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Embrittled Vision Panels put Operators at Risk

Figure 1: Process observation is inevitable in spite of ever increasing automation; source: Chiron

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Even though future production is deemed to be, due to safety regulations, more and more behind closed machine guards, "process observation" remains necessary in spite of increasing automation. If parts of the tool or the workpiece are ejected, the operator safety depends directly on the impact resistance of the guards. It is obvious that vision panels must not be embrittled due to ageing.

Ever increasing machining speed is leading to higher mechanical risks during process observation due to ejected parts (figure 1). Consequently, the German Machine Tool Builders' Association (VDW) started a research project "Design and Dimensioning of Guards in Machine Tools" in 1997. The intention was to collect the state-of-the-art in a clearly arranged manner and to highlight areas of possible improvements. Subsequently, the results have been presented for the incorporation into the type C standards of machine tools [1], [2] and [3]. Accident statistics show for turning machines that workpiece clamping means (chuck parts) are of primary importance because of their comparatively high mass even beyond 2,5 kilograms [3]. For milling machines and the like, ejected parts are expected to stem from the milling tool, therefore parts with a mass below 100 gram are assumed [2], nevertheless the inherent energy can be considerable since high speed machining is state of the art [4].

Vision panels as a part of machine guards play an important role for the operator safety. Polycarbonate proved most suitable in comparison with other pane material. But, it was found that polycarbonate is prone to embrittlement (ageing) due to aggressive fluids, as those can be found for instance in coolant lubricants and cleaning agents (figures 2, 3 and 4).

Figure 2: Impact of projectile, penetration of compound design (glass /polycarbon.); source: IWF

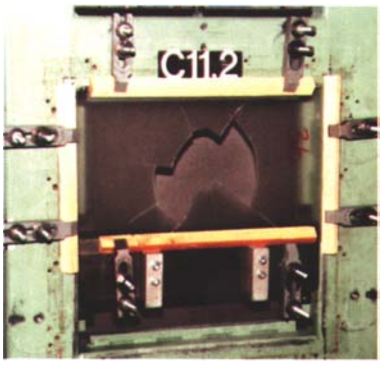


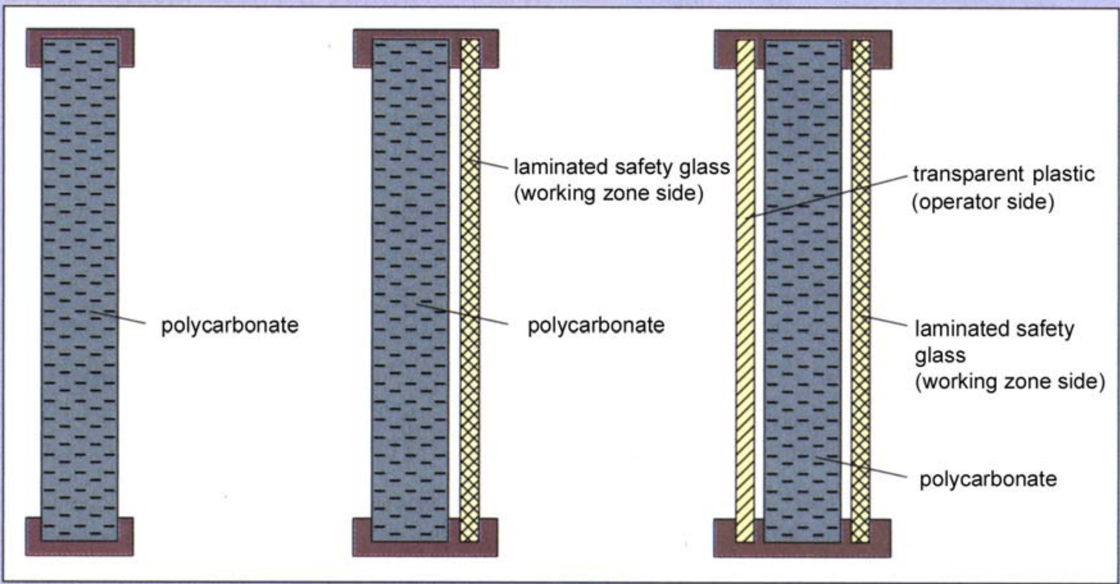
Figure 3: Embrittled polycarbonate pane after impact; source: BIA

Figure 4: New polycarbonate pane tested with the same impact energy; source: BIA

VDW regards polycarbonate vision panels as wearing parts

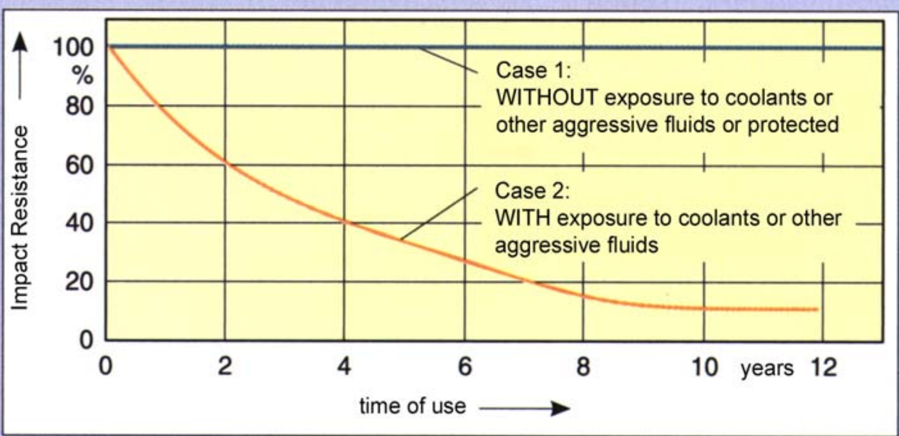
The findings have been considered in the elaboration of type C standards for machine tools. In order to protect the polycarbonate pane against embrittlement, an all around protection (i. e. from working zone side, operating side and edge sealing) was found to be the most sensible technical solution, because it avoids frequent replacements of embrittled panes (figure 5). For, it was shown that all around protected polycarbonate panes can be used without any reduction of withstand capability over a time period of at least ten years (figure 6).
Since polycarbonate vision panels can loose their impact resistance due to operational environmental influences, VDW regards them as wearing parts. Manufacturers of polycarbonate vision panels are expected to define a specific period of time for a safe use of their respective products.

Design of polycarbonate vision panels



5 Three different types form different levels of protection against ageing; source: BIA

All around protection provides durability against abrasion and ageing



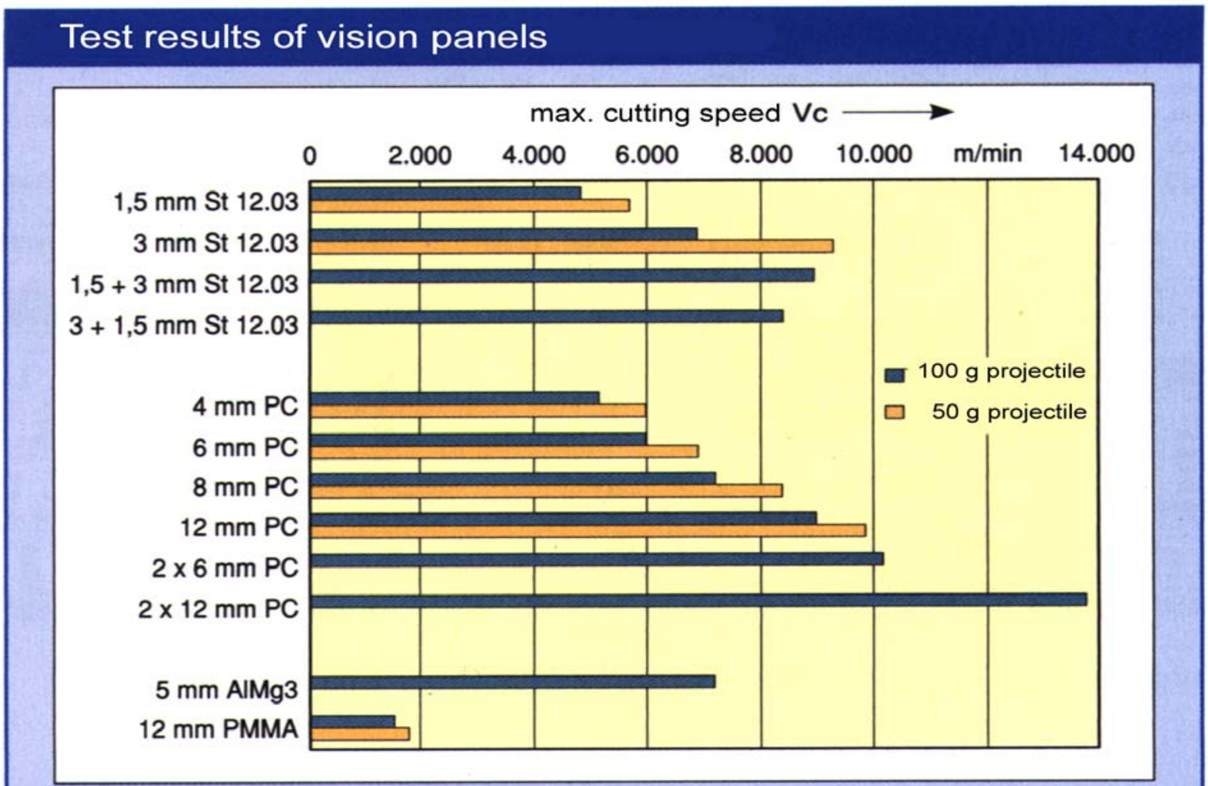
6 All around protected polycarbonate panes show now loss of impact resistance even after a period of at last ten years time.

In machine tools hard-coated polycarbonate is not resistant against ageing

Investigations of the "Institute for Occupational Safety of the Accident Insurance Institutions (BIA)" in St. Augustin (Germany) show that all recently presented hard-coatings cannot provide sufficient protection against abrasion in the heavy duty machine tool environment. Well selected test data suggest a categorization into the two-yearly exchange period formerly proposed by VDW. The test report concludes the findings as follows [5]:
»The impact resistance of new polycarbonate panes, as well as the resistance of selected panes already in use in machining centres for several years, has been evaluated by the impact test method with the 100 gram projectile according to EN 12417. The longer the time for their use in the production environment was, the less was the impact resistance. The reduction in mechanical strength was about 30 percent in three years of use for uncoated and hard-coated polycarbonate as well.«

Tool monitoring can reduce mechanical hazards

The safety of polycarbonate panes against penetration events of ejected parts can be improved by means of a sensible combination of mechanical impact resistance (strength) and tool monitoring by means of the NC-control and respective data. Figure 7 shows the situation for machining centres. Different thicknesses of steel sheet and polycarbonate panes are allocated to the respective maximum tolerable >fictitious< cutting speeds for the 100 gram standard projectile. For comparison purposes the test data for the 50 gram projectile from the high speed machining research project "Argus" are filled in, too [4].



7 Impact resistance of guards for the 100 gram standard projectile and the 50 gram comparison projectile

For high speed spindles, a feared failure case is that a large-scale tool is accelerated up to a over-critical rotational speed causing tool burst. For instance, for >fictitious< cutting speeds of more than 8000 m/min it could happen that even a 12 mm strong polycarbonate pane would not provide enough impact resistance, (real cutting speed reach up to 2000 to 5500 m/min, e. g. when milling aluminium and copper).
Instead of ever increasing thicknesses of the polycarbonate panes, as it is recommended in EN 12417 in a first step, a tool monitoring seems to be desirable in order limit the thickness of the polycarbonate panes reasonably and accomplish penetration safety even so. The machining centre standard has therefore added a remarkable restriction in clause 17.2 dealing with dimensioning of mechanical guards and tool monitoring as an alternative [2]:

»Guards shall be provided to contain the energies of, or protect persons from, the machine parts and/or components which can reasonably foreseeable be ejected (see annex A and EN 953:1997, 5.5 and 5.6).
Thicknesses of guard materials calculated from annex A may be reduced, where maximum ejection energies are limited by incorporation of systems which identify the tool to the NC system, enabling limitation of spindle speed applied.«

An example shows a practically important limitation of 3 mm steel sheet, which is almost comparable with 8 mm polycarbonate, this is a widely applied state of the art for machining centres. Figure 7 gives a maximum tolerable cutting speed of
V_c = 7000 m/min. A run-of-the-mill machining centre may have a motor spindle with 12000 min^{-1} maximum possible rotational speed. The maximum tolerable tool diameter is calculated in accordance to the standard to $D_{max} = V_c / (\pi \, n_{max})$,
D_{max} = 0,186 m. Accordingly, all tools with standard diameters beyond 160 mm have to be monitored here in order to ensure penetration safety for large-scale tools being operated mistakenly at too high rotational speeds. Tools with smaller diameter need not be monitored in this example, since the mechanical impact resistance is sufficient even at maximum rotational speed.
By means of well-differentiated intervals of rotational speed and safely designed limitations for the monitoring parameters (i. e. based on a safe control logic) a tool monitoring can be provided that excludes the tool failure case due to critical rotational speed.

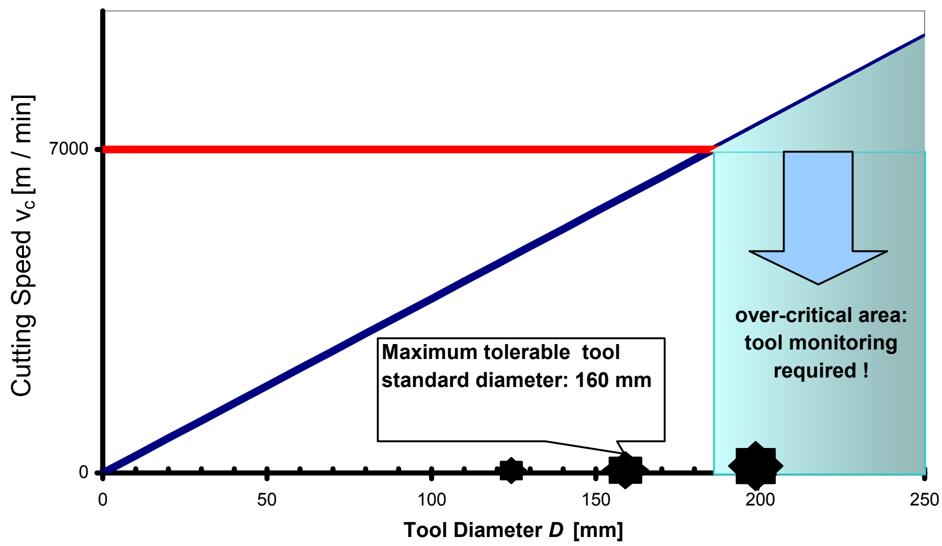


Figure 8: Practical state of the art for machining centres (3 mm steel sheet, 8 mm polycarbonate)

Actions and reactions

The German Machine Tool Builders' Association (VDW) and the German Institute of Occupational Safety (BIA) work closely together in order to inform all concerned groups about the safety gap which may occur due to embrittled polycarbonate.

Information sheets have been distributed recently from both, VDW and BIA, and meanwhile in Germany all interested parties in the area of machine tools should be informed about the ageing problem.

In addition, VDW und BIA have contributed to the European Working Groups of CEN / TC 143 ›Machine Tool Safety‹ trying to achieve better awareness of the embrittlement problem of polycarbonate. According recommendations have been incorporated into the type C standards for machine tools [2], [3].

Apparently, there is still a significant need of informing machine tool manufacturers inside and outside the European Union who import their machine tools into Germany. Important international discussion partners are in England, France and the United States. Test institutes reported recently that Japanese manufacturers endeavour to catch up with the new state of the art on reliable mechanical guards.

References:

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