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Smart Servo Sensing in Industry 4.0

Tomer Goldenberg

Lead Technical-Marketing Engineer**,** *Elmo Motion Control*

Abstract

In a revolution aimed at transforming factories, the less talked about motion control technology can help achieve many of the goals driving Industry 4.0 (I4.0) forward. Intelligent, compact, efficiently communicating decentralized servo drives, mounted deep inside a machine, act as advanced telemetry devices that can sense, monitor, and react. The silent impact of innovative motion control in smart manufacturing is demonstrated in a pick-and-place (P&P) application. "Pure Power" control, smart servo technology, compact load mounted, rugged, and highly reliable servo drives, not only lead to the very results promoted by I4.0, but also help create leaner machinery that is smarter, smaller, lighter, safer, greener, more efficient and also cost effective.

Elmo Motion Control Ltd.•60 Amal St., P.O. Box 3078,Petach-Tikva 49516, Israel
Tomer Goldenberg: • Cell +972-5-06380720 • tomerg@elmomc.com• www.elmomc.com

Motion Control in the Age of Industry 4.0

Motion control, although less talked about in the context of I4.0, is essential in achieving some of its main goals. Let us compare the following case analyses of two Surface Mount Technology (SMT) P&P machines. Both are used for highly demanding manufacturing tasks with high throughput and uncompromised quality, both have a double gantry structure, Z-axis mounting heads which control the linear and angular component orientation, and both handle the same size PCBs, where similar small and high density components are placed. However, they differ dramatically in their design, motion approach, and component per hour (cph) throughput. Machine 'A' weighs 2,000kg, with a volume of 5.2m^3, while machine 'B' weighs just 1,200kg with a volume of 3.9m^3 (33% less) and a higher overall cph throughput. How is it possible that the smaller, lighter, and seemingly less "equipped" machine outperforms the "heavy-duty" machine?

What is "Pure Power"?

Smart servo drives operating in systems where most of the consumed power is invested purely in moving the loads ("Pure Power"), possess a significant advantage in the I4.0 ecosystem. Servo drives which are highly-responsive and have high resolution servo have the capability to precisely sense, monitor, analyze machine movements, parts and devices that are motion controlled. High-level, real-time sensing of force, torque, speed, and position, offers a unique high-resolution magnitude and time-stamp data for each of the parameters. With this data, multi-dimensional plant analysis could be used to provide valuable information regarding the on-going state of the machine, and could offer Indications for predictive maintenance, ultimately reducing failures and down-time.

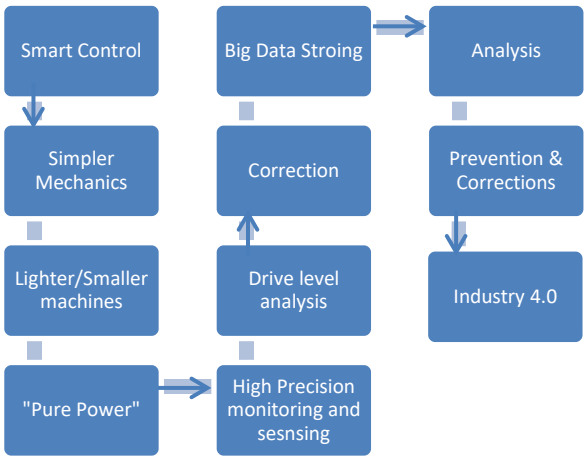

Figure 1: The role of Smart Control in I4.0

How is "Pure Power" achieved?

1. Unique Gantry Control

A traditional approach would utilize complex centralized Gantry control architecture with a master controller and multiple drives for each axis. Aside from physical complexity, such architecture also tends to suffer from excessive field bus network loads. Machine 'B' however was designed with a lean control philosophy where a distributed Gantry control is operated by two servo drives

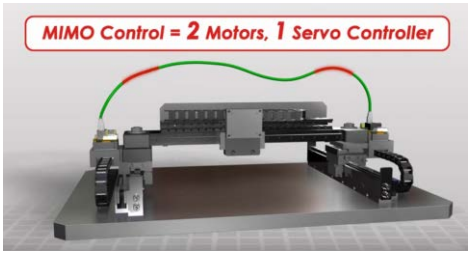

Figure 2: Gantry operation with just 2 servo drives

only. With no controller and load mounted drives, there is a significant overhead reduction. Cables, connectors, heat- sinks, and cables guides which otherwise would consume excessive power are reduced or eliminated. This enables a real “Pure Power” operation.

2. Pick-and-Place - It’s all in the Head

Lighter Machine ‘B’ was achieved by also minimizing the mounting head design. Ultra-small, light, and powerful, servo drives were directly mounted to the moving XY axes. Thus, the mounting heads consume less power, since parasitic power required by flexible cables, cable-carriers and connectors is significantly reduced. This allows the drives to be more sensitive and attuned to the load itself.

Figure 3: Ultra-compact 16 high power servo drives

One of the numerous challenges met by machine ‘B’ due to “Pure Power”, is precise "sensor-less” force control in the range of 0.3N to 10N. This was also achieved with a current loop resolution ratio better than 2000:1, and with very fast response time and a wide bandwidth (as high as 4 KHz). Such sensitivity requires

3. Smart Motion & Servo Control

P&P machines must be highly dynamic to reach high performance with high throughputs. Intelligent servo drives mounted deep in a machine allow for high precision telemetry and analysis with high resolution and sensitivity, and a fast response time. Consider motion effects within Machine ‘B’ as show in the graph below, where vertical head units (Z-axis) oscillations were accurately measured in response to high speed coordinated motions along the XY plane. Intensive parasitic mechanical oscillations and system non linearity is evident at high operational XY speed.

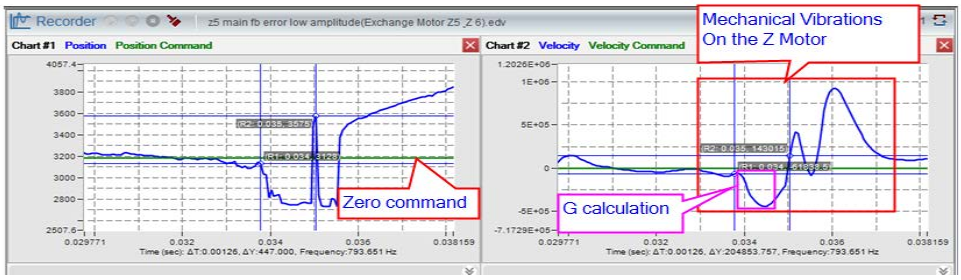

Figure 4: Advanced detection of parasitic behaviors. These can be overcome with smart control

Machine builders quite often resort to traditional methods to overcome such “undesirable” behaviors. They are commonly addressed with the addition of heavy and bulky mechanics, ultimately requiring larger motors, gears, and higher power drives. This leads to a much heavier and less agile machine, as seen with Machine ‘A’, making it more challenging to reach high dynamics and throughputs. A better approach embraces light and agile mechanics, monitors the consequential behaviors, and addresses the inevitable parasitic resonances with smart motion and servo control functionality such as multi-dimensional plant identification, position-based gain scheduling, high order filters, oscillation predictive signal-conditioning and more. This approach is not only more cost effective than that of the mechanical fix, but also helps with highlighting “Pure Power” within the system, since little power is wasted on bulky mechanics.

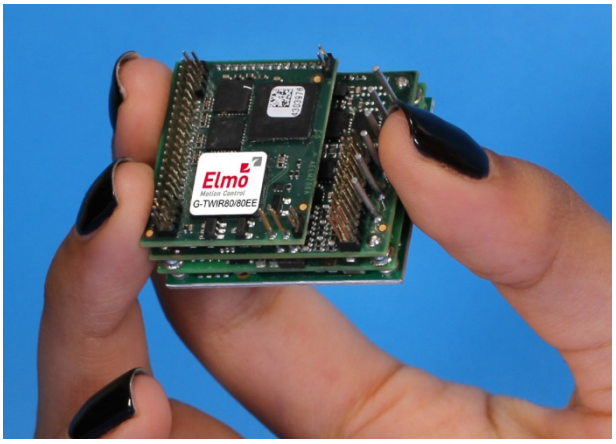

Figure 5: Ultra-small, high power servo drive: 80A, 80V

Utilizing “Pure Power”

High Precision (Sensor-less) Force Control

Given “Pure Power”, the capability to promptly and accurately monitor the mounting force of the placement process allows the detection of short and the long term deviations in the mounting force that might occur due to mechanical wear-out, mechanical component failure, or bad batch of components with some mechanical inaccuracy.

Force values and response can be handled in two ways:

- Real time: immediate reaction to the monitored results in the drive level. The drive can to collect, analyze and respond to significant amount of data.
- Long term: The data is transferred to higher level controller, motion controller, or an upper level host, where “Big Data” is analyzed by a dedicated algorithm to detect any deviations or abnormalities.

Predictive Performance & Operation

Smart servo drives can also monitor the short and long-term load stability, repeatability, and control performance of the XY table. "On the fly" changes of the Torque-Speed relation, the load, response, or appearance of "new" oscillations can all be monitored and recorded. The accumulated data can be analyzed in real-time to detect future risks of malfunctioning, mechanical wear-out, and other mechanical problems. Thus, the drives can correct and/or

prevent failures before damage to the process or components occur, or before a machine halt is reached.

“Pure Power” is achieved as a "bonus" due to intelligent motion and servo control, aimed to at machine performance optimization by means of control rather than (costly) mechanical design. As 80-90% of the power consumed is “Pure Power”, high-sensitivity, high resolution monitoring may be achieved.

Conclusion

An innovative motion control approach has been demonstrated to give a P&P machine intelligent I4.0 capabilities.