Will Industry Adopt PKMs?

The most radical change in machine tools this century has been basing their design on parallel kinematics rather than the traditional serial-link approach. However, does the cost/performance ratio of this type of parallel kinematic machines (PKMs) justify their purchase for machining applications?

Most commercial PKMs available today are high-cost six-axis machines that provide less accuracy than conventional five-axis machines (which offer three translations in *X-Y-Z* and two rotations). Dimensional errors exist in PKMs not only because of machine geometry and temperature-expansion errors, but also because of interpolation errors when moving along the main axes. This type of error does not exist in conventional *X, Y, Z* Cartesian-coordinate machines.

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While some researchers claim a better stiffness than conventional machines, most researchers report that PKMs provide inferior stiffness. The workspace/footprint ratio of most PKMs is smaller than that of conventional machines. Calculation of that ratio is more complex, and singular points (which cause instability) exist in the PKM's workspace. In addition, PKMs have low dexterity and typically provide only a small orientation range for the tool. Furthermore, the issue of process planning for PKMs is quite complicated and has not yet been addressed.

Given PKM performance, why would a manufacturing enterprise buy an inferior machine at higher cost? We need to explore how the research community can make PKMs more attractive to industry. Researchers need to realize that not every application requires the functionality and flexibility of a six-axis machine. In fact, since the cutting tool is symmetric, five degrees-of-freedom (DOF) can move the cutting tool to any point with any orientation in the workspace. What should we do with the sixth DOF? Some researchers suggest using it for calibration, but a methodology for six-axis utilization of a generic PKM has not been suggested yet.

Actually, many applications don't need five axes; three or four axes are adequate. Although a three-axis or a four-axis PKM has the functionality needed for many applications at lower cost, only a few three-axis PKMs that move in Cartesian coordinates have been introduced. To reduce the ramp-up time of PKMs, industry needs quick calibration techniques and three-axis PKMs.

Also, PKMs do not address a target market. Most PKMs are too small for many aerospace parts, for example. Designers can achieve larger work volume with machines that employ fixed-length struts (i.e., supporting legs) with joints that move along long axes, rather than the conventional design based on telescopic struts.

If the target market is automotive (over 60% of the machine tool sales in the USA), another problem arises. In typical automotive applications, the machine tool operates as a component in a large machining system. But PKMs are not designed for integration into machining systems or transfer lines. Loading and unloading parts on PKMs, a task very critical for automotive applications, is not taken into the design considerations.

Most applications in the powertrain industry require three-axis PKMs that can move the spindle or part in three Cartesian axes. Cost-effective, three-axis PKMs may capture part of this industry.

Current research topics like PKM dynamic analysis, workspace calculation, error compensation analysis of alternative mechanisms, and advanced servo-controllers that enhance machine performance should continue. However, the research community must also address two additional significant topics: the issue of which market segment PKMs fit into, and the issue of PKM integration. There are hundreds of possible PKM structures. We need computational tools that will match the optimal structure of the PKM to the family of parts machined, and to the application or task in mind. Industry requires a solution to the integration issue. Design of PKMs must make it possible to operate several machines in concert. The PKM can capture a reasonable market share only if we address these two issues.

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