Workshop 11: Distribution of residence time

Lecture notes for chemical reaction engineering

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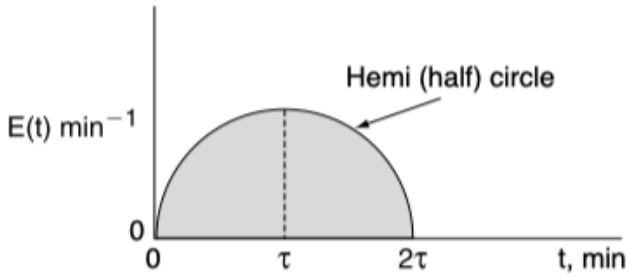
Try following problems from Fogler 5e (Fogler (2016)) P 16-3, P 16-6, P 16-11

We will go through some of these problems in the workshop.

P 16-3

Consider the $E(t)$ curve below.



Mathematically this hemi circle is described by these equations:

For $2\tau >= t >= 0$, then $E(t) = \sqrt{\tau^2 - (t-\tau)^2}$ min^{-1} (hemi circle)

For $t > 2\tau$, then $E(t) = 0$

(a) What is the mean residence time?

(b) What is the variance?

P 16-6

An RTD experiment was carried out in a nonideal reactor that gave the following results:

$E(t) = 0$	for	$t < 1\,min$
$E(t) = 1.0\,min^{-1}$	for	$1 <= t <= 2\,min$
$E(t) = 0$	for	$t > 2\,min$

(a) What are the mean residence time, t_m, and variance σ^2?

(b) What is the fraction of the fluid that spends a time 1.5 minutes or longer in the reactor?

(c) What fraction of fluid spends 2 minutes or less in the reactor?

(d) What fraction of fluid spends between 1.5 and 2 minutes in the reactor?

P 16-11

The volumetric flow rate through a reactor is 10 dm^3/min. A pulse test gave the following concentration measurements at the outlet:

t (min)	$c \times 10^5$	t (min)	$c \times 10^5$
0	0	15	238
0.4	329	20	136
1.0	622	25	77
2	812	30	44
3	831	35	25
4	785	40	14
5	720	45	8
6	650	50	5
8	523	60	1
10	418		

(a) Plot the external-age distribution $E(t)$ as a function of time.

(b) Plot the external-age cumulative distribution $F(t)$ as a function of time.

(c) What are the mean residence time t_m and the variance, σ^2 ?

(d) What fraction of the material spends between 2 and 4 minutes in the reactor?

(e) What fraction of the material spends longer than 6 minutes in the reactor?

(f) What fraction of the material spends less than 3 minutes in the reactor?

(g) Plot the normalized distributions $E(\Phi)$ and $F(\Phi)$ as a function of (Φ).

(h) What is the reactor volume?

(i) Plot the internal-age distribution $I(t)$ as a function of time.

(j) What is the mean internal age α_m ?

References

Fogler, H. Scott. 2016. *Elements of Chemical Reaction Engineering*. Fifth edition. Boston: Prentice Hall.