

# PKM Research – important Issues, as seen from a Product Development Perspective at ABB Robotics

**Torgny Brogårdh**  
**ABB Automation Technology / Robotics**  
**SE 721 68 Västerås**  
**Sweden**

In spite of the high performance potential for manipulator structures based on parallel kinematics, this technology has not yet made any big impact on industrial automation. However, there is an interesting trend towards the use of general purpose industrial robots for applications with higher demands on accuracy, stiffness, eigenfrequency, cycle time etc. Thus, big efforts are now made to use industrial robots for such applications as measurements, laser cutting, laser welding, high precision assembly, grinding, deburring, milling etc. Because of the inefficient robot performance for these applications, several compensation methods are used, as for example fine adjustment of robot positions, on site servo tuning, kinematic error identification and compensation, iterative learning control with external measurement systems, 2D and 3D vision based trajectory adjustment, force control etc. However, these methods add cost, make installation as well as programming and service difficult and the robustness of robot installations will be poor. One way to solve these problems could be to make use of robots based on parallel kinematics. However, then new parallel kinematic structures are needed to achieve working envelopes and dexterity similar to the industrial robots used today. Thus, from an industrial point of view, it could be valuable to have some academic research focussed on methodologies to search for parallel kinematic structures in a more systematic way. Probably, all parallel structures useful for industrial manipulation have not yet been discovered. Moreover, it is not necessary that the best industrial solution is a true 6 links parallel structure for the manipulation of all the 6 degrees of freedom of the tool or working object. Instead, it is more likely that the best industrial solution is to use a compound structure with for example one 6 links parallel structure for the manipulation of the position and another parallel structure or a common serial structure for the manipulation of the orientation.

Now, assuming that a new parallel structure useful for high performance robot applications is found, then the next challenge is to obtain the price/performance needed for the applications, in which the present serial robot technology is not good enough. For example, to achieve a competitive measurement robot, this should be accurate, fast, have a short settling time, high accuracy, low temperature dependence etc. If a tactile measurement probe with very low weight and inertia is used in this application, then the parallel structure does not need to transmit big dynamic forces and torques and the structure could therefore be made of lightweight material with moderate stiffness and low temperature coefficient, for example carbon epoxy. However, if a parallel kinematic robot is designed for machining applications, then it needs to have the capability to carry a heavy load and stand big tool forces, which means that the robot structure must be able to transmit big forces with high accuracy and high stiffness. Looking at other applications, new combinations of demands will be found and it is therefore very important to develop methods to optimise the parallel structures for different applications. To keep the cost level at a minimum, it is not possible to custom design the robots for each application, but modularization is needed. Both the modularization and optimisation strategies for robots based on parallel kinematics differ from the corresponding strategies used for robots based on serial kinematics. Therefore, optimisation and modularization of parallel kinematic robots should be an interesting research task, especially if the research covers both the mechanics, the drive system and the controller.

One important part of the optimisation is to find out how different control concepts can help to improve the price/performance of parallel kinematic robots. To avoid the need of expensive high precision components and the use of high precision assembly, calibration must be made before the delivery of the robots. For this, improved methods for measurement, modelling, identification and compensation of kinematic errors must be developed. Even if a lot of research has been made on kinematics of parallel structures, there are still interesting research topics concerning the whole calibration procedures.

For high performance real time control of the dynamics of parallel structures, both rigid and elastic body models are needed. A lot of useful research results can be found for rigid body modelling, but more research is needed in the area of elastic modelling, including static compliance, damping, structural resonances etc. Since it is very difficult to achieve the same stiffness with a link structure as with for example a gantry structure using hydrostatic bearings, it is important to compensate for the lack of stiffness by using advanced control, which could also include feedback from sensors mounted on the the parallel arm structures. The research made up to now concerning advanced control methods for

parallel kinematic manipulators is limited and since this is the only possibility to take care of the stiffness limitations in the joints and the link structures, it should be an interesting topic for academic research in automatic control.

The problem mentioned above concerning the stiffness limitations in the joints is very important to solve for parallel kinematic robots. Compared with serial kinematic robots, parallel structures need more complicated joints and the bearing technology in these joints is critical. Even if big efforts have been made to develop different joint structures using different bearing concepts and different material combinations, more research is needed to find joint concepts that will guarantee lifetime, stiffness and accuracy, especially for applications generating big stress on the joints.

The different potential research topics mentioned above will be discussed from the perspective of ongoing development of parallel kinematic robots at ABB. Before the production of parallel kinematic robots can start, all the demands on industrial robots such as cost, safety, reliability, serviceability, agility etc. must be fulfilled, simultaneously with improved motion performance. This is a big challenge and several basic problems still need to be solved.