

## Chapter 73

# Optimal Location of the Workpiece in a PKM–Based Machining Robotic Cell

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### ABSTRACT

*Most machining tasks require high accuracy and are carried out by dedicated machine-tools. On the other hand, traditional robots are flexible and easy to program, but they are rather inaccurate for certain tasks. Parallel kinematic robots could combine the accuracy and flexibility that are usually needed in machining operations. Achieving this goal requires proper design of the parallel robot. In this chapter, a multi-objective particle swarm optimization algorithm is used to optimize the structure of a parallel robot according to specific criteria. Afterwards, for a chosen optimal structure, the best location of the workpiece with respect to the robot, in a machining robotic cell, is analyzed based on the power consumed by the manipulator during the machining process.*

### INTRODUCTION

A Parallel Kinematic Manipulator (PKM) is a complex closed-loop mechanism, made by two rigid bodies, or platforms, that are connected by at least two independent open kinematic chains. PKMs have considerable advantages over their serial-based counterparts, such as higher precision

and stiffness, and better dynamic characteristics. In the last few years PKMs have been used in several areas, like robotics, motion simulators and machining-tools (Merlet and Gosselin, 1991, Lopes, 2009, Staicu and Zhang, 2008).

Machining has been regarded as a high-precision task, traditionally carried out by dedicated CNC machine-tools. However, there are many tasks where the requirements for precision can be relaxed, such as machining of soft materials (e.g.,

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polymers and composites), machining of large wood or stone workpieces, and end-machining of middle tolerance parts. In this kind of tasks, industrial (serial-based) robots started to be used as alternatives to CNC machine-tools, taking advantage of their flexibility and user-friendly programming interfaces (Olsson et al., 2010, Vosniakos and Matsas, 2010, Mitsi et al., 2008, Zaghbani et al., 2011, Lopes and Pires, 2011). When properly designed, PKM-based robots can bring together both accuracy and flexibility that are usually needed in most machining tasks.

For a given PKM configuration, the geometric parameters that define the manipulator's kinematic structure must be determined. This is an extremely important question, since most performance characteristics, like structural stiffness and dexterity, depend on it.

Another important issue in a machining robotic cell is the positioning of the workpiece with respect to the robot. The best position depends on the trajectory and the forces that the robot has to exert on the workpiece during the machining process.

Both problems can be formulated as optimization problems where the objective functions are chosen in order to meet specific performance criteria.

The computational complexity in optimization problems appears in several robotics problems. In fact, we can find that problem in trajectory planning (Chen & Liao, 2011, Pires et al., 2007), robotic structure synthesis (Lopes et al., 2011), and manipulator control (Zi et al., 2008) among many others. Obtaining the optimal solution can result in a significant economic saving, or in the efficient use of scarce resources along the machinery lifetime. Lately, some bioinspired algorithms have been proposed to solve robotic problems. These algorithms represent a valid alternative since some problems are not differentiable and classical methods, such as gradient or derivative methods, can not be used. Another important factor is to solve the problem while having a limited knowledge about all details. Moreover, a large part of the

models used to solve the problems is simplified from real world. Therefore, the resulting solution leads to a poor performance, or is not adequate. The reduction of the objective number is a common practice. To overcome these shortcomings, a multi-objective PSO is used in this study.

Several works using bioinspired algorithms have been proposed in robotics. Barbosa et al. (2010) adopt a genetic algorithm to design a 6-dof parallel robotic manipulator. The dexterity of the robot is optimized using two algorithms: a genetic and a neuro-genetic algorithm. Chen and Pham (2012) propose a multi-objective genetic algorithm trajectory planner for a PKM. In this work is considered the dynamics, the trajectory duration and the required energy. Jamwal et al. (2009) propose a soft parallel robot for ankle joint rehabilitation. They use two genetic algorithms to determine an optimal robot design, adopting the Jacobian matrix as the performance index. Chen and Liao (2011) propose a hybrid scheme for determining the optimal time and the energy efficient trajectory of a parallel platform manipulator. The algorithm uses a combination of PSO and conjugate gradient methods. Lopes et al., (2011) use a MOPSO to optimize, simultaneously in one execution, the dexterity, the stiffness and its isotropy for a parallel robot. In addition, PSO algorithm has been also proposed to find similar ways of coordinating and controlling groups of robots (Sharkey, 2009, Atyabi and Powers, 2010).

Typically, the large number of optimization parameters, the complexity of the objective functions and the number of objectives that usually are involved, makes optimization, in this context, a difficult and time-consuming task. In such a case, evolutionary algorithms can be used as an effective option (Gosselin and Angeles, 1991, Pittens and Podhorodeski, 1993, Chen and Pham, 2012).

In this chapter a PKM-based machining robotic cell is proposed and the PKM manipulator designed according to specific criteria. Given the PKM configuration, the maximum stiffness and dexterity structure is firstly determined. Af-

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