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Production scheduling of continuous make-and-pack processes with byproducts recycling

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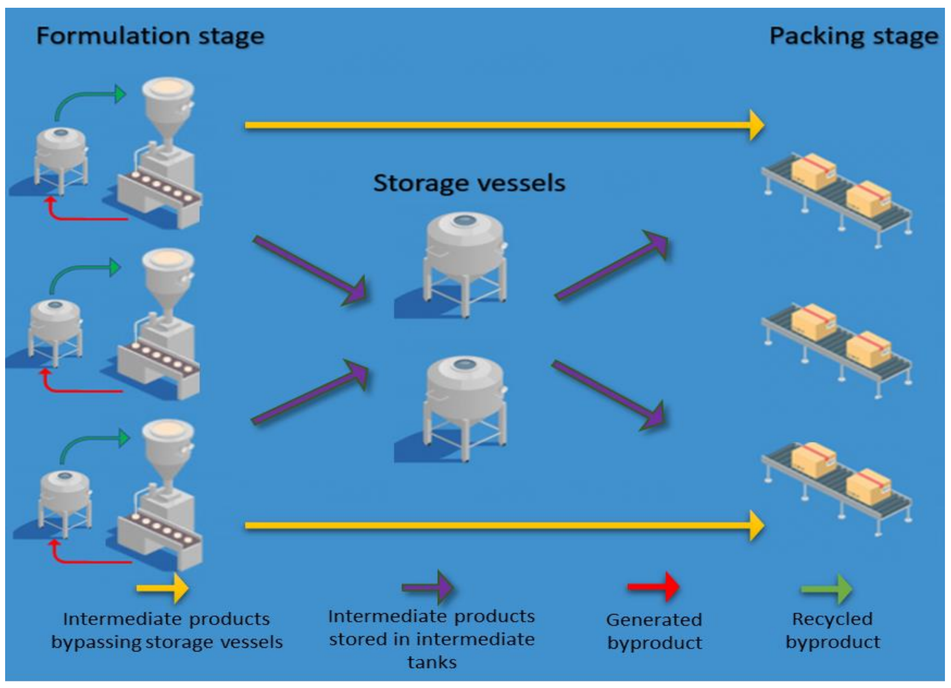
Scope of the Study - Problem definition

- Scheduling of continuous make-and-pack industries, including flexible intermediate storage vessels.
- Flexible vessels are used for storing multiple intermediates of the same recipe
- Formulation stage → recycling of byproduct waste due to cleaning operations
- Efficient models required to get nearly optimal solutions minimizing changeover times, equipment idle times and byproduct waste



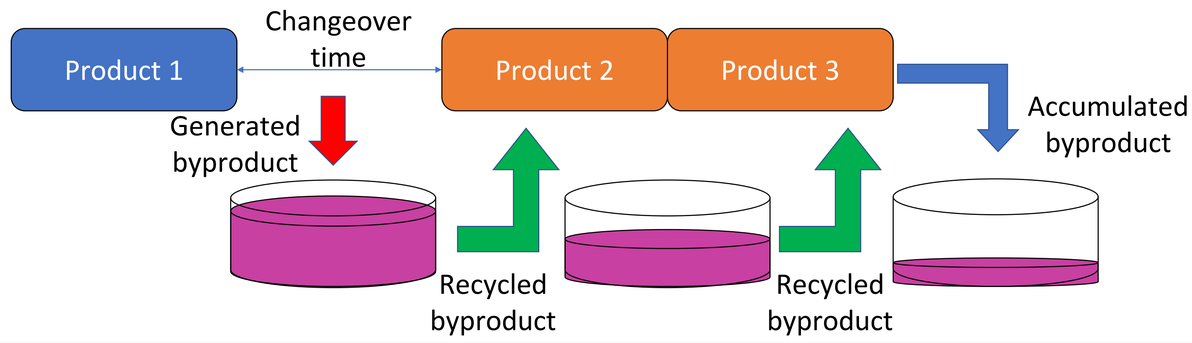
Modelling Framework

A novel continuous-time, precedence-based, MILP model is developed

- Unit allocation, timing and sequencing are decided
- Full weekly demand satisfaction
- Intermediate products can be temporarily stored in a storage vessel or can be transferred directly to a packing line
- Mass balance constraints of storage tanks are correctly handled only via a set of auxiliary binary variables

Modelling of byproducts recycles

- Resource constraints related to the generation and recycling of byproduct waste
- Explicit material balance constraints are introduced to prevent the overloading of storage vessels of byproduct waste without using further binary variables



Results - Discussion

- A flexible storage policy allows both stages to operate at their highest rate
- The utilization of intermediate buffers leads to a better synchronization of the production stages and increased plant productivity

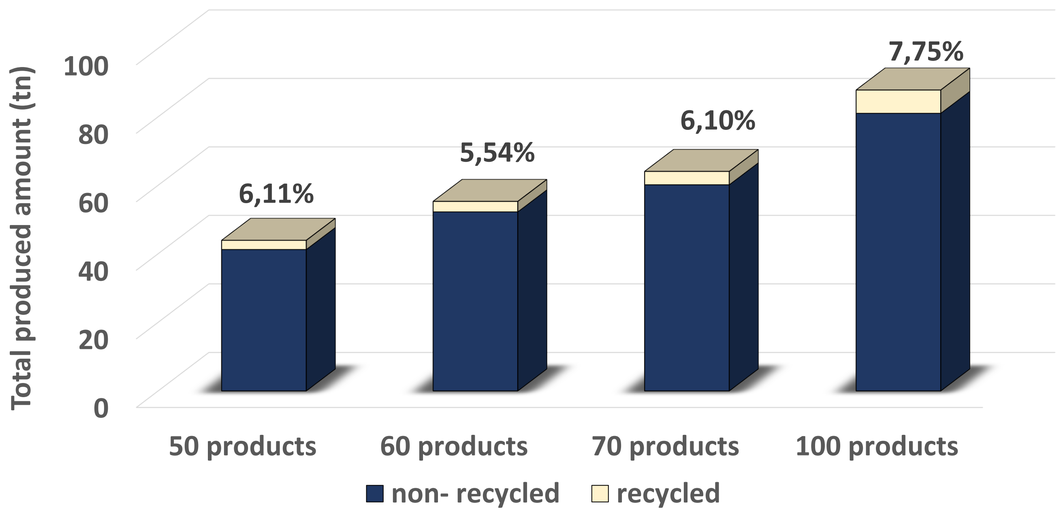
	Number of Products	Coupled plant layout*	Decoupled plant layout*	Difference (hours)*	Productivity gain (%)
Case 1	15	124.75	170.13	45.37	26.67%
Case 2	20	186.63	225.63	39.00	17.29%
Case 3	25	249.92	261.99	12.06	4.61%
Case 4	35	355.34	371.82	16.48	4.43%
Case 5	50	422.14	442.70	20.55	4.64%
Case 6	70	596.23	680.88	84.64	12.43%

*the values represent the total operational time of all production units of both stages in hours

- The proposed improvement step leads to notable benefits in terms of total cost reduction.
- The improvement is mainly achieved by reducing the idle time cost

	Products	Algorithm step	Total Cost
Case 1	60	Constructive step	1326,87
		Improvement step	1301,67 (-1.90%)
Case 2	100	Constructive step	2561,49
		Improvement step	1999,60 (-21.90%)

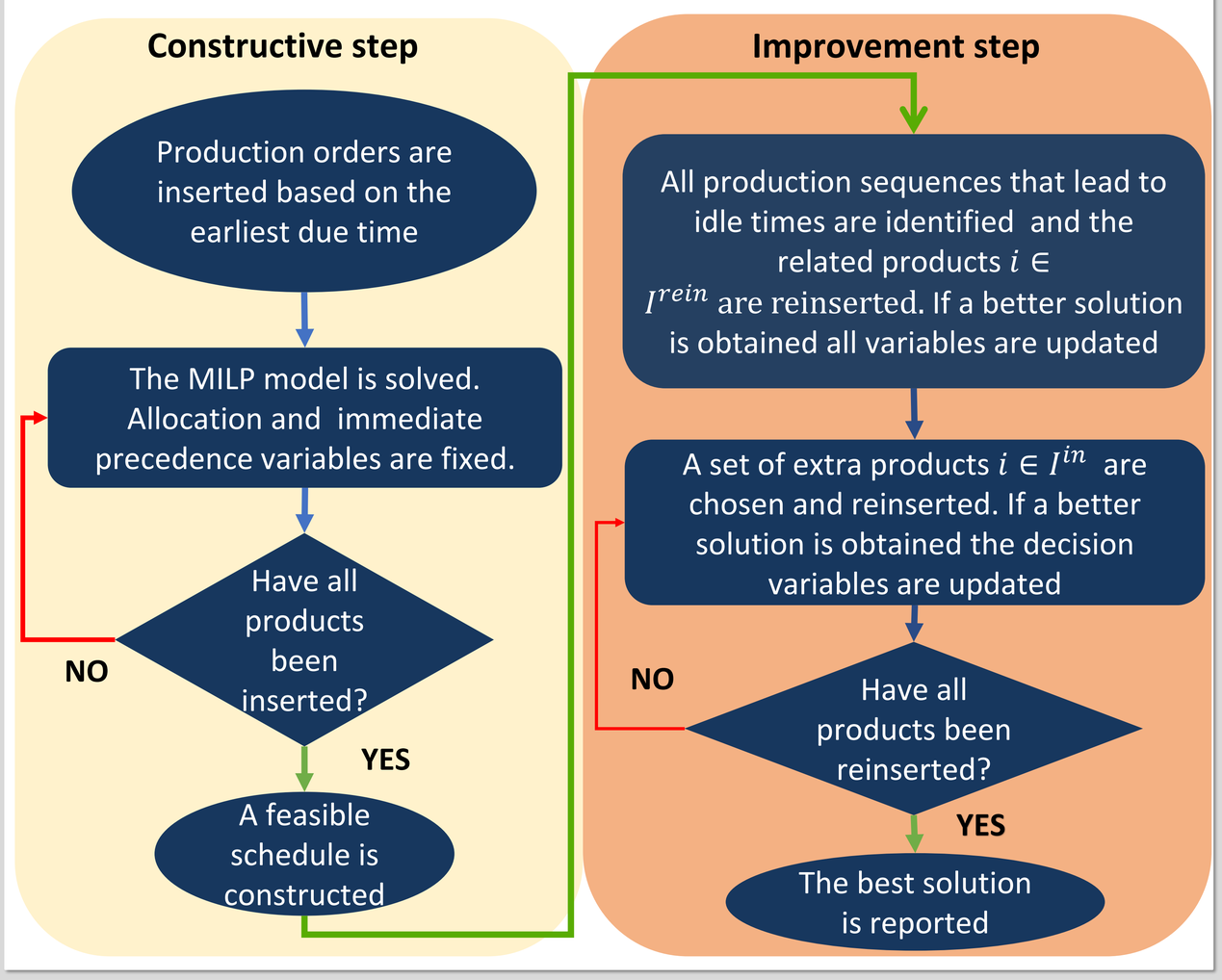
- The consideration of byproducts recycling constraints leads to better utilization of resources and significant reduction of material cost
- Even 7,75% of the total produced amount may consist of byproduct recycling streams



Solution Strategy – Decomposition Algorithm

A two - stage decomposition algorithm based on the MILP mathematical model is proposed:

- The initial problem breaks into tractable subproblems
- The MILP-based model is solved in an iterative mode
- Nearly optimal solutions are provided, in reasonable computational times, accepted by the industry
- The initial feasible solution can be enhanced by reducing the idle times



Conclusions

- ✓ Results illustrate significant improvements in the economic operation of the plant
- ✓ The MILP-based decomposition algorithm generates good quality solutions in reasonable computational times
- ✓ The proposed approaches can potentially constitute an important optimization tool for engineers to make rigorous scheduling under a dynamic environment

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