Simulation-based optimization of selective assembly costs in a hybrid production context

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Selective assembly is a production technique whereby components are smartly instead of randomly matched based on their measured feature values. Although it can reduce scrap while increasing product quality, it is often not adopted due to the high logistic costs related to measuring and matching operations.

Therefore, we propose and investigate a hybrid assembly strategy whereby a number of random assembly rounds are performed before switching to selective assembly. At each round, components are randomly picked from their corresponding piles and the assembly is attempted. At this point, components are either removed from their corresponding piles because matching was possible, or placed into their corresponding unmatched piles after the current round. Those piles will then be the starting point for the random selection of components in the following assembly round. When N such rounds have been performed, the remaining unmatched components will finally be assembled using selective assembly.

Due to these prior random assembly rounds, fewer selective assembly operations will eventually be needed, which considerably reduces logistic costs related to selective assembly. On the other hand, every additional round also implies random assembly trial costs. Hence, an optimal number N^* of random assembly rounds before moving on to selective assembly has to be determined.

Therefore, we develop a cost function together with an optimality condition. This cost function is expressed in terms of the matching probabilities at each round and the relative costs of selective and random assembly. These probabilities express the likelihood of a successful match when components are randomly picked from their corresponding unmatched piles after a certain round.

Since the analytic calculation of the matching probabilities is in most of the practical cases not feasible, we develop a simulation technique to estimate these probabilities. First, we use simulation to obtain a sample of the unmatched components after each assembly round. Then, we use these samples to estimate the matching probabilities. Finally, we evaluate the cost function in order to find the optimal number of random assembly rounds prior to selective assembly.

To assess the performance of this method, we apply it to two study cases from literature: a Shaft and Hole two-components assembly [1] and a four-components Ball Bearing assembly [2]. In order to reduce variability, we investigate and compare three estimation methods for the matching probabilities, and we study their impact on the total variability of the cost function using the Delta Method. Finally, with sensitivity analysis we investigate the behavior of the optimal number of random assembly rounds N^* as the relative cost of selective assembly to random assembly varies.

Despite the differences between the two cases concerning component features' distributions, complexity and assembly matching functions, we observe similar results. Since the matching probabilities rapidly decrease with every additional random assembly round, the highest cost reductions are achieved within the first few rounds. In both cases, the proposed hybrid assembly technique can significantly reduce average assembly costs while still delivering higher quality products.

By addressing the gap in the existing literature about selective assembly around its combination with traditional assembly, this study achieves a double goal. On the one hand, it provides a framework to evaluate the effects on the average assembly cost of performing a number of random assembly rounds prior to apply selective assembly. On the other hand, it allows to estimate assembly costs taking component features' distributions as an input parameter. Moreover, since it provides an efficient way to estimate matching probabilities, this model could also be used to estimate and compare average assembly costs as a function of the quality of incoming components by repeating the analysis with different types of component features' distributions.

References

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