1910
Teorija kliznih linija

SIEBEL
1925

LIPPMANN
1960

Osnove teorije plastičnosti

HILL, MARKOV
GREENBERG
1950

Glavna načela metode gornje granice

1965

Varijacijske metode
Conventional Product Development

Customer Specs -> Design & Tool Dev. -> Prototype Testing -> Pilot Stage -> Mass Production

Expensive Fixes:
- visible defects
- press capacity exceeded
- underfilling (drop forging)
- high localized die loads

More Expensive Fixes:
- "invisible" defects
- unacceptable tolerances

Most Expensive Fixes:
- short die life
- unstable process conditions

Reduce "s, improve time to market!
Simulation-Aided Product Development

Customer Specs → Design & Tool Dev. → Prototype Testing → Pilot Stage → Mass Production

Shorter Development Time:
- less trial and error
- less blocking of production line
- optimized for available press
- less visible defects

Less Fine Tuning:
- improved quality
- less invisible defects

shorter time to market

Be First to Market with Better and Cheaper Products!

MSC Software
Simulating Reality
Additional Benefits of Simulation

- Customer Specs
  - Design & Tool Dev.
  - Prototype Testing
  - Pilot Stage
  - Mass Production

Optimization during product life time:
- extend die life
- minimize material scrap
- optimize process conditions
- optimize press capacity utilization

Other benefits:
- reduce number of mfg stages
- more insight into mfg process
- less machining operations
- expand state of the art
- more successful bids

Reduce Costs during Mass Production!
Figure 4. Methodology to predict & prevent the formation of cracks in metal forming operations

Figure 5. Simulation of (a) first, (b) second, and (c) third pass forward extrusion. The actual product (d) is also shown.

Figure 6. Specimens for non-uniform compression test: (a) SAE 1137 hot rolled, (b) SAE 1524 spheroidized annealed
DESIGN PART FOR ASSEMBLY

TRANSFER GEOMETRY (IGES)

DESIGN FOR NET SHAPE MANUFACTURING (BASED ON DESIGN RULES)

DESIGN PRELIMINARY DIE/MOLD (BASED ON EXPERIENCE/RULES)

VERIFY DESIGN/SIMULATE MATERIAL FLOW AND TEMPERATURES

IS DESIGN ACCEPTABLE?

NO

MODIFY DESIGN INTERACTIVELY
UPDATE RULES FOR EXPERT SYSTEM

YES

ANALYZE FINAL DESIGN FOR STRESSES, SHRINKAGE, AND PROCESS CONDITIONS

MACHINE DIES (CNC) AND PREPARE DRAWINGS

EXPERT SYSTEM

EXPERT SYSTEM

FEM PROGRAMS FOR EACH PROCESS

DATA BASE WITH DIE/MATERIAL PROPERTIES