Flexible Measurement Systems

Temperature and Absolute Accuracy Compensation for Inline Robotic Metrology

Flexible Measurement Systems are robot-based, in-line inspection systems typically based on non-contact measurement of work piece features, including holes, slots, edges, studs/bolts, etc. FMS solutions provide multiple benefits compared to traditional metrology: flexibility in model mix, fast measurement, 100% inline inspection (i.e. quick response to quality issue – minimizing scrap/waste and improving productivity), durability for plant floor environment (proven rugged components - robot and sensor).

Temperature Compensation

An FMS consists of four major components. A Standard Industrial Robot carries a Precision Small-Range Sensor (such as a 3D vision system) in close proximity to the multiple features to be measured on each production part, thus effectively providing a large measurement envelope - and even larger since one FMS can include multiple robot/sensor units. A Metrology Interface then allows the collected measurement data to be viewed, compared with CAD data, set against pass/fail criteria, analyzed for trends, etc. Finally, considering an Industrial Robot’s low intrinsic accuracy, combined with the harsh environment of production, an adequate Calibration Solution – such as Dynalog’s DynaFlex™ System - is required to guarantee and maintain the maximum measurement performance of an FMS at all times.

Repeatability and Absolute Accuracy

Standard robots from all manufacturers are quite repeatable – in a controlled environment at least! - and thus present a great potential for precision measurement applications. Indeed, the specification data sheet for most robots will boast a Repeatability of around 0.1 mm, which will vary up or down slightly depending on the size and payload capacity of each particular robot model. However, the standard robot repeatability specification published by all robot manufacturers is based on a 30-cycle test (see ISO 9283) – lasting only a matter of minutes and conducted in a laboratory’s well-controlled setting. In the real production environment, the conditions are quite different though! Over time, the metal (aluminum or steel) robot structure will experience distortions in shape and size, due to two main factors: (1) robot self-heating (i.e. heat generated by the robot’s own electric servo motors) and (2) ambient temperature swings within the
plant (whether from morning to afternoon, or from winter to summer). These position distortions lead to an actual robot repeatability-over-time of between 0.5mm to more than 1mm! In addition, the robot may occasionally collide with an out-of-position part, clamp or neighboring robot and become damaged – losing its position entirely.

Another issue with an Industrial Robot besides its Repeatability over time – is its Accuracy. Robot manufacturers typically do not specify the Accuracy of their robots, since most robots are not intended for high-accuracy applications. Yet, improving the robot’s intrinsic Accuracy in its overall envelope with respect to the “Absolute” world provides an FMS with “CMM-like” measurement capability. This essentially allows usage of the FMS as a CMM, i.e. without systematically requiring the use of a “Master” or “Reference” part to offset the inspected measurement features. Measurement data from the FMS can then be compared directly with CAD data.

Continual Compensation

Calibration is what takes care of this double issue of (1) Repeatability over time and (2) Absolute Accuracy posed by the use of a standard Industrial Robot in a FMS solution. The Calibration process guarantees the essential metrological loop required to express the local measurements obtained with the sensor mounted at the end of each robot back into the desired global part frame. Generally spoken, the Calibration process starts with identifying the “true” kinematic parameters – relative to the Absolute world, and considering their (temperature-related) drift over time – continuously defining the complete FMS loop: i.e. the robot’s so-called DH parameters, the sensor measurement frame, the part’s global frame, and much more. Then, the difference between these Identified parameters and the “nominal” ones stored on the robot controller are Compensated for, in order to guarantee the required positional performance of the FMS.

To perform the Calibration’s first phase (i.e. the Identification process), precision Calibration Targets - designed to be as temperature insensitive and as mechanically stable as possible – are located within the robot envelope.

Single-Robot FMS inspecting a rear door
These Calibrations Targets are accurately measured with the sensor carried by the robot. This measurement process occurs not only initially at installation of the FMS, but also periodically throughout the continuous usage of the FMS along the production line. This methodology of Calibration not only maximizes the robot’s initial Absolute Accuracy, but it also maintains its Repeatability over time irrespective of mechanical wear, temperature fluctuations, robot crashes, and other environmental factors. The whole Calibration process – including the Compensation phase – occurs transparently to the user, in between production cycles and without requiring any manual intervention.

**Accurate as a CMM**

Following the implementation of a pilot cell in 2003, Renault started operating an Absolute Accuracy FMS in a full production application in the Clio bodyshop at Flins. The cell incorporates four ABB IRB 4400 robots each one carrying a Perceptron FlexiCam sensor. All four robots are connected to the Perceptron platform that controls the complete FMS. The DynaFlex Calibration software provided by Dynalog also runs on the same platform. In this cell, two robots are positioned on either side of the line. The cycle time to measure a single point on the body-in-white is roughly 2.5 seconds each (including movements of the robot and image acquisition). Renault is currently using the FMS to measure 50 points per car body every cycle (10 to 15 points per robot). “The goal is to be as accurate as a CMM machine”, comments Fabrice Legeleux from ABB. FMS are used widely in automotive production for measurement of the body-in-white, body-sides, under-body, doors, hoods, etc. The systems are also used in some Aerospace applications for high accuracy inspection of work piece components.

Dynalog’s DynaFlex system has become the standard Calibration solution for a variety of FMS solutions - delivered by different integrators, incorporating a wide variety of small-range sensors, and fully integrated with virtually all industrial robot brands. As manufacturers demand faster speed, more flexibility and better productivity, the market for FMS continues to grow. Dynalog and FMS providers are constantly improving their technology, adapting their systems for new and more demanding applications in both automotive and non-automotive sectors.