Optimizing the control procedure in a mass-production line

ESGI-57 Danfoss Problem

Many of our products are produced in large numbers in an automated production line. An important step in this is the check measurement of an important property of the product in order to minimize the number of malfunctioning products leaving our factory. This property is a sort of decay rate—the product will gradually lose its function—and we shall denote it Q. As it is today, each single product is checked. This seems, at first sight, to be a very logical way to ensure quality. However, the problem is that the time we have available for the entire control procedure of each product equals the cycle time of the production line. This is about 12 seconds (corresponding to more than 2.5 million products per year). Such a short time interval not only makes it difficult to measure Q with sufficient sensitivity and accuracy, but also means that products which are actually malfunctioning but exhibit slow dynamic response times are not caught in the check measurement.

The question is then; can we make a better control procedure by employing some sort of statistical sampling? This would allow us to check some of the products to a higher sensitivity, accuracy and over a longer period. Obviously, we cannot live with checking only a few of the products, but perhaps combining an "optimal" statistical sampling procedure with a crude and fast check of each component would be best?

To answer this question we shall have to define some *parameters*:

1. The risk of not finding malfunctioning products (either because they are not checked in the statistical sampling or because they are not caught because of the limited time available) as a function of the threshold Q_T defining malfunctioning.
2. The impact factor: the larger the value of Q of products slipping through the control procedure, the worse.
3. The robustness of the production line: the more time we have for each check measurement and the less sensitivity is required, the more robust the production line will be. At present this factor is quite low.

We shall then combine these parameters in the most sensible way in order to define some overall "goodness of the control procedure". This should then be optimized as a function of these variables:

1. The distribution function $f(Q)$, i.e., the distribution of decay rates of the products. Currently, we do not have detailed information of this distribution function, but for most products it looks qualitatively as shown in Fig. 1.
2. The distribution function $f(\tau)$, i.e., the distribution of the delay time (the dynamic response of the observed signal after the check procedure is initiated). Again, we shall

probably also have to make reasonable assumptions, but experience tells us that the function resembles that of Fig. 2. In figure 3, the temporal development of the signal in the control procedure is shown, perhaps clarifying what is meant by the delay time.

3. The rate of sampling, i.e., how often are products taken out for more detailed check measurement. Perhaps also looking at more sophisticated sampling methods?
4. In this respect, the threshold Q_T is also a variable.

Hopefully, this optimization study will reveal whether or not we should change strategy and attempt to incorporate sampling in our production control. As is perhaps clear, another simple motivation for having this problem scrutinized by a group of mathematicians is to improve our general understanding of statistics.

Looking forward to some interesting days in Lyngby!

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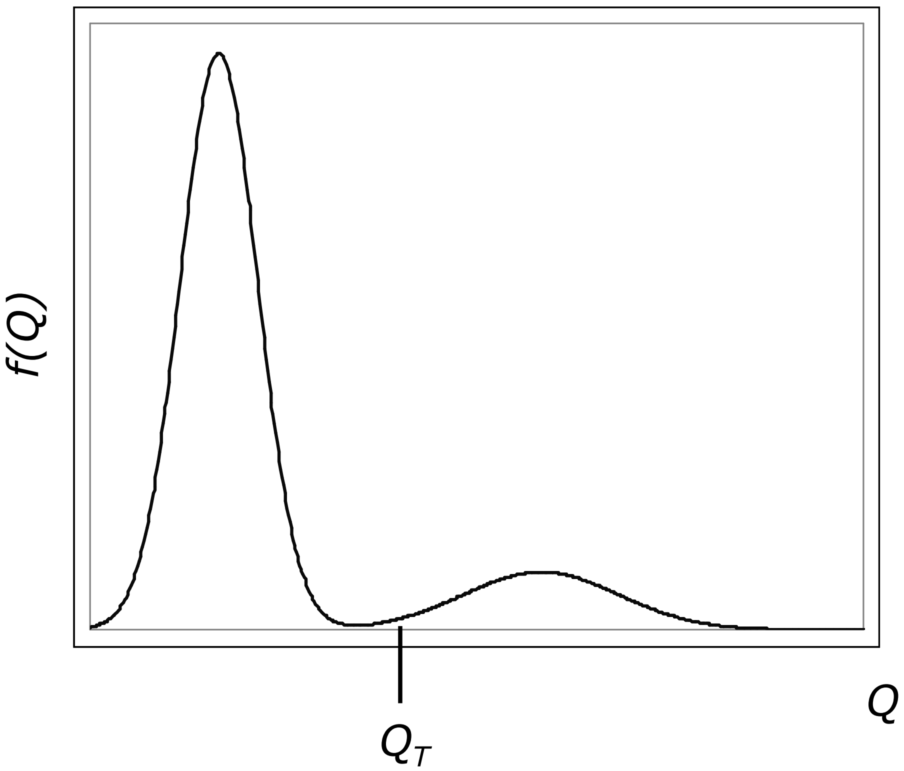

Figure 1: Typical distribution of decay rates. Most components have decay rates lower than the threshold, but some have larger, and should therefore be discarded by the control procedure.

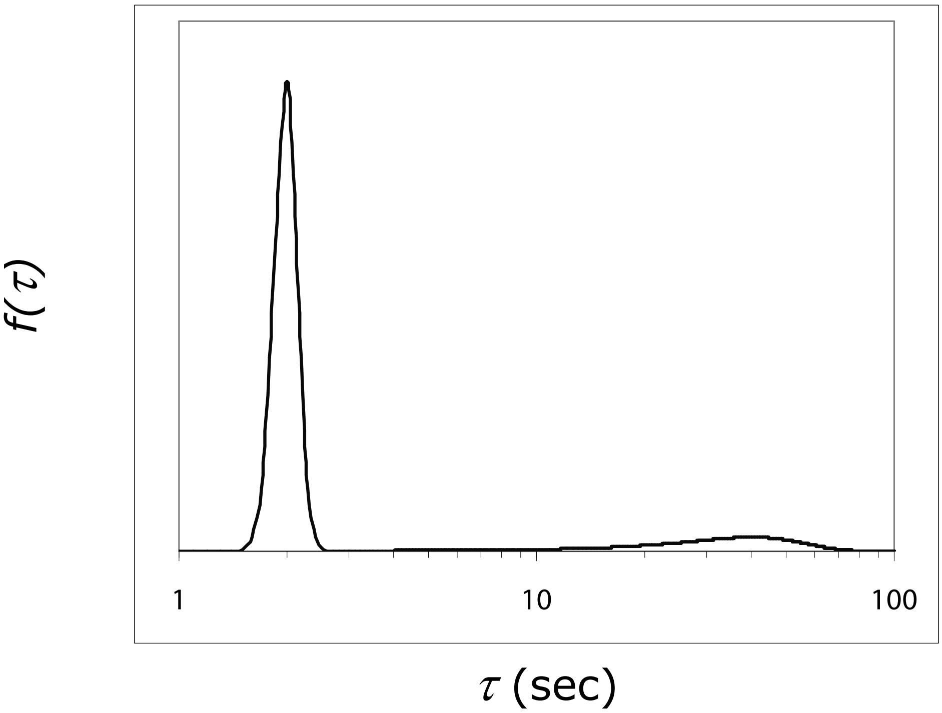

Figure 2: Typical distribution of the dynamic response, which is actually the delay time after the control procedure is started on a component until the signal from its Q begins to build up (see Fig. 3). With only a couple of seconds available, some malfunctioning components will actually not be caught in our present control procedure.

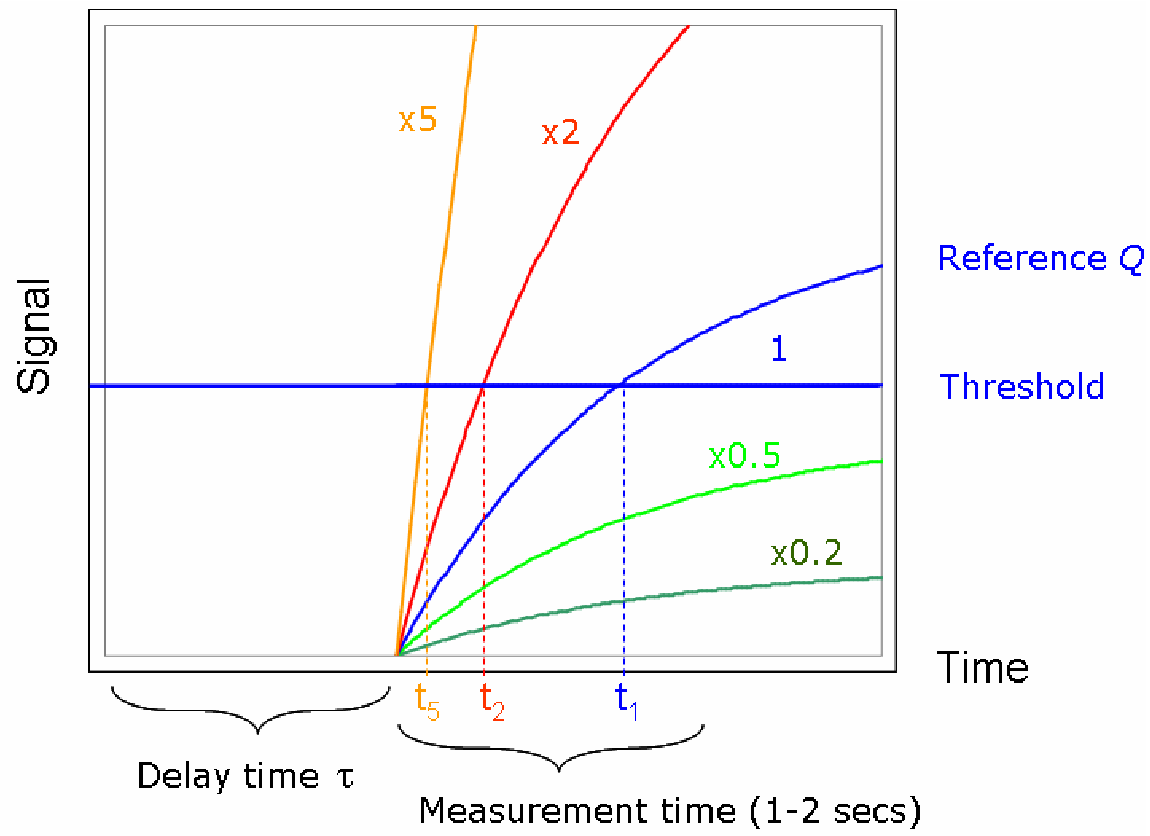

Figure 3: The temporal development of the signal after the control procedure is started. After a certain delay time, the signal starts to build up exponentially. The magnitude of the signal is then recorded during a short measurement period time (1–2 secs), often before it has reached its steady state value. If it is above that of a calibrated reference which has $Q = Q_T$, like those denoted x2 and x5 in the figure, the control procedure makes sure that the component in question is discarded.