

# Robot machining

**Now in its second year, the European COMET programme aims to develop technologies that will allow high accuracy robot machining. Andrew Allcock reports**

**T**he 30-month COMET project, started in September 2010, aims to overcome the challenges facing European manufacturing industries by developing innovative machining systems that are flexible, reliable and predictable, with an average of 30% cost efficiency savings, in comparison to machine tools.

Industrial robot technology could offer the answer for machining, being both flexible and cost efficient – robots cost two to five times less than machine tools, but they lack absolute positioning accuracy, are unable to reject disturbances, in terms of process forces, and lack reliable programming and simulation tools to ensure the correct machining processes, once production commences. These three critical limitations currently prevent the use of robots in typical machining applications.

COMET, which sits within Europe's €1.2 billion Factories of the Future programme, sets out to achieve absolute accuracy of 50 microns from a robot-based machining

system, although COMET partner Fraunhofer IPA reckons that, with its High Dynamic Compensation Mechanism (HDCM, see later), this could be 20 microns. The project has made use of robots where the component is held by the robot and moved against a rotating tool held in a spindle of fixed location, as well as vice versa for larger parts.

COMET is led by the UK's Delcam as co-ordinator, but has 14 partners drawn from eight countries. These partners include technology suppliers, systems integrators, universities and end user SMEs having varying areas of expertise and requirement (see box item).

#### **FOUR CRITICAL ELEMENTS**

Delcam is developing one of four critical elements – adaptive robot path generation. There are three other elements: machine-specific kinematic and dynamic models, high dynamic compensation mechanism and an adaptive tracking system (see graphic, p20).

These areas of development are being led by: BTU University of Brandenburg, Cottbus; Fraunhofer IPA; and Nikon Metrology.

The Kinematic and Dynamic Model for Industrial Robots (KDMIR) is said to act as the brain of the COMET solution, modelling the robot behaviour and letting the toolpath calculation software, developed by Delcam, adapt the milling path to a robot's specific characteristics. Consortium member ARTIS has developed its Genior Modular Open Architecture (GEM OA) device, for capturing robot-specific characteristics to support the KDMIR.

GEM OA will support accurate definition of the static and dynamic behaviour of any industrial robot, with this behaviour stored in a unique signature that contains mathematical models to optimise and adapt the robot toolpath, in order to improve the accuracy of robot movement.

The HDCM, developed at Fraunhofer IPA, is a high frequency mechanical 3D actuator, on which the cutting tool spindle will be

## Consortium members

- AMRC Manufacturing Ltd – an SME spin-out company from the AMRC at Sheffield. Its scope is to consolidate its established consultancy arm, and also grow into pre-production and production projects within the aerospace sector. It is also in the process of delivering turnkey machining projects using robotics, replacing standard machine tool design platforms with multiple robot solutions.
- ARTIS – Germany's ARTIS is a leading international company in tool, process and machine condition monitoring and adaptive control of processes in metal machining.
- BTU University – an internationally recognised, innovation-driven institute, in Germany.
- Delcam – the world's largest CAM specialist software supplier, providing CAM solutions for any kind of machine tool, such as high speed, 5-axis milling and turning machines. The control of robot systems for high precision manufacturing operations is a rapidly developing area of Delcam's expertise.
- DemoCenter-Sipe – a technology transfer centre located in Italy.
- Fraunhofer IPA is supporting the COMET consortium with its experience in the set-up of high precision robot machining cells.
- Gizelis Robotics – a major industrial robot system integrator in Greece.
- Lund University – the largest institution for research and higher education in Sweden with extensive connections within the industrial robotics industry (mainly ABB), and experience from earlier European projects, such as SMErobot.
- N. Bazigos S.A – a Greek SME, Bazigos' mould shop has up to now focused on using robots for handling applications, but the possibility of using robots for processes like drilling and trimming is of high interest.
- Nikon Metrology – non-contact industrial motion and displacement measurements, plus adaptive robot control, are its contributions.
- Nisaform s.r.o – this Czech Republic SME offers design and production of injection moulds for all kinds of plastic. During the course of the project, it will be investigated whether the High Dynamic Compensation Mechanism, developed by Fraunhofer IPA, allows parts to be manufactured by Bazigos and/or NISAFORM.
- SIR SpA – a leading international robotic system integrator company, located in Italy.
- TEKS – a French SME that has experience in drilling, using ABB robots, and with machining and drilling with hexapods. In all applications involving robotics, machine stability is a major issue. TEKS has expertise in adaptive control and damping to enable optimum performance to be achieved from a robotic platform.
- University of Patras, Laboratory for Manufacturing Systems, Greece – LMS has expertise and interest in robotic assembly systems, particularly in terms of: simulation; design and optimisation of robotic assembly operations; design and configuration of flexible robotic stations and offline programming; process control of robotic joining operations using advanced systems for robot vision capabilities; and co-operative robots for flexible assembly operations.

located (where the component part is robot-held), that will continuously compensate for the positioning errors and oscillations of the robot, such that a stable machining process can be obtained. This element is critical in the achievement of 50 micron absolute accuracy, as such a figure is significantly beyond the structural capacity of the robot system on its own.

In combination with piezo-staple-actuators and flexure elements, axial displacement can be up to 500 micron. (The HDCM is not a part of the system where the component part is very large and where the cutting tool is manipulated by the robot.)

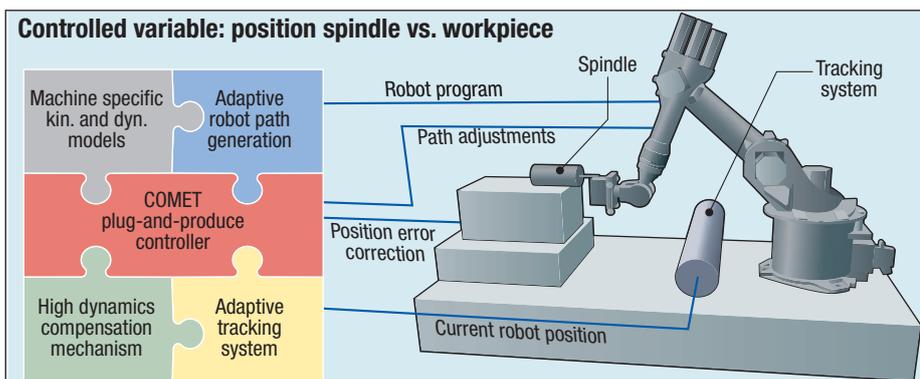
Nikon Metrology's adaptive tracking system (ATIR) will, in real time, support adjustment of the robot arm positioning in relation to the robot toolpaths programmed in the Programming and Simulation Environment (PSIR, see later). The ATIR tracks the location of the robot head and feeds back the metrology data, using a closed feedback loop, to the controller and also to the HDCM, when the HDCM is employed. Where the HDCM is involved, the ATIR sends a low frequency signal to the robot controller, while a high frequency part is sent to the HDCM. A first proof of principle for ATIR is imminent.

## PROGRAMMING ROBOTS

Looking specifically at programming, Delcam's area of activity, the most common robot programming methods involve using teach-and-learn methods, or online programming, which are not suitable for even simple machining processes, says the company. For this reason, programming methods that combine both CAM system and robot code programming are being developed.

CAM systems such as Delcam's PowerMILL are able to generate toolpaths, with the resulting CNC code then translated into robot code in the native robot language – Rapid for ABB or KRL for KUKA systems. However, there is no 'closed loop'.

What the CAM systems lack, explains Delcam, is knowledge about the kinematics and dynamics of the robot system; they are programmed to compute the toolpaths for the simpler kinematics of standard machine tools. When confronted with a robot



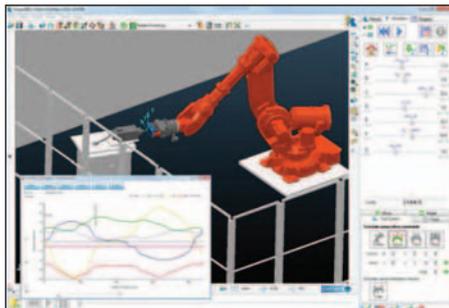


kinematic profile, the system cannot produce collision-free toolpaths, automatically avoid 'singularities' or identify reachability. Also, the redundancy of certain robot axes is not used in support of potential optimisations.

The COMET PSIR is being developed to incorporate the robot kinematics and dynamics to cope with these problems and use all possible optimisations – a combination of Delcam's development and the KDMIR technology.

The PSIR module contains a set of tools to manipulate the robot toolpath to calculate robot poses; to avoid singular points; to analyse robot behaviour using the kinematic and dynamic models from the KDMIR module; to optimise and adapt the toolpath for specific robots, using the unique signature developed in the KDMIR module; and to perform 3D collision simulations of the complete robot cell.

Delcam's commercial product name for the PSIR being used in the COMET project is



**The Delcam PowerMILL Robot Interface is being used to support COMET's aims**

the PowerMILL Robot Interface. The Robot Interface is an add-on product to Delcam's PowerMILL CAM package. The software is commercially available and used across various robot cells in Europe, and has been adopted by the COMET partners for performing real-world industrial machining tests with various brands of robots, including ABB, Kuka and Fanuc.

Toolpaths are calculated using machining strategies within Delcam's PowerMILL. From these toolpaths, it is possible to calculate the required robot poses and analyse the movement of the robot arm for the calculated toolpath and identify any problems, such as singularities. The PSIR module contains a set of analysis and edit tools to manipulate the robot and optimise the robot toolpath, and the robot poses and position.

### FINAL STEP – THE RIGHT LANGUAGE

The final step is to post-process the fully simulated and verified toolpaths to a specific robot language: for example, ABB Rapid or KUKA KRL. Currently, most robot brands are supported, including external axes, such as rotary tables or linear rails. Future developments will add optimisation tools, using the KDMIR signature of a robot to correct the toolpath for a number of error

sources to improve the overall accuracy of the machining operation.

COMET partners received a dedicated PowerMILL for Robots training course in January 2011 at Delcam's headquarters in Birmingham and started to use the software in real-world machining experiments. In January 2011, TEKS engineers were the first inside of the COMET project to mill aluminium with a standard industrial robot. The COMET robot cell at TEKS is an ABB robot with a 42,000 rpm spindle.

As of January this year, full machining experiments in aluminium are being performed on seven robot cells across Europe – "providing interesting initial results". A special test pattern has been designed to study the main error sources affecting workpiece accuracy. In this first step, the Delcam PSIR component of the COMET platform is being used.

During this year, the COMET project will continue to integrate each part of the COMET platform and concentrate on demonstrating the advantages of robot machining in a variety of applications, such as automotive parts, mould and die components, and aerospace parts.

The intention is to be able to provide the COMET technology as a commercially available solution once the project has been completed, during Q1 next year. Delcam says it believes the prospects for the UK market are very promising, as robots offer a low-cost manufacturing alternative to machine tools, which, with new programming tools designed to improve the accuracy and ease of programming robots (such as the PowerMILL Robot Interface), makes them even more appealing.

Added to this is the flexibility to easily machine both large and small parts, their ability to work in hostile environments, such as stone, composites and nuclear environments, and the ability to be used for a number of different applications (eg, sculpting, trimming, deburring, laser cutting, finishing etc). ■

### COMET videos on the web

Project overview – <http://bit.ly/FPOLMG>

Project update (Feb 2012) – <http://bit.ly/AgeaGz>

Robot machining examples – <http://bit.ly/yz314Z> and <http://bit.ly/xRf7SE>

The COMET project website – <http://www.cometproject.eu>