

Models and Algorithms for Scheduling in Automotive Stamping Plants

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Michigan**Engineering**

Industrial and Operations Engineering



Themes and Goals

- Primary focus is on scheduling stamping operations at Ford Motor Company
- Common goals and approaches as other projects
 - ◆ UPS
 - ◆ Airline industry
 - ◆ Scheduling of manufacturing enterprise systems
- All are large-scale scheduling problems with complex networks and combinatorial challenges

Primary Objective

- Goal is not to find “provably optimal” solutions
- We want solutions that:
 - ◆ are high-quality
 - ◆ have reasonable run times
 - ◆ realistically model the real world
 - ◆ are “easily implementable”

Math Programming Approach

■ MP pros:

- ◆ Global viewpoint
- ◆ General solution techniques
- ◆ Established commercial solvers

■ MP cons:

- ◆ Large numbers of constraints, variables
- ◆ Non-linearities
- ◆ Weak LP relaxations
- ◆ No exploitation of problem-specific structures

Customized Scheduling Algorithms

■ Pros:

- ◆ Exploit problem structure
- ◆ More realistic
- ◆ Fast run times, convergence

■ Cons:

- ◆ Feasibility?
- ◆ Solution quality?
- ◆ Adaptability?

Hybrid Approach

- *Complex variable definitions*
 - ◆ Capture model complexity within the variable definition
- MP-based *master problem*
 - ◆ Global vision
 - ◆ Dual information
- Application-specific algorithms to generate columns
 - ◆ Tractability
 - ◆ Implementability
 - ◆ Run time
 - ◆ Leveraging user expertise

Stamping Plant Application

Automotive Stamping Plant

Step 1

Sheet Metal Blanking

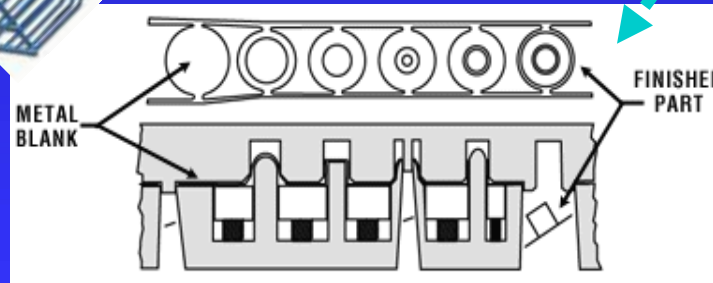
Forms coils of sheet metal into blank



Step 2

Sheet Metal Stamping

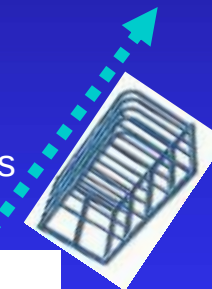
Forms sheet metal into 3D parts



Step 3

Sub-Assembly/Assembly

Pressed parts undergo additional operations
(e.g. adding nuts and bolts)



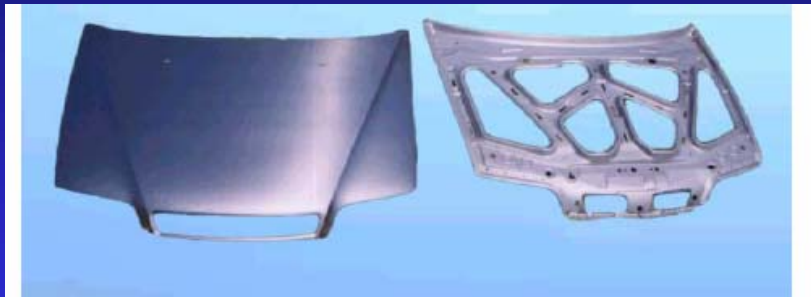
Racks

Move parts between
workstations

Diagrams from <http://www.advantagefabricatedmetals.com> and <http://www.maybury.com/>

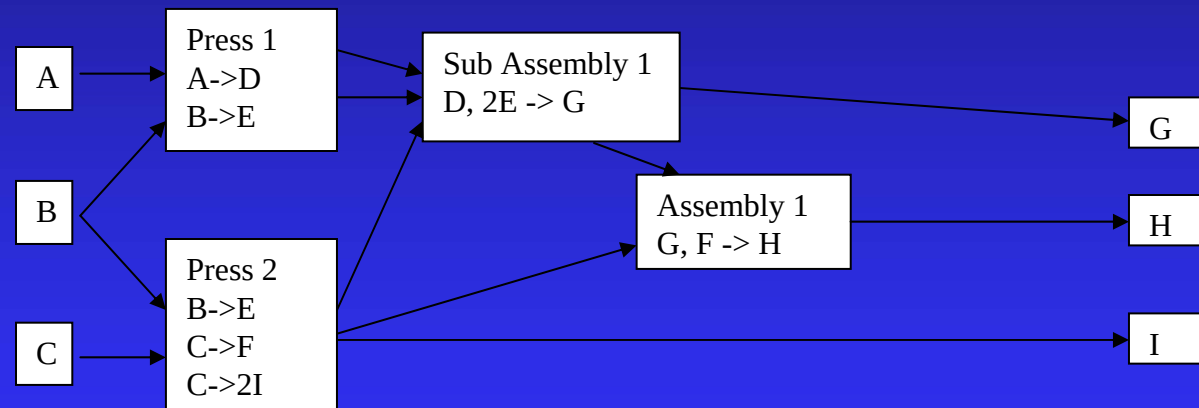
Stamping Plant Application

■ Automotive Stamping Plant – Example Parts



Diagrams from <http://www.advantagefabricatedmetals.com> and <http://www.maybury.com/>

Sample Product Flow



Problem Definition

- Sequence all product demands (final and up-stream) on all machines so as to minimize cost while satisfying:
 - ◆ Demand constraints
 - ◆ Production limitations
 - ◆ Rack capacity
 - ◆ Rack movements
 - ◆ Machine setup time (implicit and explicit)

Variable Definition

- Most challenging constraints are machine change-overs
 - ◆ Critical to feasibility
 - ◆ Rely on substantial previous information
- Define a variable to represent a *feasible schedule for an entire machine*
 - ◆ One (potentially very large) set of variables for each machine
 - ◆ Captures all machine constraints *implicitly*
- Master problem considers all inter-machine constraints *explicitly*

Model

Constraints:

1) A machine can only be assigned one feasible schedule

$$\sum_{s \in S[m]} x[s] = 1 \quad \forall m \in M$$

2) Production can only occur if the rack is at the machine

$$\sum_{s \in S[o[p]]} b^w[n, p, s] * x[s] - \sum_{s' \in S[e[p]]} g[n - r[p], p, s'] * x[s'] \geq 0$$

$$\forall p \in P, n : r[p] + 1 \leq n \leq d[p]$$

3) The time the nth rack of product p is completed has to be earlier than the time that it is consumed on another machine.

$$\sum_{s' \in S[e[p]]} u[n, p, s'] * x[s'] - \sum_{s \in S[o[p]]} t[n, p, s] * x[s] \geq 0 \quad \forall p \in P, n : n = 1..d[p]$$

Current Status

- Working on coding infrastructure
 - ◆ C++ calling CPLEX
- Developing algorithms to generate candidate machine schedules
- Hope to have preliminary results by early 2006 (and certainly by next INFORMS!)

Future Research

- Expanding level of detail
 - ◆ Cranes
 - ◆ Labor
- Generalization
- Expanded supply chain scope
- Variability, robustness, and responsiveness

Questions

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