A unified low-cost framework for general bonding equipment through iterative learning

Introduction
Next-generation bonding equipment in the semiconductor assembly processes aim at very high throughput under stringent process requirements. An accurate feedforward methodology is the key to improving the servo performance of such systems.

Iterative Learning Control (ILC) is a superior feedforward methodology that exploits measured data to improve servo performance for perfectly repetitive motion tasks. Besides such tasks, bonding systems in semiconductor assembly processes also involve almost repeating tasks, which prohibit the direct application of ILC. In this research [1], a unified ILC design framework is proposed for bonding systems that:

- achieves high servo performance for repetitive tasks,
- is based on loop-shaping based design,
- allows for trajectory variations.

Projection-based ILC
After each iteration:

1. **Step 1.** determine ILC feedforward as: $f_{j+1} = Q(f_j + L e_j)$, using frequency-domain loop-shaping design for $Q$ and $L$ filters.

2. **Step 2.** Approximate $f_{j+1}$ with a lower order feedforward $\hat{f}_{j+1}$ using basis functions [2], [3] that are dependent on the current reference. The approximation is done using ‘Weighted-projection’ method that retains ILC performance.

Experimental Results
Experiments conducted on a high-speed axis of wire-bonder.

Figure 1: Bonding systems: Die- and Wire-bonder.

Figure 2: Projection-ILC block scheme.

Key features:
- added robustness against standard ILC,
- loop-shaping based $Q$ and $L$ filters,
- analytic solution (allowing update in each iteration)

Figure 3: Z-axis of wire bonder. The reference trajectory is varied in final position by 6 % after 10th iteration.

Figure 4: 2-norm of servo error for Standard ILC (red) and Projection-ILC (blue).

Figures 4 and 5 show deterioration in S-ILC performance for variations in the task, while P-ILC performance is hardly effected. This experiment confirms that proposed method offers both high performance and allows for trajectory variations.

Figure 5: Error time plot after the change in the reference trajectory for S-ILC (red) and P-ILC (blue).

Ongoing Research
- Friction, cogging, position varying effects
- Input-shaping [3]

Conclusion
- standard design rules
- extension towards NXP tasks
- low cost: time, money and training

References