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DVS – DEUTSCHER VERBAND FÜR SCHWEISSEN UND VERWANDTE VERFAHREN E.V.

Calculation of tanks and apparatus made of thermoplastics – Application examples

Technical Code DVS 2205-1 Supplement 7

Examples which describe the determination of the material parameters or the permissible operating times for various applications are listed in this supplement.

Contents:

1 Strength parameter with constant stresses

Sought: Strength parameter K_K^*

Given: Operating temperature ϑ = 50°C
Service life t = 15 years
Filling material Water

The strength parameter K_K is obtained from the creep strength diagram for pipes, e.g. made of PE 80 (Fig. 1). The line for a service life of 15 years intersects the 50°C creep curve for water at the P_1 point. A line parallel to the abscissa through the P_1 point results in the P_2 point on the ordinate at which K_K^* = 4.6 N/mm² can be read off.

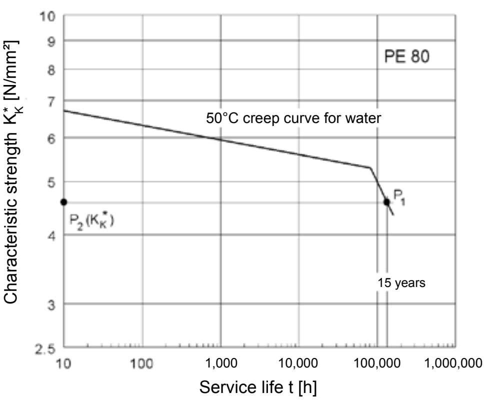

Figure 1. Determination of the strength parameter K_K^* with constant stresses.

2 Determination of the service life with intermittent stresses

Remarks:

The creep curves have been established with the absolute temperature $T = (\vartheta^{oC} + 273)$ in kelvin.

In order to estimate the computational service life t_X with intermittent stresses, the material parameter K_S^{vorh} assigned in each case is initially established with the existing stresses K_K^{vorh} of the individual partial stresses and the stipulated reduction coefficients A_1 and A_2 as well as with the safety coefficients and, if necessary, the welding factor f_S.

$$K_S^{vorh} = \frac{K_K^{vorh} \cdot \gamma_F \cdot \gamma_I \cdot \gamma_M \cdot A_1 \cdot A_2}{(f_S)}$$

With this parameter, the relevant service life with partial stresses is read off the creep curves of the utilised material for the temperature in question. Thus, the resulting service life t_M can be calculated with the aid of Miner's rule (Equation (5) in DVS 2205-1).

In order to establish the influence of the ageing, the beginning ageing with partial stresses can be read off the heat ageing limits for the temperature in question (for PE and PP, see DVS 2205-1, Supplement 1, Section 5 and Supplement 2, Section 5). A second calculation with Miner's rule (Equation (8) in DVS 2205-1) leads to the resulting ageing time t_A. The lower value of t_M and t_A is the permissible operating time t_X.

In Sections 2.1 to 2.3, the handling of the various stress cases is portrayed using simple examples.

2.1 Changing temperatures with constant stresses

Sought: Permissible service life t_X

Given: Stresses K_S^{vorh}
Operating temperatures ϑ_1 and ϑ_2

Corresponding to the time proportions at the individual temperatures, the computational service life t_M is located between the service lives of the partial stresses t_{M1} and t_{M2}. With the given stresses K_S^{vorh}, the line parallel to the strength axis through t_M results in the P point. P is located on a creep curve which would result between ϑ_1 and ϑ_2 at a constant temperature ϑ_X.

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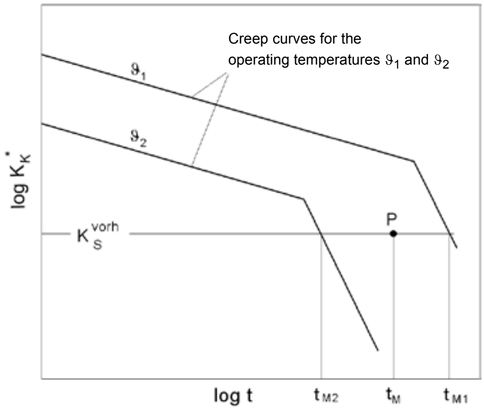

Figure 2. Service life at changing temperatures with constant stresses.

Example for PE 63

Operating conditions and damage proportions

Partial stresses	Stresses K_S^{vorh}	Temperature ϑ	Time proportion a	Computational service life with partial stresses t_M	Damage proportion %
1	5 N/mm²	30°C	90 %	314.593 years	2.6
2		42°C	10 %	0.946 years	97.4

(Values from DVS 2205-1, Supplement 1, Section 1.1)

According to Equation (5) in DVS 2205-1, the service life to be expected on the basis of the mechanical stresses is:

$$t_M = \frac{100 \cdot 314.593 \cdot 0.946}{90 \cdot 0.946 + 10 \cdot 314.593} = 9.21 \text{ years}^{1)}$$

1) The same service life would be achieved with K_S^{vorh} = 5 N/mm² at a constant temperature of 37.6°C.

Ageing and damage proportions

Partial stresses	Temperature ϑ	Time proportion a	Beginning heat ageing t_A	Damage proportion %
1	30°C	90 %	175.6 years	68.8
2	42°C	10 %	43 years	31.2

(Values from DVS 2205-1, Supplement 1, Section 5)

According to Equation (8) in DVS 2205-1, the service life to be expected on the basis of the ageing is:

$$t_A = \frac{100 \cdot 175.6 \cdot 43}{90 \cdot 43 + 10 \cdot 175.6} = 134.2 \text{ years}$$

$t_M < t_A$, the permissible operating time is thus t_X = 9.21 years.

2.2 Changing stresses at a constant temperature

Sought: Permissible service life t_X

Given: Stresses K_{S1}^{vorh} and K_{S2}^{vorh}

Operating temperature ϑ

Corresponding to the time proportions with the individual stresses, the computational service life t_X is located between the service lives of the partial stresses t_{M1} and t_{M2}. The line parallel to the strength axis t_M intersects the creep curve at the P point. This results in the equivalent stresses K_{SM}^{vorh}.

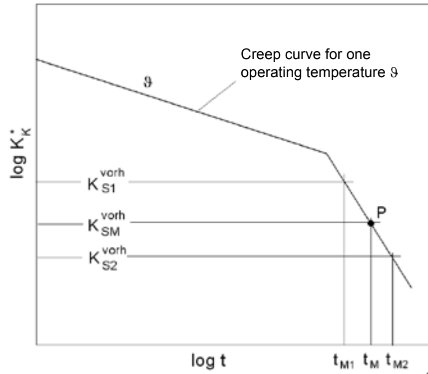

Figure 3. Service life with changing stresses at a constant temperature.

Example for PP-B

Operating conditions and damage proportions

Partial stresses	Stresses K_S^{vorh}	Temperature ϑ	Zeitanteil a	Computational service life with partial stresses t_M	Damage proportion %
1	3.5 N/mm²	60°C	20 %	16.3 years	2.6
2	2 N/mm²		80 %	138 years	97.4

(Values from DVS 2205-1, Supplement 2, Section 2.1)

According to Equation (5) in DVS 2205-1, the service life to be expected is:

$$t_M = \frac{100 \cdot 16.3 \cdot 138}{20 \cdot 138 + 80 \cdot 16.3} = 55.35 \text{ years}^{2)}$$

2) The same service life would be achieved at a temperature of 60°C with a constant stress of K_{SM} = 2.54 N/mm².

Ageing and damage proportions

Partial stresses	Temperature ϑ	Time proportion a	Beginning heat ageing t_A	Damage proportion %
1	60°C	100 %	50 Jahre	100

(Values from DVS 2205-1, Supplement 2, Section 5)

The service life to be expected on the basis of the ageing is 50 years.

$t_A < t_M$, the permissible operating time is thus t_X = 50 years.