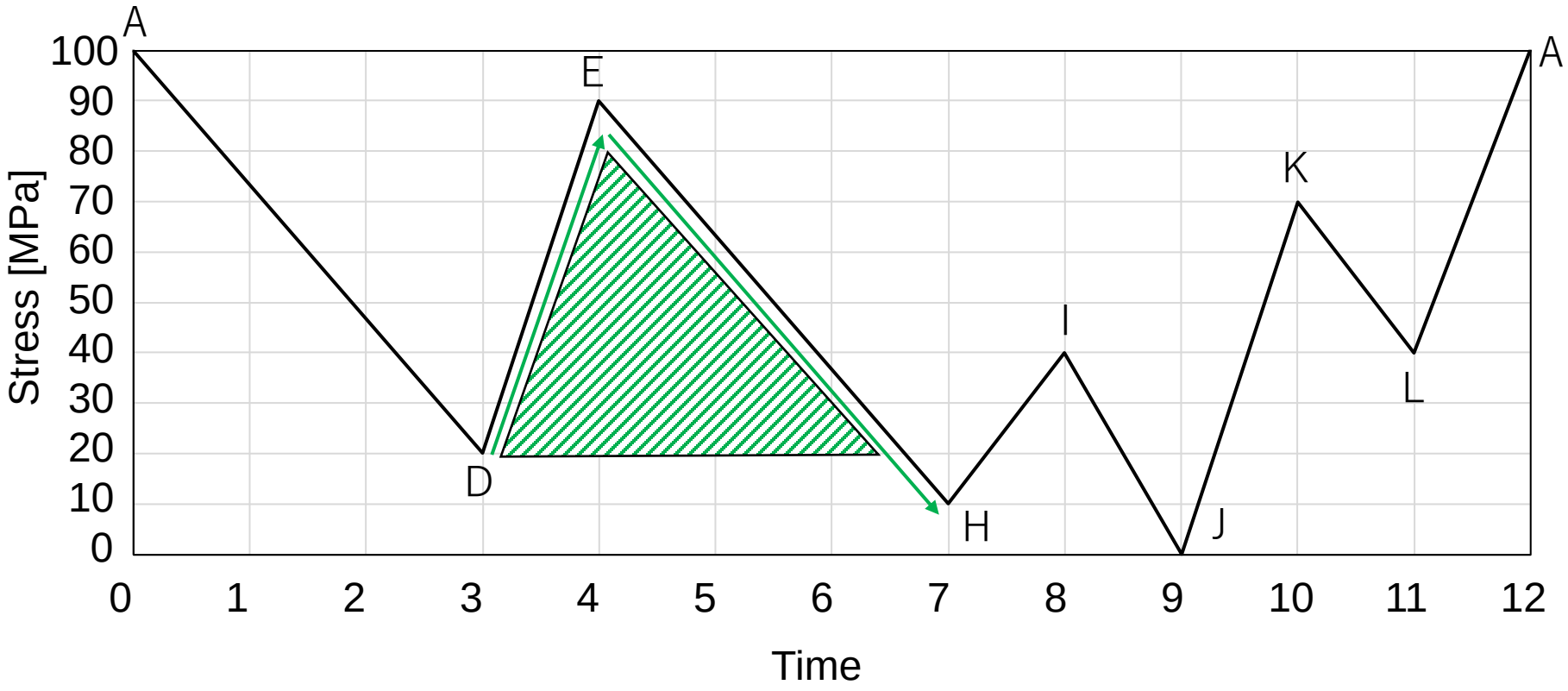


Figure 1 Load history for one repetition

Step 3

Stress range **DE** < **EH**
→then count a cycle

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa
F-G	30 MPa	65 MPa
D-E	70 MPa	55 MPa



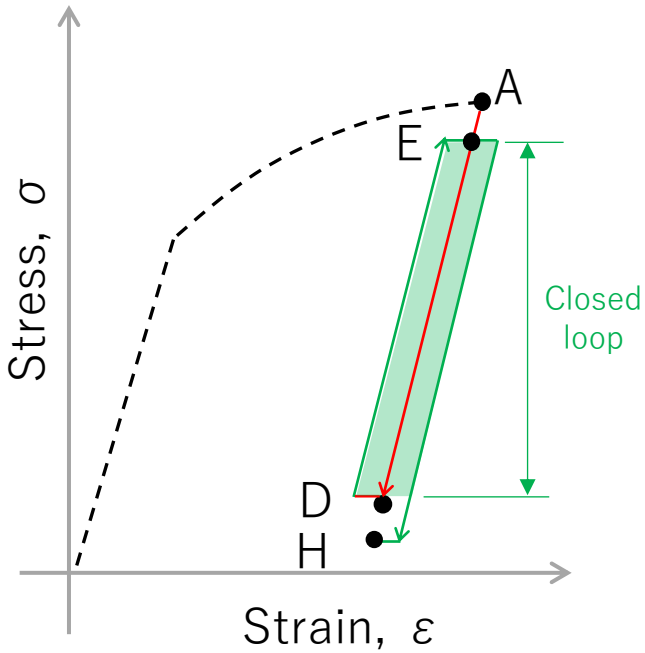


Figure 1 Load history for one repetition

Step 4

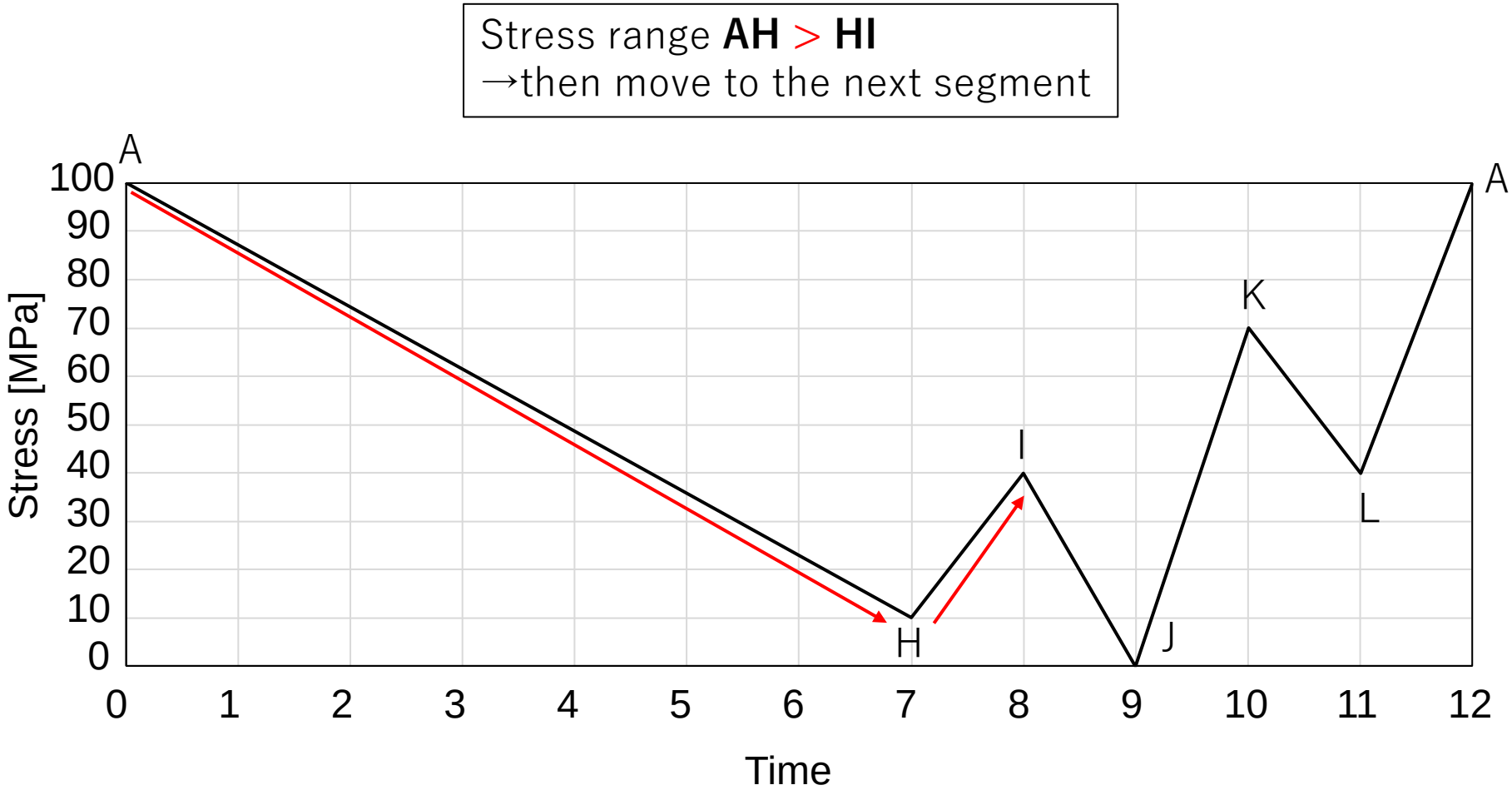
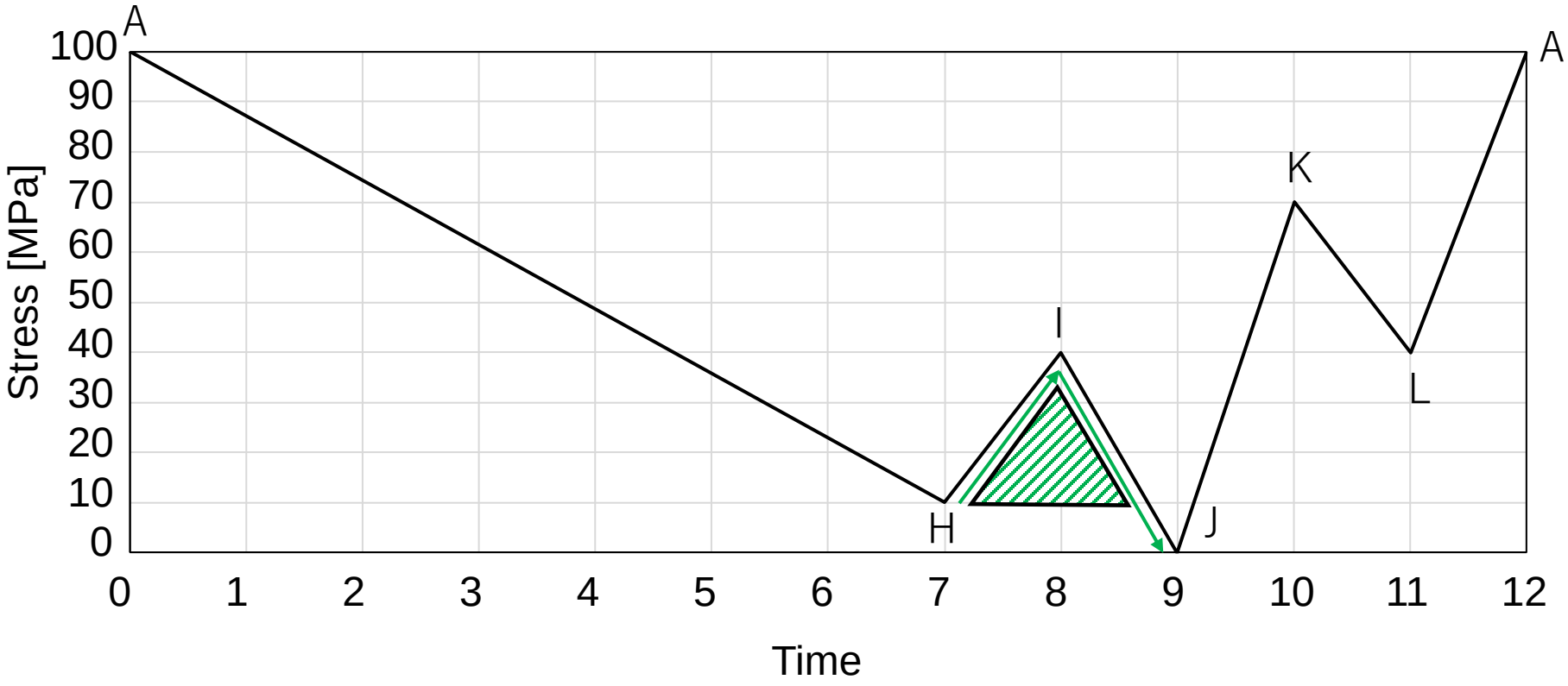


Figure 1 Load history for one repetition

Step 4

Stress range **HI** < **IJ**
→then count a cycle

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa
F-G	30 MPa	65 MPa
D-E	70 MPa	55 MPa
H-I	30 MPa	25 MPa



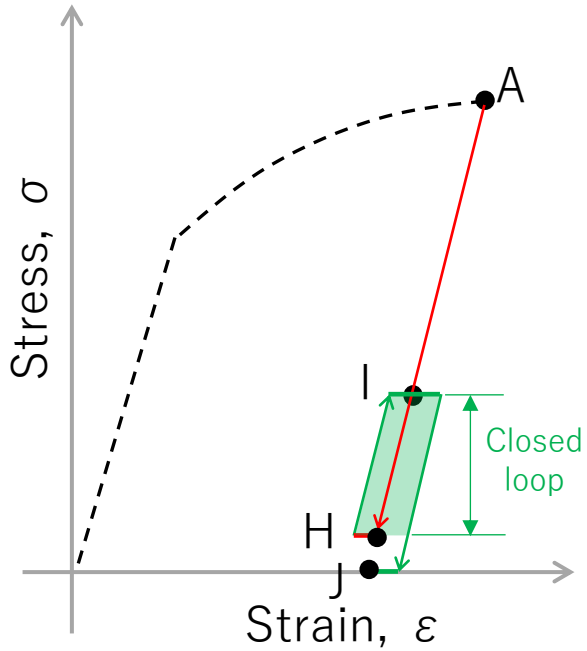


Figure 1 Load history for one repetition

Step 5

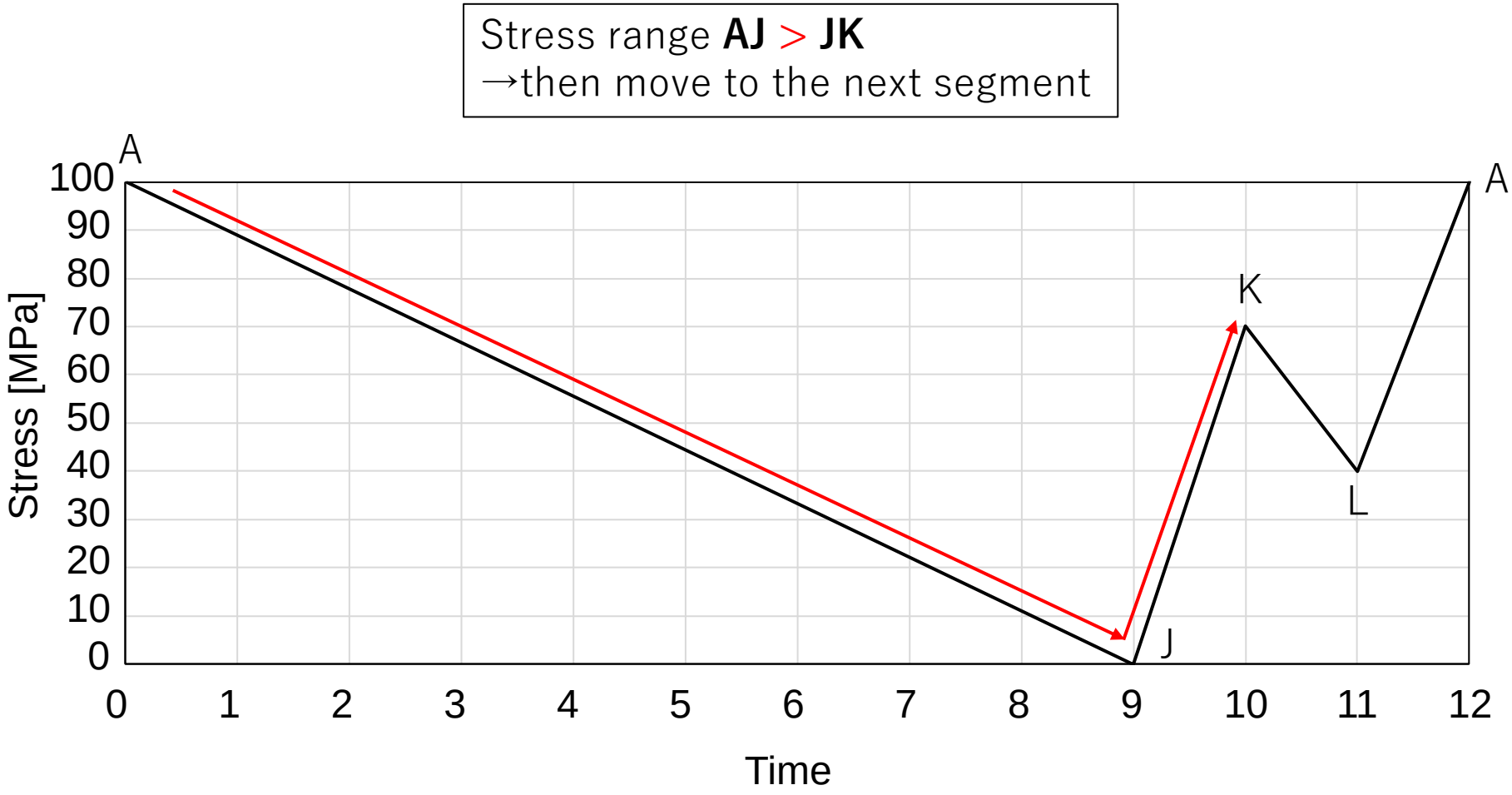


Figure 1 Load history for one repetition

Step 5

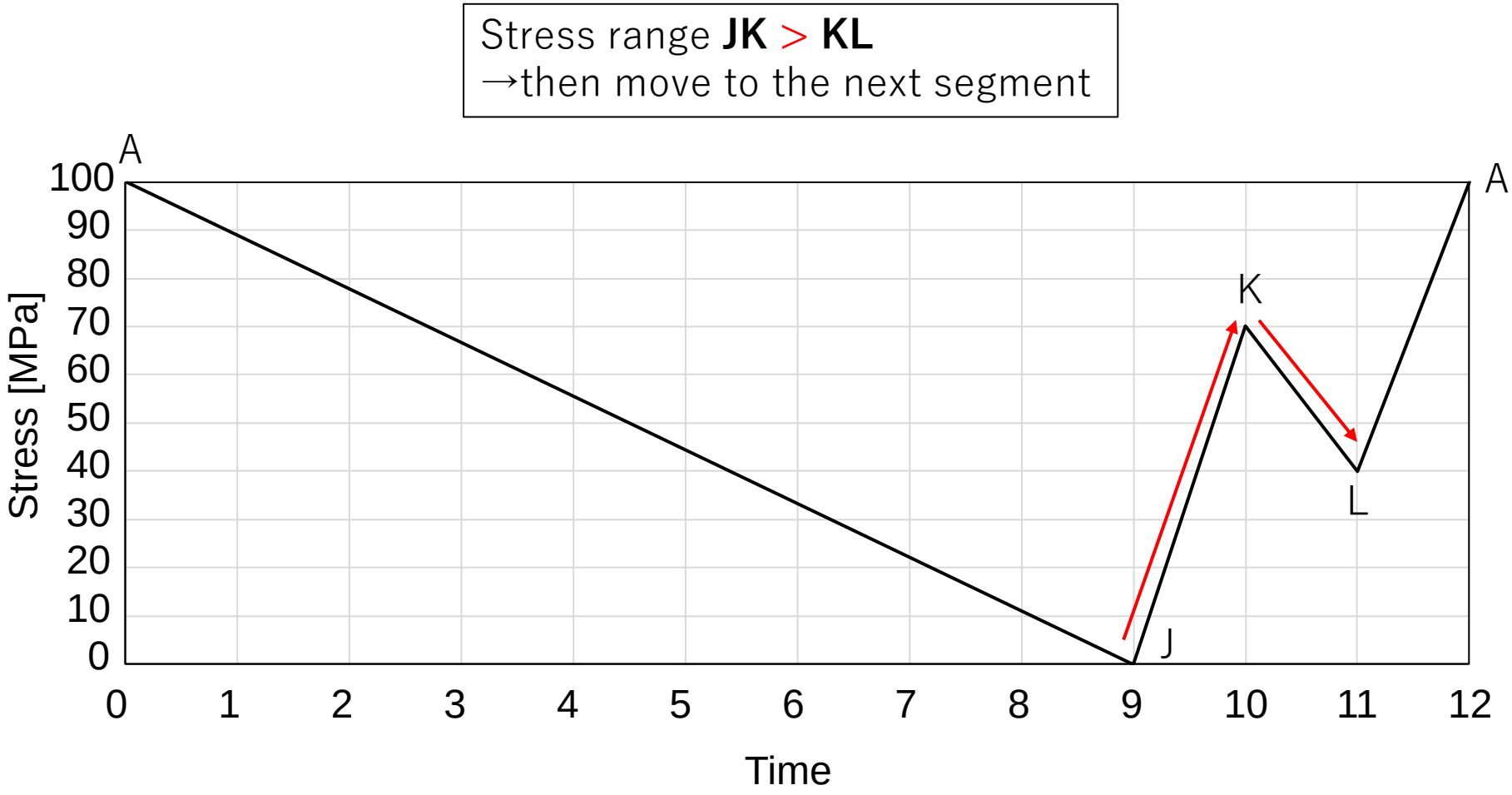
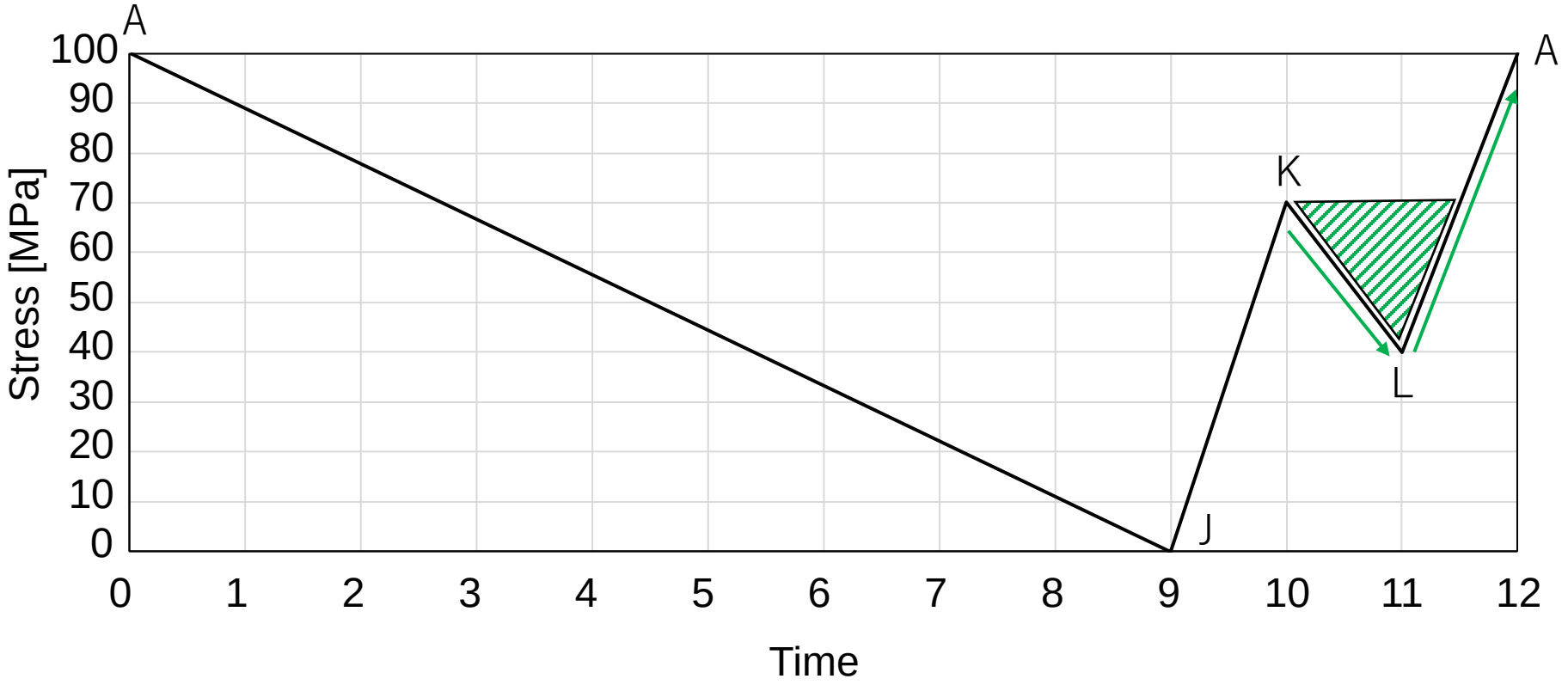


Figure 1 Load history for one repetition

Step 5

Stress range **KL** < **LA**
→then count a cycle

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa
F-G	30 MPa	65 MPa
D-E	70 MPa	55 MPa
H-I	30 MPa	25 MPa
K-L	30 MPa	55 MPa



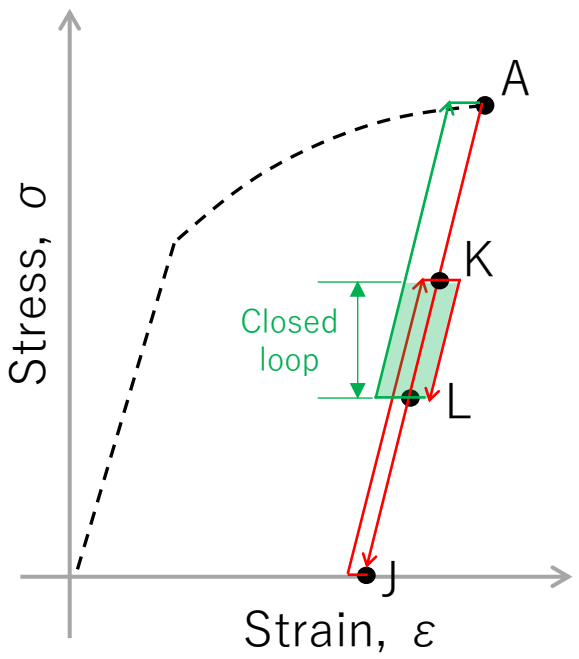
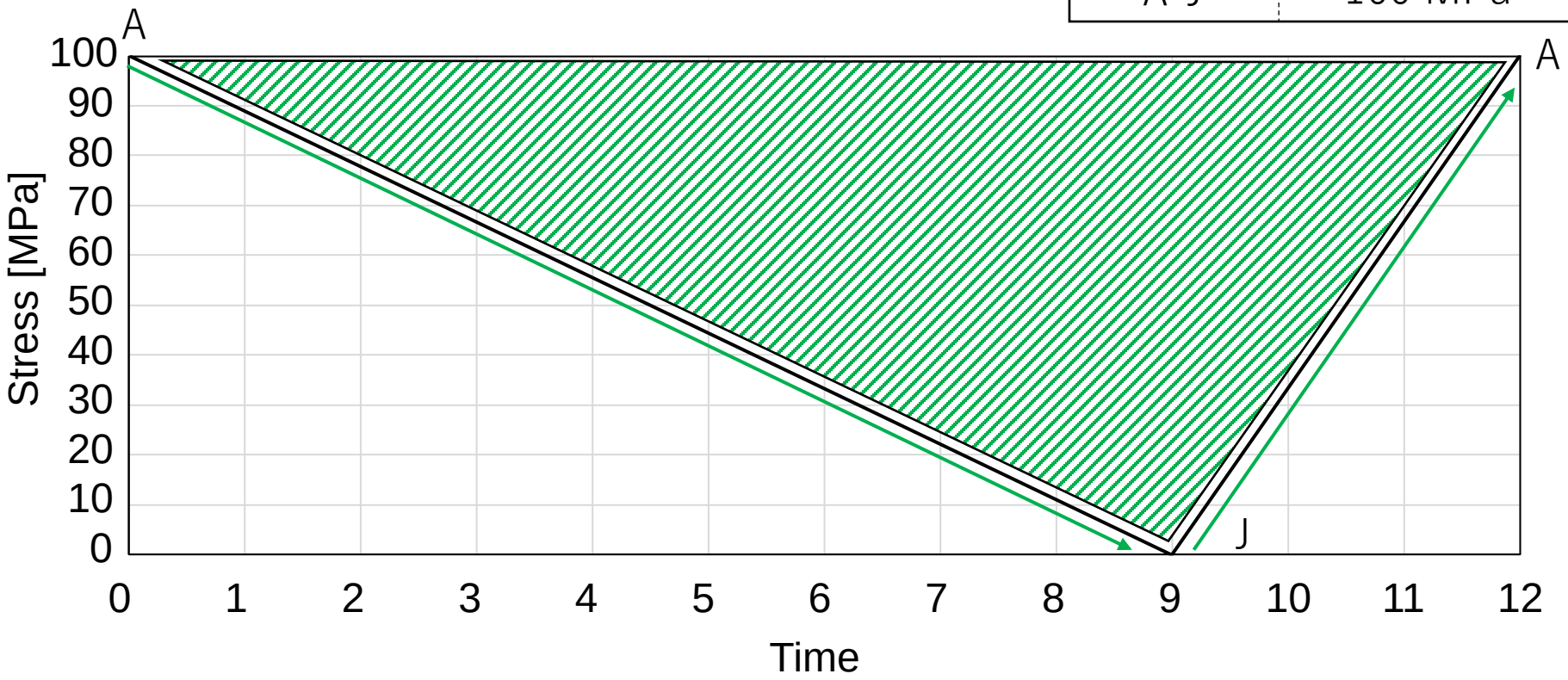


Figure 1 Load history for one repetition

Step 6

Stress range **AJ** = **JA**
→then count a cycle

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa
F-G	30 MPa	65 MPa
D-E	70 MPa	55 MPa
H-I	30 MPa	25 MPa
K-L	30 MPa	55 MPa
A-J	100 MPa	50 MPa



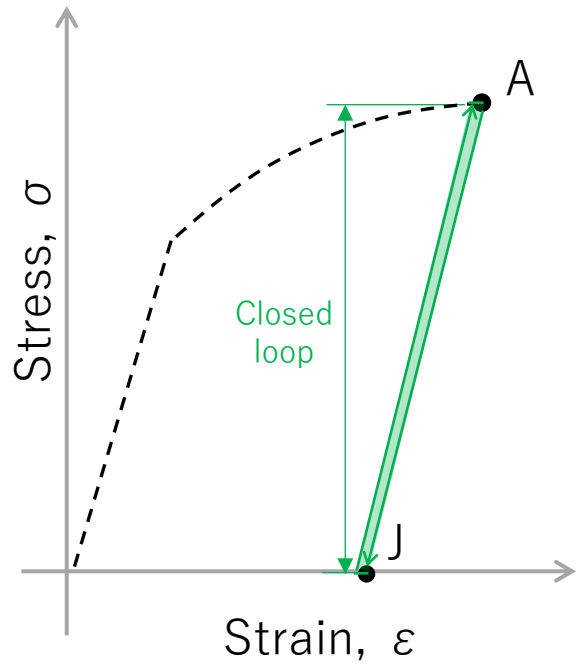


Figure 1 Load history for one repetition

Results for Problem 2

Cycle	Stress range	Mean stress
B-C	20 MPa	50 MPa
F-G	30 MPa	65 MPa
D-E	70 MPa	55 MPa
H-I	30 MPa	25 MPa
K-L	30 MPa	55 MPa
A-J	100 MPa	50 MPa

Problem 3

An unnotched member fabricated from Man-Ten steel (see Table 1) is subjected to the load history shown below.

a) Perform a Rainflow counting of the load history for one repetition (see Figure 1).

b) Estimate the number of repetitions and the number of cycles to failure (Miner rule). Use the Goodman equation (see Dowling book section 9.7 and Lecture 2 slides):

Note: Constants for Goodman equation from Table 1.

$$\sigma_a = \left(1 - \frac{\sigma_m}{\sigma_u}\right) \cdot A \cdot N_f^b$$

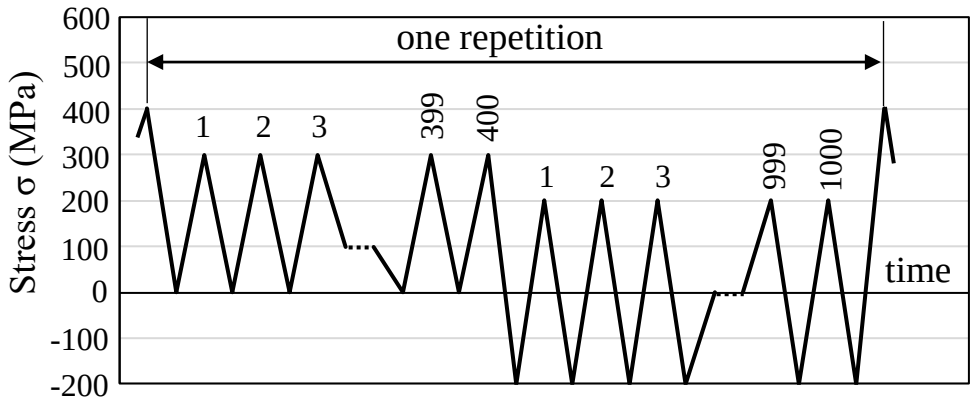


Figure 2 Load history for one repetition

Table 1 Constraints for stress-life curves: tests at zero mean stress on unnotched axial specimen

Material	Yield Strength σ_o	Ultimate Strength σ_u	True Fracture Strength $\tilde{\sigma}_{fB}$	$\sigma_a = \sigma_f'(2N_f)^b = AN_f^B$ σ_f'	A	$b = B$
(a) Steels						
AISI 1015 (normalized)	227 (33)	415 (60.2)	725 (105)	976 (142)	886 (128)	−0.14
Man-Ten (hot rolled)	322 (46.7)	557 (80.8)	990 (144)	1089 (158)	1006 (146)	−0.115
RQC-100 (roller Q & T)	683 (99.0)	758 (110)	1186 (172)	938 (136)	897 (131)	−0.0648
AISI 4142 (Q & T, 450 HB)	1584 (230)	1757 (255)	1998 (290)	1937 (281)	1837 (266)	−0.0762
AISI 4340 (aircraft quality)	1103 (160)	1172 (170)	1634 (237)	1758 (255)	1643 (238)	−0.0977

Notes: The tabulated values have units of MPa(ksi) except for dimensionless $b = B$. See Table 14.1 for sources and additional properties.

Results for Problem 3 a)

The loading history for one reptation contains three loading blocks: block 1, block 2, and block 3

		Block 1	Block 2	Block 3
Count cycles	N	1	400	1000
Maximum stress	σ_{max}	400	300	200
Minimum stress	σ_{min}	-200	0	-200
Stress range	$\Delta\sigma$	600	300	400
Stress amplitude*	σ_a	300	150	200
Mean stress**	σ_m	100	150	0

$*\sigma_a = \frac{\sigma_{max}-\sigma_{min}}{2}$, $**\sigma_m = \frac{\sigma_{max}+\sigma_{min}}{2}$

Results for Problem 3 b)

The Goodman equation is applied in order to determine the maximum number of repetitions for each loading block to failure.

Step 1: From Table 1, we can pick up the following parameters for Man-Ten steel:

σ_u = 557 MPa, A = 1006 MPa, and b = -0.115.

Step 2: Then, the repetitions can be obtained by using equation: $\sigma_a = \left(1 - \frac{\sigma_m}{\sigma_u}\right) \cdot A \cdot N_f^b \rightarrow N_f = \left[\frac{\sigma_a}{A(1-\frac{\sigma_m}{\sigma_u})}\right]^{1/b}$

For block 1: $N_{f1} = \left[\frac{300}{1006(1-\frac{100}{557})}\right]^{-1/0.115} = 6638$

For block 3: $N_{f2} = \left[\frac{200}{1006(1-\frac{0}{557})}\right]^{-1/0.115} = 1260640$

For block 2: $N_{f2} = \left[\frac{150}{1006(1-\frac{150}{557})}\right]^{-1/0.115} = 1004936$

Step 3: Then we can apply Miner's rule as follows:

$$B_f \sum \frac{N_i}{N_{fi}} = 1 \rightarrow B_f = \frac{1}{\sum \frac{N_i}{N_{fi}}} = \frac{1}{\frac{1}{6638} + \frac{400}{1004936} + \frac{1000}{1260640}} = 745$$

Thus, the specimen fails after 745 repetitions and, equivalently, after $745 \times 1401 = 1044026$ cycles.