Design of Impact Experiments for Polycarbonate Vision Panels – Models, Limitations of Measurement and Proposals for Aging Period and Sample Size

Heinrich Mödden

German Machine Tool Builders' Association (VDW), Lyoner Straße 18, 60528 Frankfurt am Main, Germany,

As is well known, the actual objective of the impact tests defined in the product safety standards is to determine the withstand capacity (the so-called impact resistance) of various materials used for guards. Commonly used for this purpose are steel sheets and transparent plastics for the viewing windows (also called vision panels), the latter being of great importance for the safe use of the machine: The vision panels in machine tools serve two purposes: they allow the machining process to be observed and, in the event of an accident, they protect the operator from ejected tool fragments, for example. Polycarbonate is used as a material for such vision panels because of its excellent impact resistance. However, polycarbonate is subject to aging processes that leads to a reduction in its properties. Cooling lubricants in particular accelerate these aging processes as UHLMANN et al. [1] pointed out in a preliminary study "KSS-PC", but the effect of modified cooling lubricants on polycarbonate sheets in impact tests is not entirely clear due to the relatively short exposure time in the "KSS-PC" study. Therefore, funding for a comprehensive follow-up project "KSS-PC-2" was obtained via the German Machine Tool Builders' Association (VDW) in order to substantiate the statements of the preliminary study within a larger time frame of 2 years [2], project start is in November 2022, right after the 12th Dresdener Probabilistik-Workshop.

The total scatter of the determined impact resistance adds up to numerous individual effects, which can lead to a considerable random measurement error, as described in separate papers [3,4]. A typical test sequence with the interval halving method looks like this:

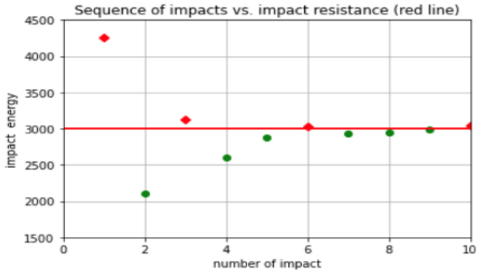

Figure: Test sequence with interval halving method

Only when a model for this measurement error is available can the impact resistance of the polycarbonate sheets under investigation be determined indirectly from the velocity measurements of the projectile with some "accuracy". This is because the impact resistance of polycarbonate sheets, considered in isolation, also scatters itself to a not inconsiderable extent, as is generally known for plastics. The total scatter of the determined impact resistance adds up from the individual effects as follows: a) a limited repeatability in the velocity measurement resulting from a very complex test technique, therefore normative tolerance ranges for the impact velocity measurement are given, b) significant deviations in repeat tests for the exact impact conditions. The overlap of these scatter effects causes an inherent measurement error of the whole measurement apparatus. For this purpose, a distribution function is to be determined (estimated) as a model for the first time using the means of descriptive statistics. The interaction of the scattering effects is assumed to be random and symmetrical. Because of the

numerous random individual effects in a) and b), a (first) Gaussian bell curve can be assumed in the sense of the Central Limit Theorem.

Based on this Gaussian bell curve, the Student-t-distribution provides a good approximation for sample sizes smaller than N=30, such that inference statistics can be applied. In doing so, a parameter variation with virtual impact tests (Monte Carlo simulation) can be supplemented in order to conduct a hypothesis testing such that the question of the necessary sample size for a significance level of 99% can be answered. This value is common, if live and limb is at stake as is the case in safety of machinery. As the significance level depends on the significance of the ageing effect as such, reasonable proposals for the artificial aging periods can be derived, too.

Keywords: Safety of machinery, machine guard, polycarbonate, aging, design of experiments, descriptive statistics, inference statistics, hypothesis testing, Monte Carlo simulation

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