PROBABILITY DISTRIBUTION OF TIME DURATION OF MANUAL OPERATION IN THE PRODUCTION OF GLASS EYES

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This work was supported by the Student Grant Competition of the Technical University of Liberec under the project No. SGS-2020-5027 - Research of new approaches to process improvement.

Abstract: When precise planning of capacities and times of production is needed, there must be precise data for calculation. Not all operations have to have a normal time duration distribution. Counting with average values or use values from guessed distribution can lead to mistakes in actual production planning. This article aims to determine time probability distributions to manual operations. Tests of goodness of fit are used to search for more suitable distributions. This approach is presented in a case study of glass eyes manufacturing. Results show that there can be differences between the estimated normal distribution and another more suitable one. By using tests of goodness of fit to define the correct distribution, more precise production and capacity planning results can be achieved.

Keywords: Capacity planning, Duration distribution, Manual processing, Production planning, Tests of goodness of fit

1 Introduction

Activities in production processes have not only a normal distribution of time duration. [1] This must be taken into account in calculations of production capacity and planning. Precise data about the time duration of operations is needed to have a more precise simulation model of the production system. Nowadays, there is more and more use of computer simulations of production processes and systems. Companies are trying to have highly accurate simulated systems. Simulations are then used for different kinds of improvement efforts. Production planning, layout design [2], or enhancement of productivity and efficiency of the process [3,4], these are just some of the possible applications of the production system simulation.

To get a relevant result from the simulation a valid data and its probabilities must be found. That is why a right probability distribution should be chosen. [5] The use of probability distributions to evaluate time can be seen, for example, in [6].

The aim of this paper is to define the probability distribution of the duration of production of one whole glass black eye in the glass eyes production process.

2 Methods

An operation that should be tested must be firstly sampled – more measurements give a better result. For our purposes, 40 measurements are considered as enough data samples to describe the distribution well. A few extra measurements should be made for the case when some of the measured samples must be eliminated.

2.1 Goodness-of-Fit Tests

A Shapiro-Wilk test could be used to test the normality of the distribution of the duration of sampled operation. The test is used for the determination of if the normal distribution models the data. The Shapiro-Wilk test tests a null hypothesis that the distribution well. A few extra measurements should be made for the case when some of the measured samples must be eliminated.

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The process consists of several steps. Firstly, the wire loop is joined to the glass tube. Then the eye is formed on the loop in a fire and formed in a mold. Also, a diameter check is made at the same time. After that, eyes are slowly cooled down, and tubes are broken off. By using pliers, the remaining glass from the tube is cleaned off the wire loop. Eyes are then stored; packing depends on the type of customer’s requirement. Several process phases can be seen in figure (Figure 2) below.

Figure 1: Produced black glass eye with wire loop
For the whole glass eye production, a 40 measurement was done, a sample consists of values ranging from 53.17 to 86.08 seconds. Data were collected by direct measuring in production. Tests of goodness of fit were used to determine which distribution fits best on the real sample of measured time durations of production operations. For practical use, Statgraphics 18 software was used.

### 3 Results

Firstly the measured data sample was analyzed, and test to normality was done.

#### Figure 2: Process phases of glass eye production

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#### Figure 3: Density trace of whole eye duration

A density trace is essentially a smoothed histogram, which shows the shape of the distribution from which the sample comes. The trace is constructed by counting the number of observations within an interval of fixed width as it is moved along the x-axis, and weighting them in such a way as to give a smooth estimate of the underlying density function.

#### Figure 4: Histogram for whole eye duration

Graph in figure (Figure 4) shows a frequency histogram for whole eye duration. In this plot, 7 intervals have been formed ranging from a lower limit of 51.0 to an upper limit of 91.0. The number of data values in each interval has then been tabulated. The plot shows these frequencies. In addition, the probability density function for the fitted largest extreme value distribution has been superimposed on the histogram. If the distribution fits well, the top of the bars should be relatively close to the line.
In [9] analytical, and Monte Carlo simulation approaches to evaluate probability distributions of interruption duration indices are described. In [1] well-fitted probability distributions of operation durations are used for capacity planning with a positive result.

5 Conclusion

A capacity or production planning can be calculated wrongly by incorrectly identifying the probability of time duration of operations in the production system. This can also be seen by using of wrong probability distribution in production system simulation. These wrong applications could lead to more significant mistakes and related costs. That is why a proper determination and verification of probability distribution of planned operation should be done. The approach to determining the probability distribution by using tests of goodness of fit was presented above.

The modeling of the simulation of the tablet coating, granulation, and nano-milling processes are discussed in [4], where probability distributions are just assumed. The goodness of fit method could search for the most fitting distributions for each process segment. A different approach for fitting probability distribution is introduced [8].

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