MetalForming Magazine

presents the 2016

THE DIE DESIGN & SIMULATION SOFTWARE EXPERIENCE

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Engineering Solutions for Design Related Problems

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Engineering Solutions for Design Related Problems

The stamping process is - and it must be managed as - a system of highly interactive input variables – as many as thirty, forty, or more - all of which affect the output of the system

The die is only one input of the system - it alone does not determine the output of the system

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System Inputs and Outputs

INGREDIENTS:

1 1/4 cups all-purpose flour
1 1/2 teaspoons vanilla
1 cup granulated sugar
1/3 cup vegetable oil
1 1/2 teaspoons baking powder
3/4 cup milk
1/2 teaspoon salt
1/4 cup chopped pecans or walnuts, optional
1 egg
1/4 cup semisweet chocolate chips

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Traditional die design and die-build standards have two significant flaws (my opinion):

1. They are constructed utilizing materials, specifications and methods based primarily on the operational **function** of the tool with little regard to performance

2. They produce inconsistent, and often times undesirable results, primarily because the tools begin as **designs**

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FUNCTION-BASED DIE DESIGN STANDARDS ARE USED ALMOST EXCLUSIVELY IN THE METAL STAMPING INDUSTRY

FUNCTION-BASED DIE DESIGN STANDARDS ARE BASED ON DIE FUNCTION, WITHOUT REGARD FOR HOW THE DIE PERFORMS

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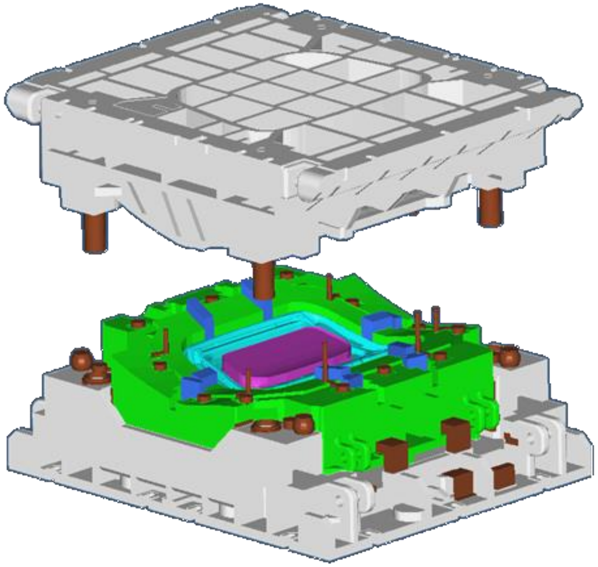
Function-Based Approach

- Draw Dies............
- Trim Dies.............
- Perforating Dies..........
- Blanking Dies.......
- Progressive Dies...
- Transfer Dies.......



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Function-Based Approach

Draw Die Example…

1. SHUT HEIGHT
2. PRESSURE PIN LAYOUT
3. TOOLING MATERIALS
4. HEAT TREATMENT SPECS
5. SAFETY REQUIRMENTS
6. IN-PRESS SERVICEABILITY REQUIREMENTS
7. NO HOES IN DRAW PAD (BINDER)
8. PUNCH TO DIE CLEARANCE – MAX MATERIAL THICKNESS (+5%)

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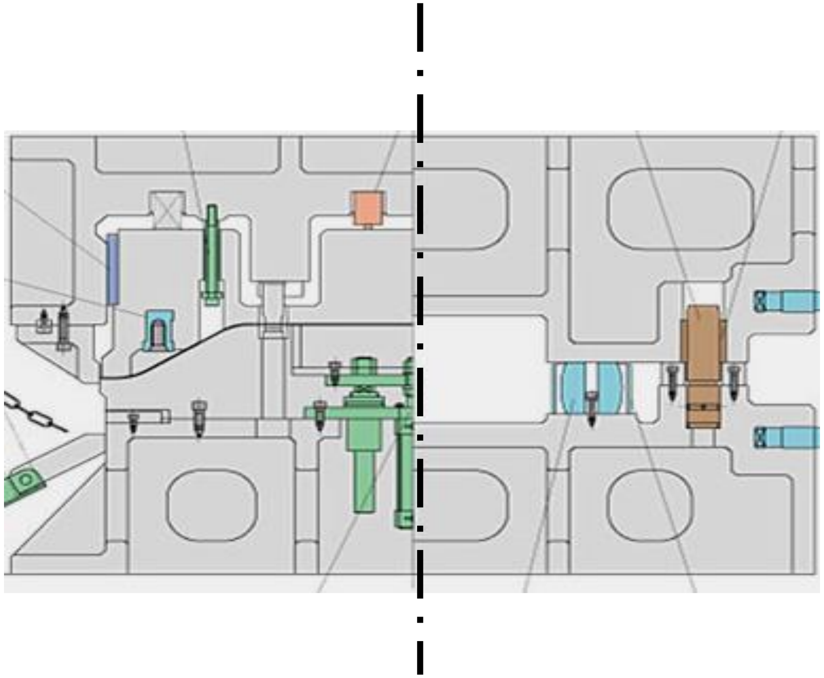
A Function-Based Approach to Die Design is Flawed



Example

Die “A” produces 150,000 parts between die maintenance

BUT

Die “B” produces 50,000 parts between die maintenance

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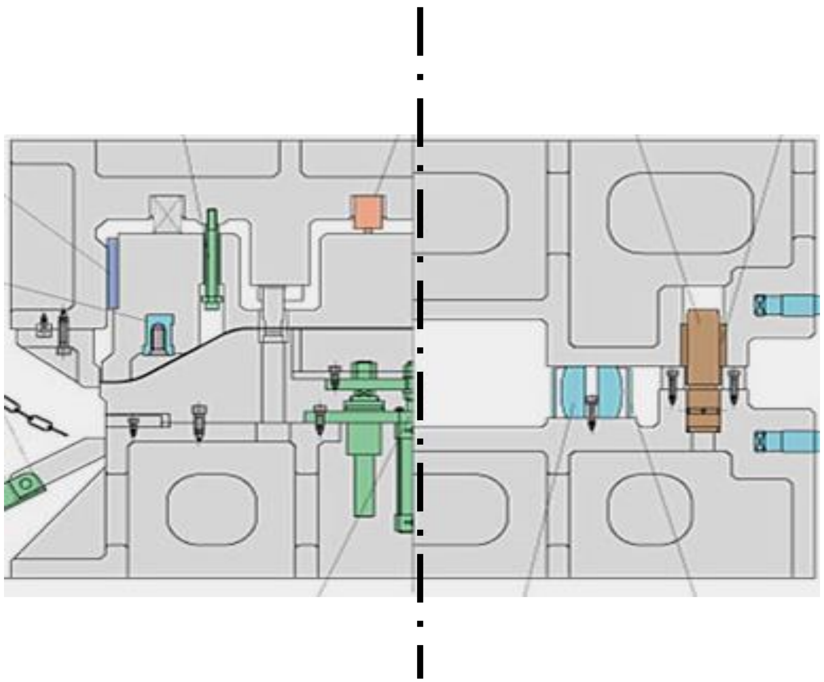
A Function-Based Approach to Die Design is Flawed



Both dies are built to the same design standards, so why don't they perform the same?

Ideally, we want Die "B" to be serviced at the same 150,000 part interval as Die "A", right?

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A Function-Based Approach to Die Design is Flawed

Die "A" produces 150,000 parts between maintenance

BUT

it creates maintenance issues for the press and tooling due to excessive side loads or tipping moments!

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SO, WHAT IS IT THAT YOU **REALLY** WANT?

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WHERE IS THIS STATED IN YOUR DIE DESIGN STANDARDS?

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HOLD ON!

AT MY COMPANY WE CONSIDER OPTIMUM PERFORMANCE…

EVERY TIME WE ENCOUNTER PROBLEMS WE UPDATE OUR STANDARDS - TOOLING BUILT TO OUR DESIGN STANDARDS **IS** WHAT WE WANT

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Engineering Solutions for Design Related Problems

The Problem with Die Designs

DIE DESIGNS

- are nothing more than opinions
- are conceived or fashioned in one’s mind
- are, more often than not, unique creations
- are based on personal experiences, **including fears**
- are the result of acquiring and applying EXPERIENCE

People who create, invent, or design have deep personal attachments to their work……………

Design related problems are dealt with **emotionally**

Engineering Solutions for Design Related Problems

TODAY, THERE IS A GROWING NEED TO REPLACE CURRENT DIE DESIGN PRACTICES WITH PROVEN ENGINEERING METHODS

PERFORMANCE-BASED DIE ENGINEERING STRATEGIES ASSURE ROBUST TOOLING PROCESSES, ECONOMICAL DIE CONSTRUCTION , RELIABLE STAMPING PROCESSES AND PROPER CONTROL OF THE METAL FORMING PROCESS.

Engineering Solutions for Design Related Problems

DIE ENGINEERING

- is based on science and mathematics
- the fundamental principles of science and mathematics are applicable across a broad spectrum of problems – not just the one we have experience with
- is the result of acquiring and applying KNOWLEDGE

People who engineer things are governed by engineering principles and analytical results

Engineering problems are dealt with **data**

Die deflection calculations are acceptable

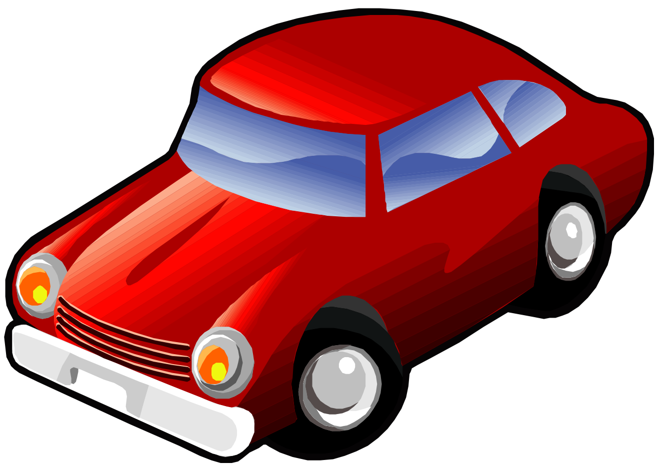
Reduced strain gradients will improved springback control

Tipping moments fall within the acceptable range with this modification

The lower cost tool steel provides plenty of compressive strength and wear resistance

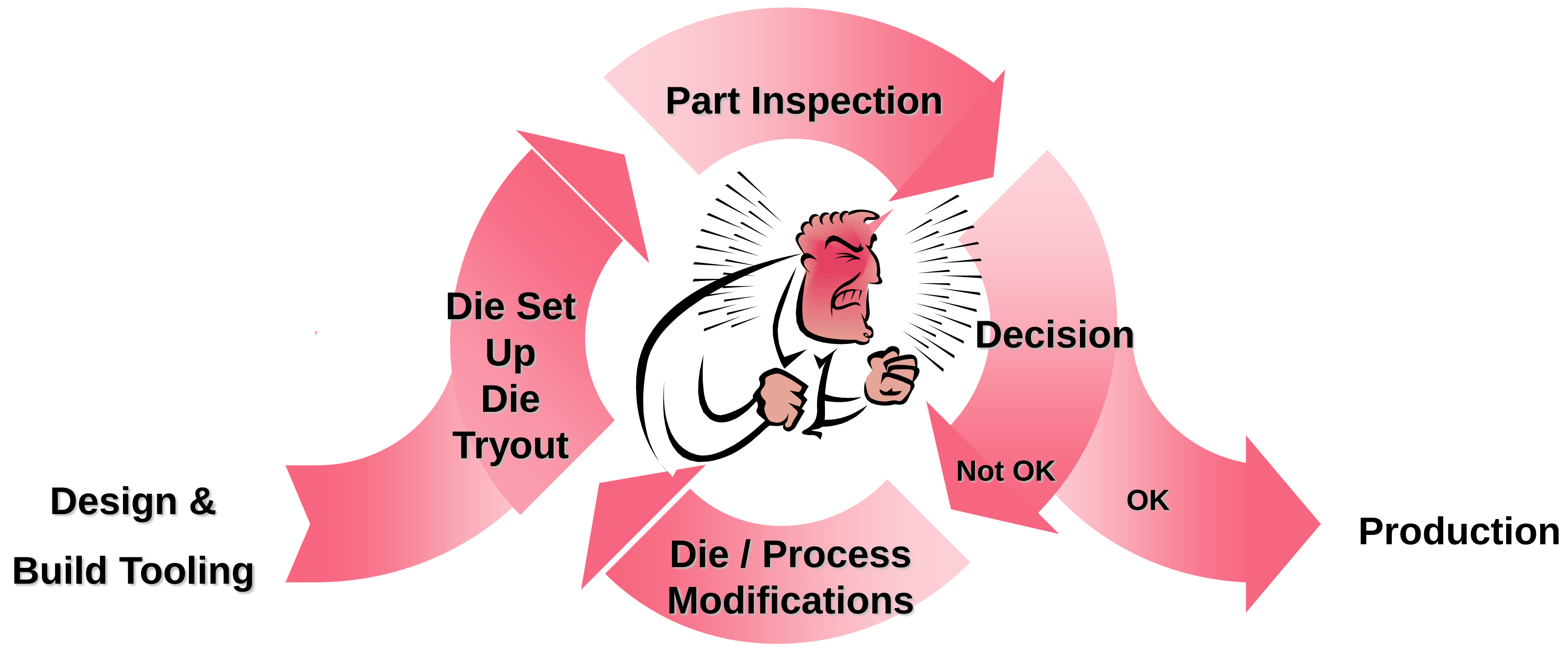
It's hard to argue with the data

Engineering Principles Apply Across a Broad Spectrum of Industries and Problems

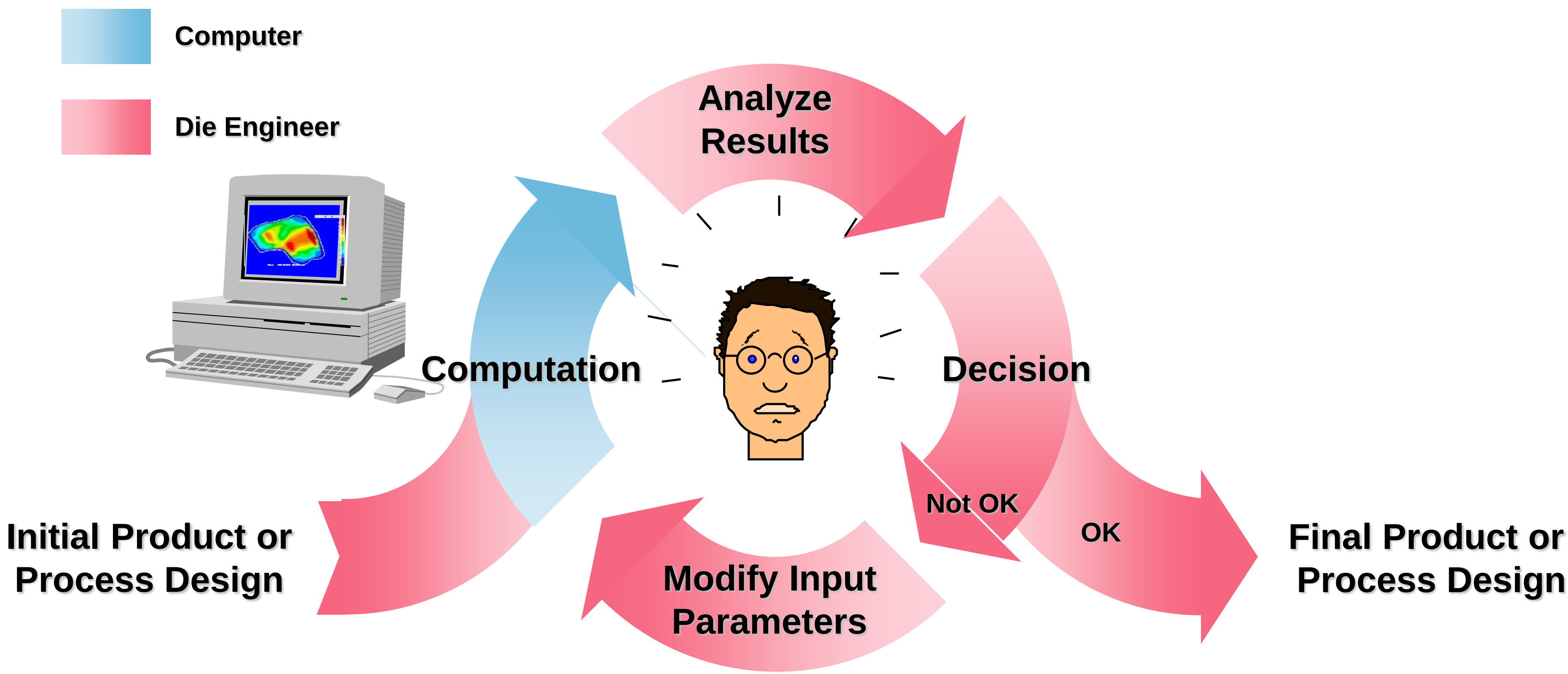


A "Master" coil does not have an advanced degree!

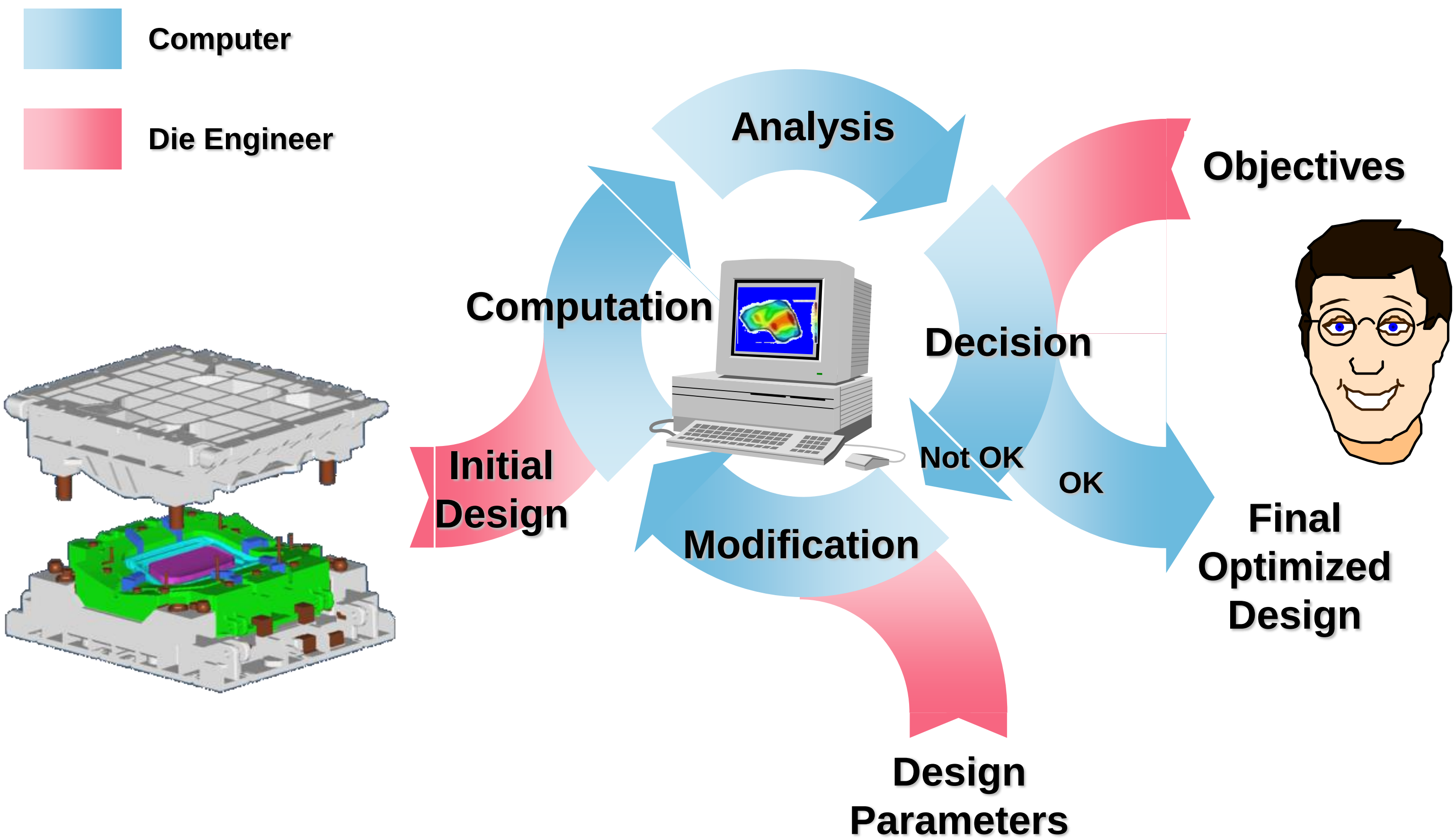
Traditional Die Design and Build Methods



Transitional Die Design and Build Methods



Performance-Based Die Engineering Methods



PRODUCT ENGINEERING
Performance-Based Criteria

SIZE BASED ON ALLOCATED SPACE

MATERIALS SELECTED BASED ON LOADING CONDITIONS & DURABILITY

LUBRICATION TYPE AND AMOUNT BASED ON LOADS, TEMPERATURES AND DURABILITY REQUIREMENTS

SURFACE FINISH, HEAT TREATMENT AND COATINGS BASED ON RELIABILITY and DURABILITY REQUIREMENTS

PIN DIAMETER BASED ON LOADING CONDITIONS

DIE ENGINEERING
Performance-Based Criteria

SIZE BASED ON ALLOCATED SPACE

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LUBRICATION TYPE AND AMOUNT BASED ON LOADS, TEMPERATURES AND DURABILITY REQUIREMENTS

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PIN DIAMETER BASED ON LOADING CONDITIONS

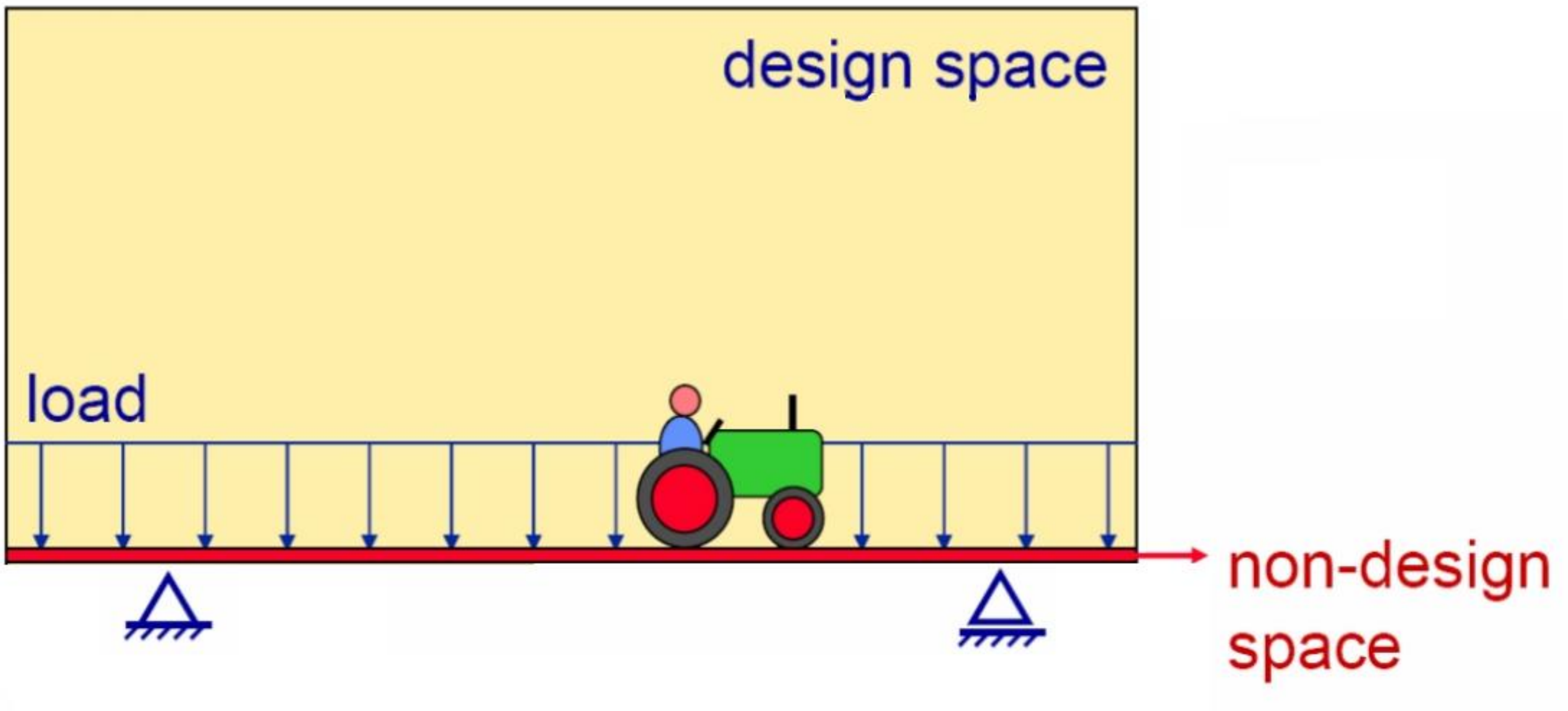
DIE ENGINEERING
Performance-Based Criteria

<u>AN ENGINEERING EXAMPLE</u>:

A **die structure** is engineered based on loading conditions, load path, force distributions, tooling deflections, machine deflections, vibrations and damping

The die is engineered based on the need of the process not the feelings or experiences of the designer or an arbitrary set of design standards

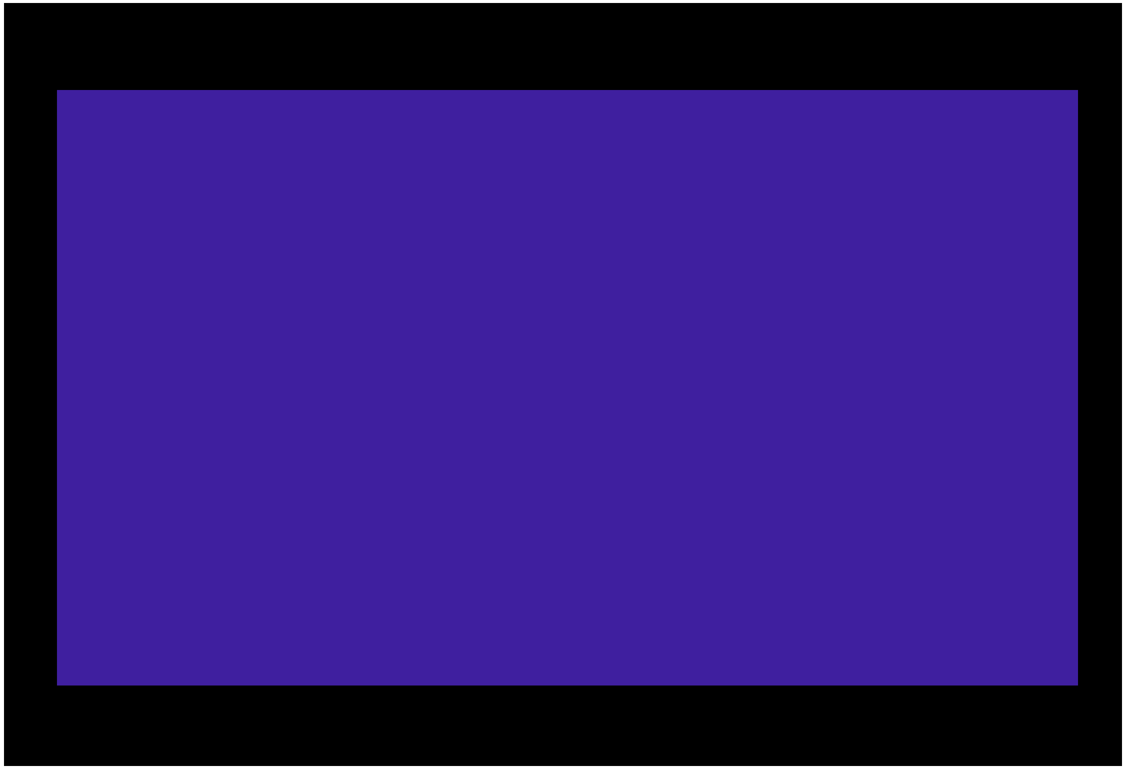
Die Structure Analysis
Likened to Designing a Bridge



The engineer defines the requirements…

Courtesy of Altair Engineering

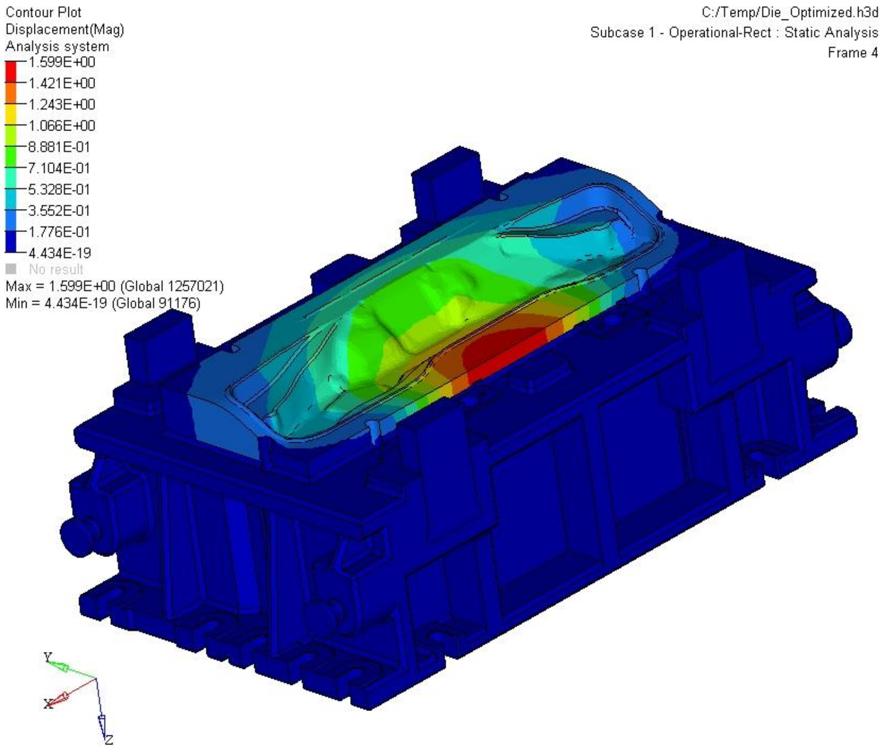
Die Structure Analysis
Likened to Designing a Bridge

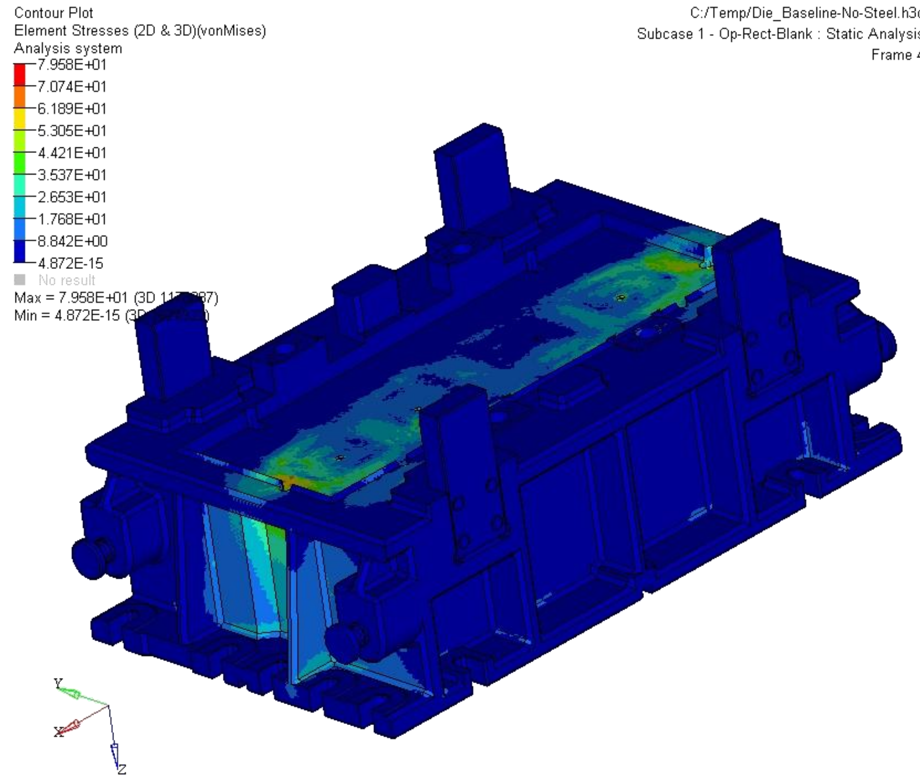


… CAE Tools Create Optimal Design Concepts

Courtesy of Altair Engineering

Die Structure Analysis
Likened to Designing a Bridge

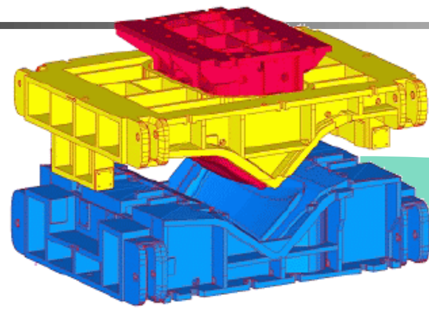




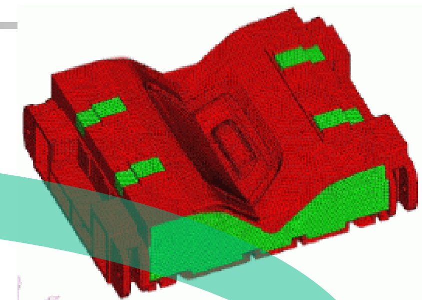
- Die deflection due to the operational loads
- Structural stresses (fatigue/durability analysis)

Courtesy of Altair Enginering

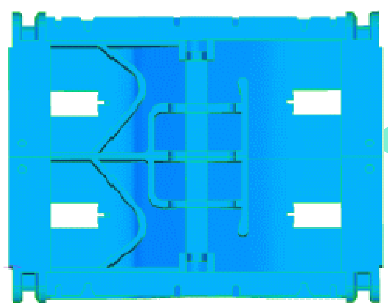
Die Structure Analysis Likened to Designing a Bridge



Original Die Design with traditional patterns

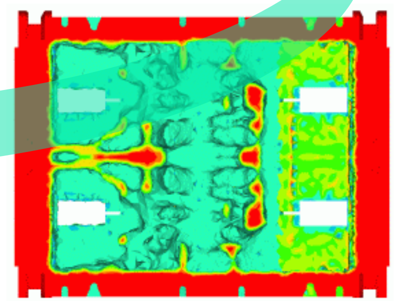


Design Space and Load definition



Optimized structural ribs

Geometry Extraction



Topology Optimization

Results layout

Courtesy of Altair Enginering

DIE ENGINEERING
Performance-Based Criteria

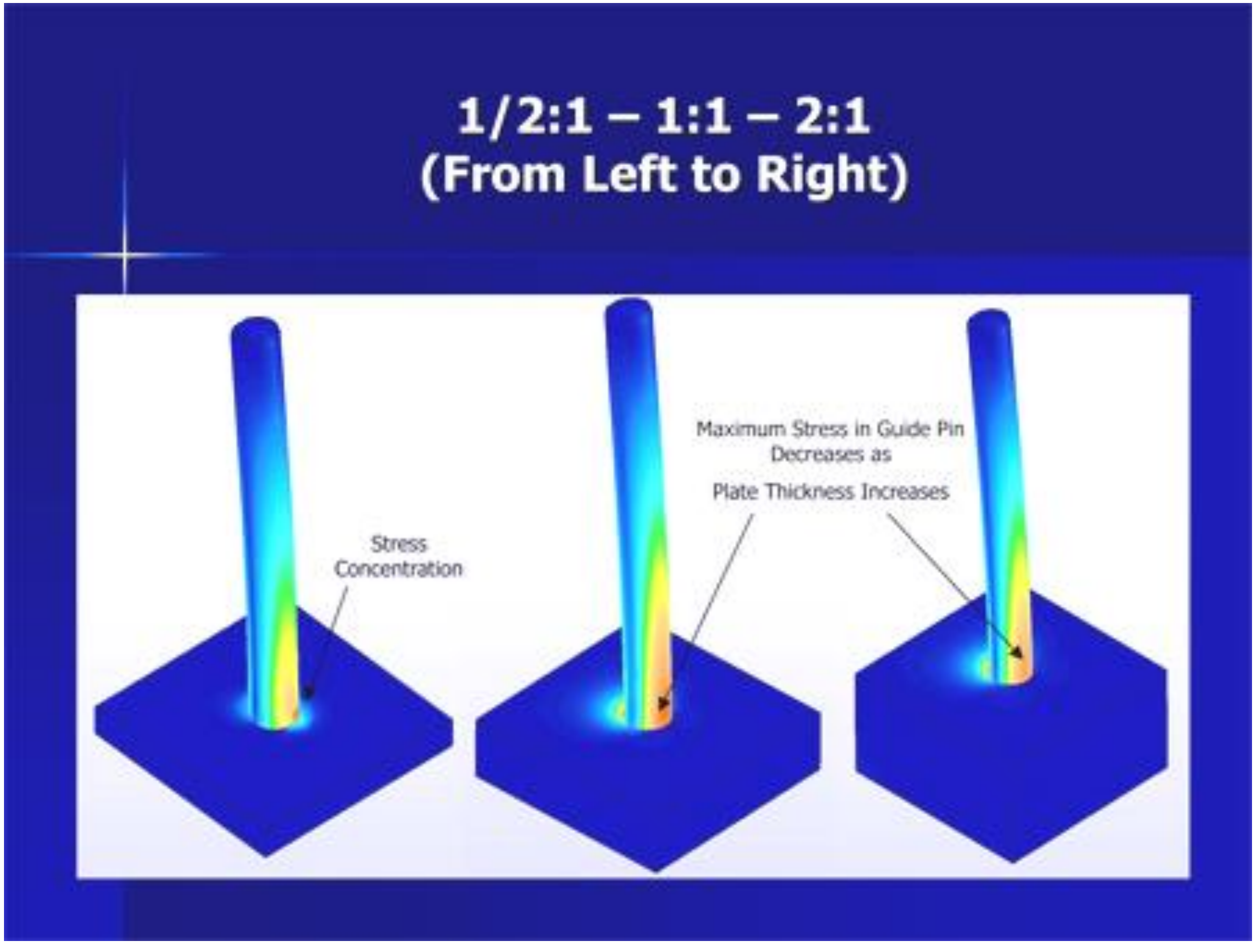


Image: Courtesy of Superior Die Set

DIE ENGINEERING
Performance-Based Criteria

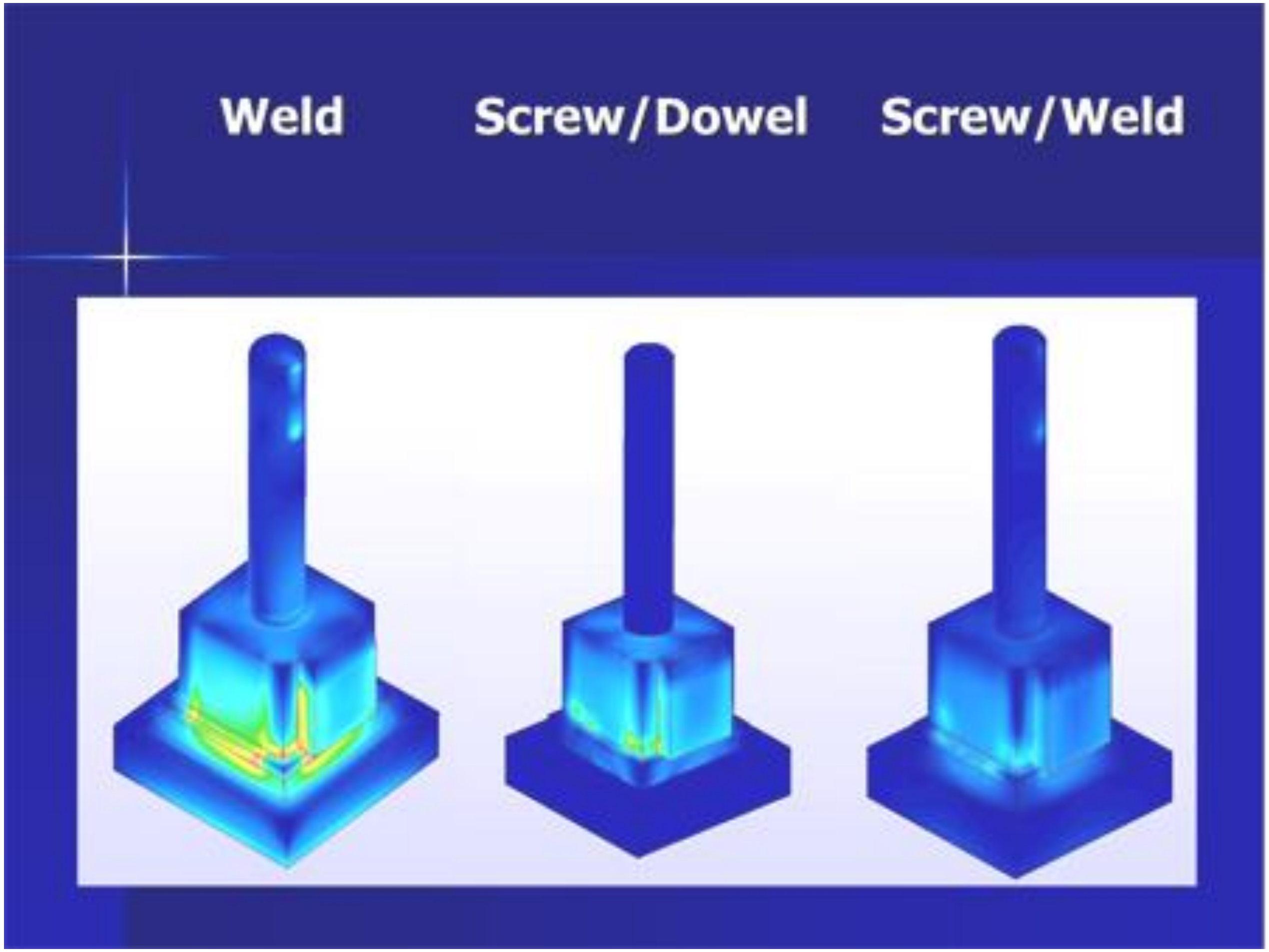


Image: Courtesy of Superior Die Set

A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design,** Sept 2012 to Nov. 2012

In order to choose the best strip layout from the several possible strips, each layout must be compared and ranked on a relevant scoring system. Among many factors that influence the cost and quality of a progressive die, four factors are of prime concern:

- Station number factor, *Fn*
- Moment balancing factor, *Fb*
- Strip stability factor, *Fs*
- Feed height factor, *Fh*

A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012

Adapted from Lin and Sheu, *Knowledge-Based Sequence Planning of Shearing Operations in Progressive Dies*, International Journal of Production Research, 2010

An evaluation score (*Ev)* can then computed based on these four factors and their corresponding weighting factors:

$$Ev = (wn \times Fn) + (wb \times Fb) + (ws \times Fs) + (wh \times Fh)$$

All four evaluation factors are then formulated to range from a total of 10 to 100. A higher score indicates better efficiency in cost and production.

NOTE: The four weighting factors, wn, wb, ws, wh, are chosen by the designer or process engineer who determines how much importance each factor contributes to the strip evaluation.

A Strip Evaluation Ranking Method

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Station number factor, *Fn,* determines how good a strip layout is in terms of the number of stations that it has. The factor has values ranging from 10 to 100.

An Fn value of 100 (best possible) is for a minimum number of stations, or two stations total. In contrast that value becomes 10 for the maximum number of stations, usually the total number of punches for cutting and bending in the proposed strip.

A Strip Evaluation Ranking Method

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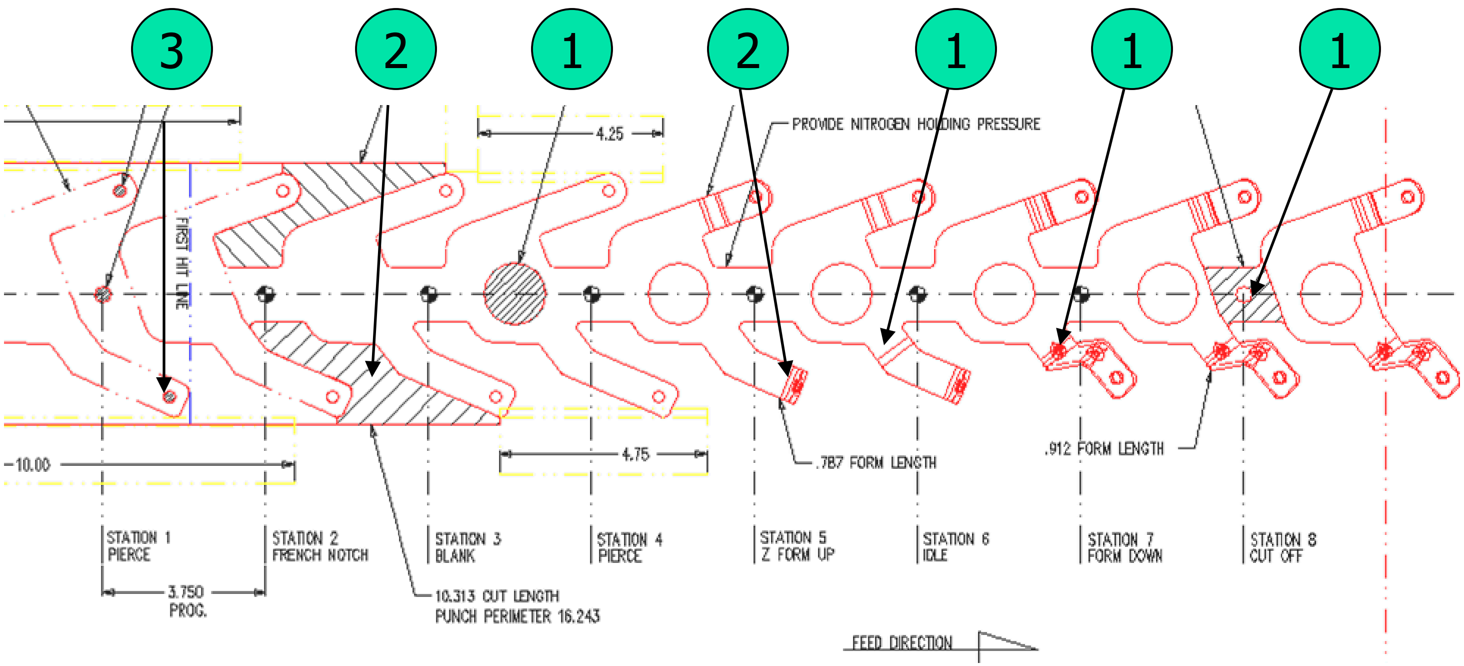

2 stations, Fn = 100

11 stations, Fn = 10

A Strip Evaluation Ranking Method

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The station number factor can be formulated by means of the following equation:

$$F_n = 100 - 90 \times \frac{N - N_{min}}{N_{max} - N_{min}} \qquad \frac{7 - 2 = 5}{11 - 2 = 9}$$

$$F_n = 100 - (90 \times 5/9) = 50$$

N = total number of stations in the strip layout
Nmax = total number of punches (cutting and bending)
Nmin = the possible minimum number of stations, *Nmin* = 2

A Strip Evaluation Ranking Method

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When two or more die stations are performing their task on the die strip, the forces are simultaneously acting on the strip at different points.

If the reaction forces are unbalanced relative to the press center line, ram tipping occurs. Since the center of the die is usually placed under the center of the ram, tipping moment severity must be considered in strip layouts.

Thus, a moment balancing factor, *Fb,* is required

A Strip Evaluation Ranking Method

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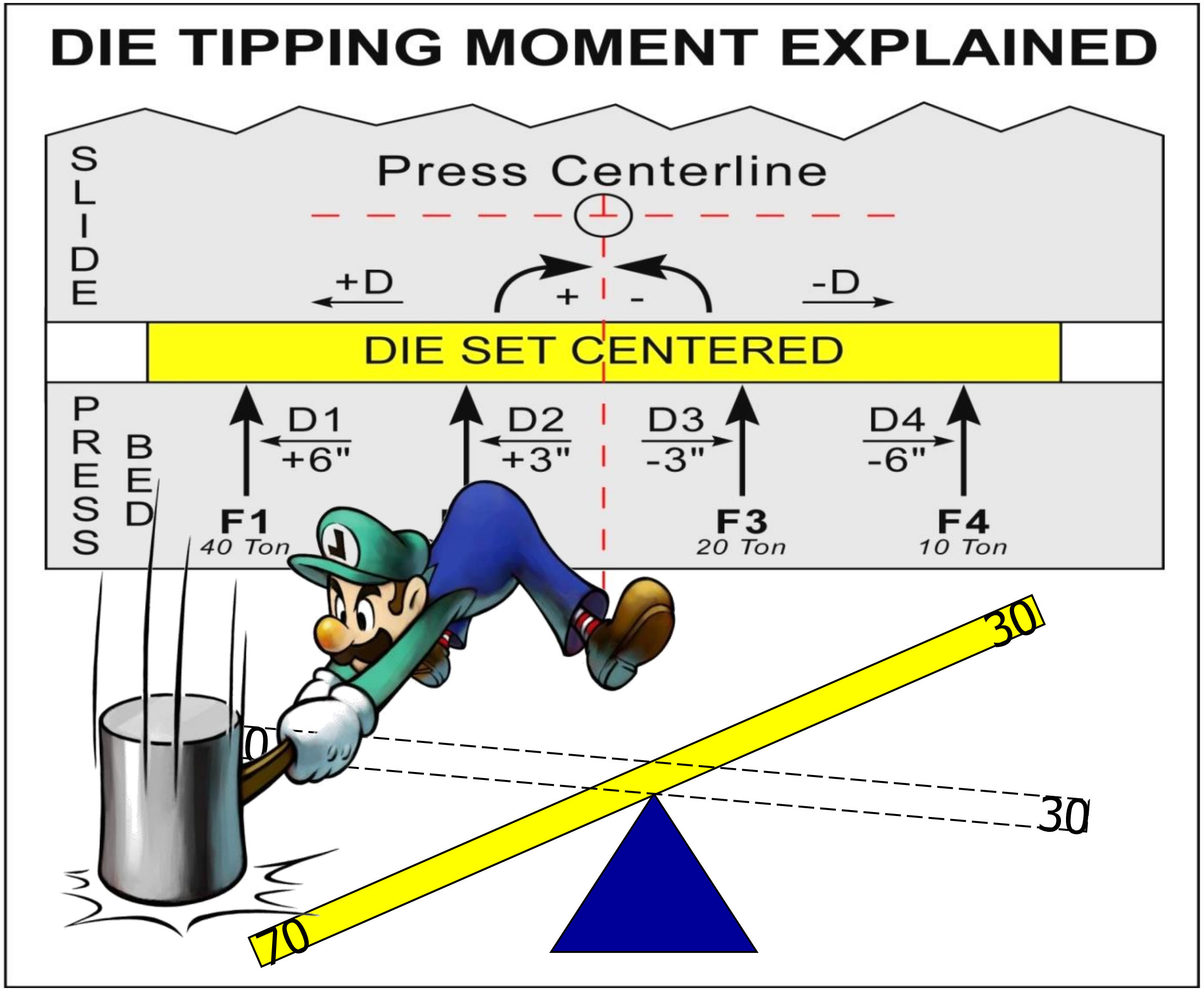


A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012

Stamping presses have maximum tipping moments established by the press machine builder. This rating can used to establish a maximum off-center loading parameter: D_{max}

The moment balancing factor can then be calculated by:

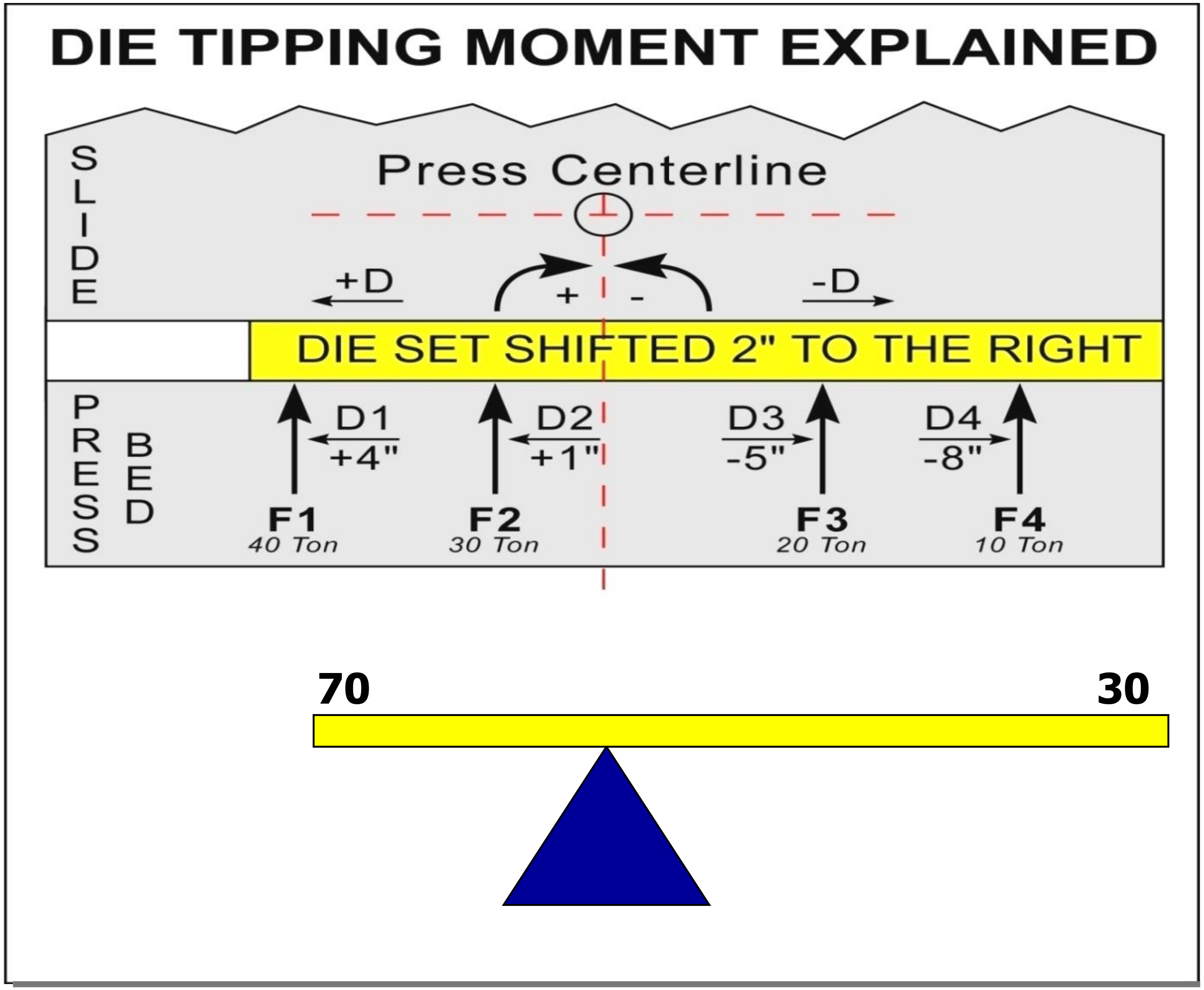
$$F_b = 100 - 90 \times \frac{d}{D_{max}} \qquad \frac{210}{400}$$

$$F_b = 100 – (90 \times 210/400) = 52.75$$

When d = 0, the center of the ram and the center of the stamping loads are completely matched, so the factor Fb = 100 (best condition). When d $\geq$ Dmax, the deviation is so serious that it makes Fb = 10 (worst condition).

A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012



A Strip Evaluation Ranking Method

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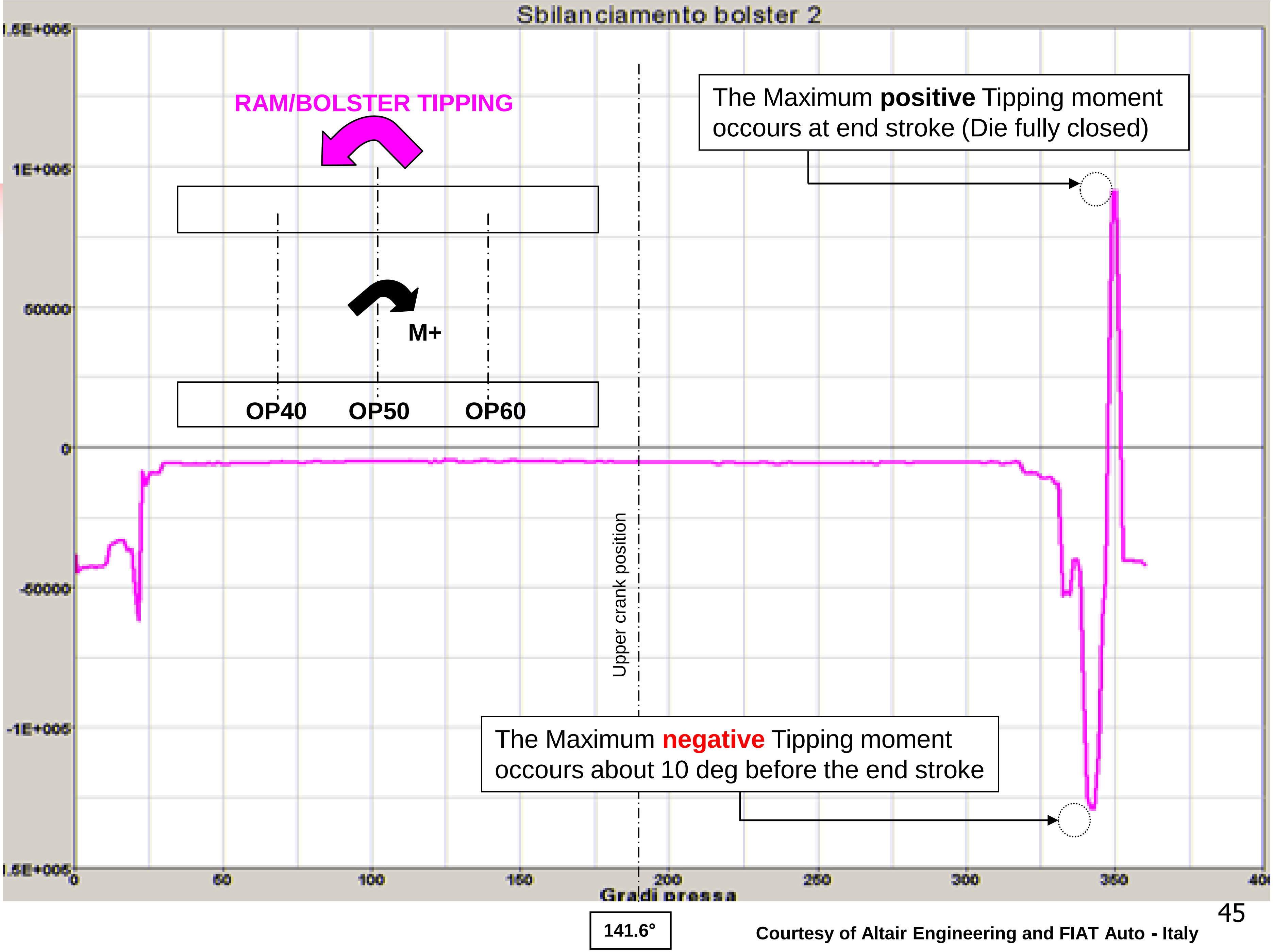
The moment balancing factor can then be calculated by:

$$F_b = 100 - 90 \times \frac{d}{D_{max}} \qquad \frac{10}{400}$$

$$F_b = 100 - (90 \text{ x } 10/400) = 97.75$$

When d = 0, the center of the ram and the center of the stamping loads are completely matched, so the factor Fb = 100 (best condition). When d $\geq$ Dmax, the deviation is so serious that it makes Fb = 10 (worst condition).

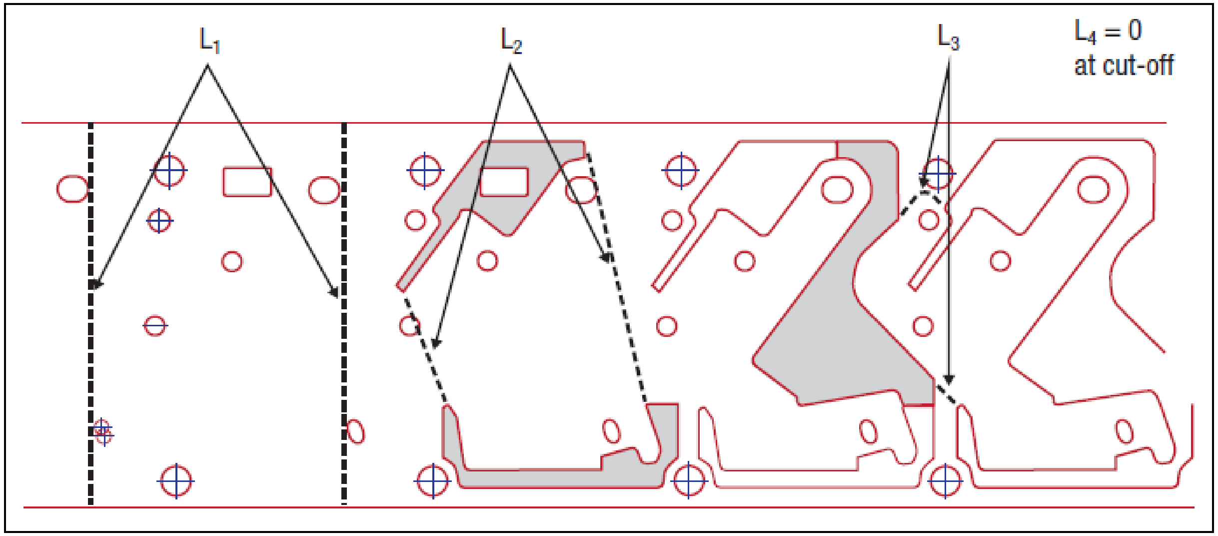


Courtesy of Altair Engineering and FIAT Auto - Italy

A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012

The strip stability factor (*Fs*) determines how reliably the strip feeds in terms of the connecting material that is left to carry the parts as the strip progresses through the die.

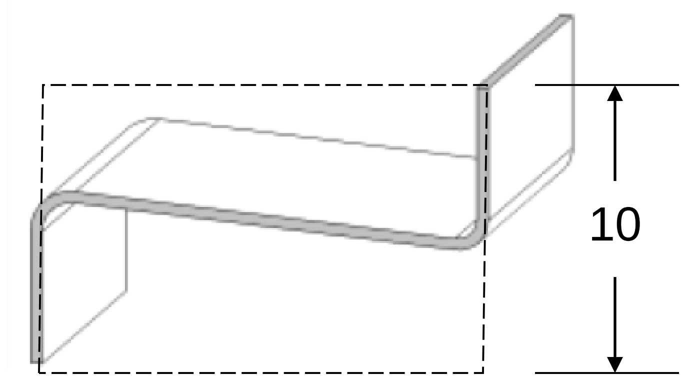


From MetalForming Magazine, *Tooling by Design*, October 2012, , P. Ulintz

A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012

The feed height factor (*Fh*) determines how reliably the strip feeds in terms of the distance that it must lift off the working stations before progressing through the die.



The maximum possible feed height is equal to the height of an imaginary rectangle that encloses the formed part, as shown above, plus the safety factor, S

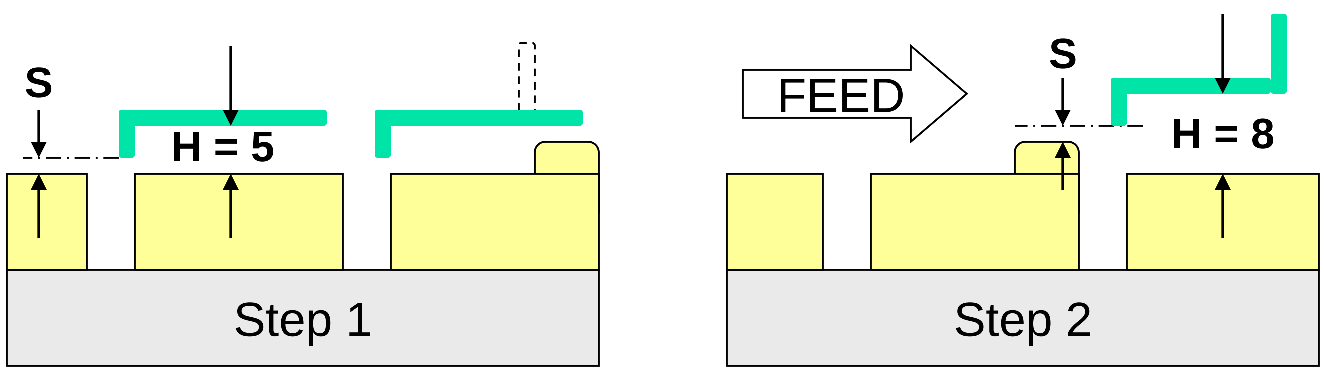
A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012

For the process illustrated below, the feed height factor is calculated by:

$$Fh = 100 - 90 \times (8-2) / (10-2) = 32.5$$

The resulting feed height factor is relatively low (100 is best)

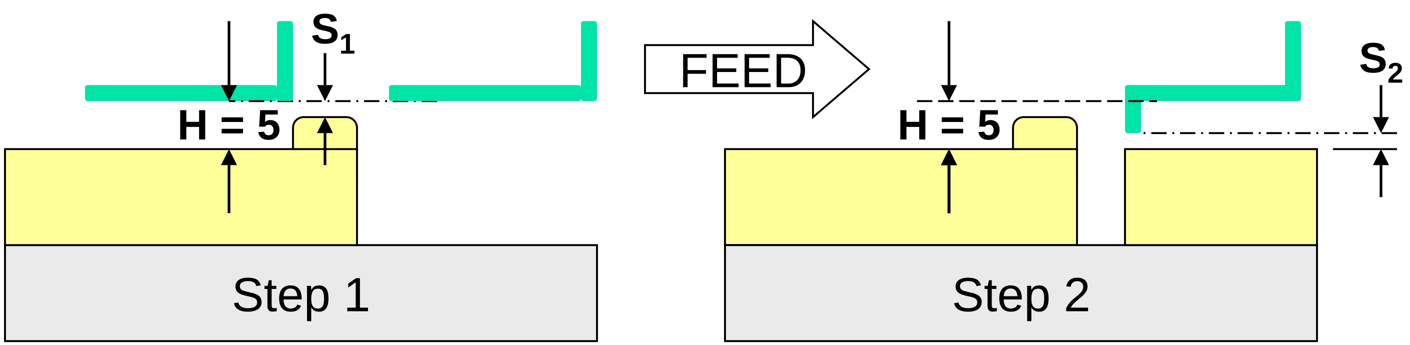


A Strip Evaluation Ranking Method

From *MetalForming Magazine*, **Tooling By Design**, Sept 2012 to Nov. 2012

The feed height factor could be improved by altering the two bending sequence. For this revised process:

$$Fh = 100 - 90 \times (5-2) / (10-2) = 66.25$$



A Strip Evaluation Ranking Method

From *MetalForming Magazine,* **Tooling By Design**, Sept 2012 to Nov. 2012

Weighting factors help prioritize each of the four evaluation factors relative to each another:

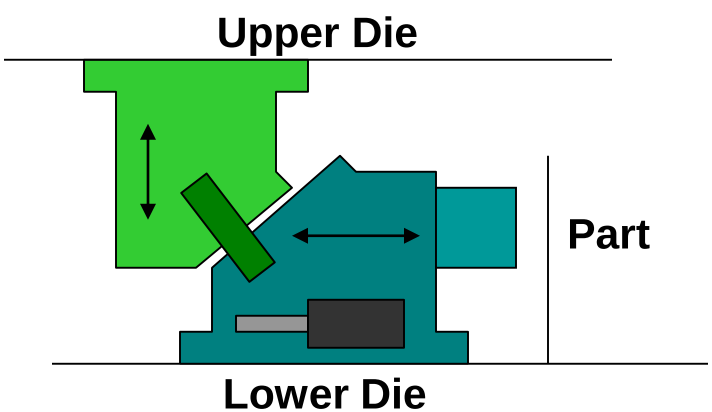
$$Ev = (wn \times 50) + (wb \times 98) + (ws \times 53) + (wh \times 67)$$

All four evaluation factors are then formulated to range from a total of 10 to 100. A higher score indicates better efficiency in cost and production.

NOTE: The four weighting factors, wn, wb, ws, wh, are chosen by the designer or process engineer who determines how much importance each factor contributes to the strip evaluation.

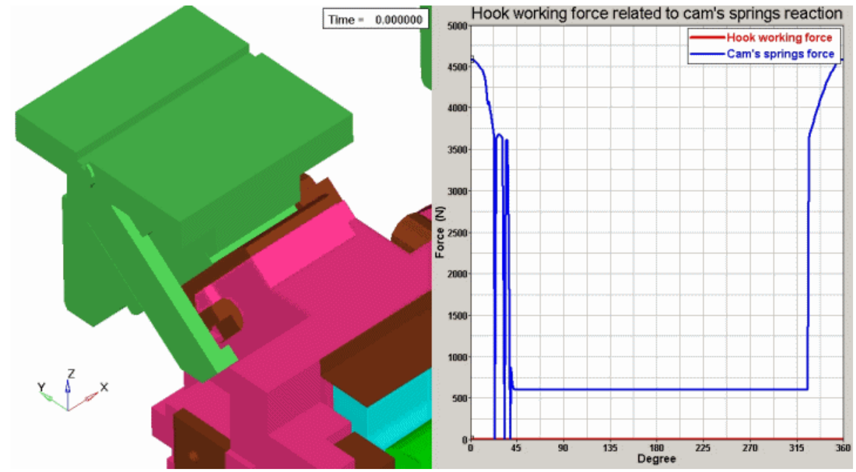
Virtual validation of a lower cam

- The **secure hook** attached to upper wedge is not suppose to work.
- The **lower cam** assembly works properly @ 10 SPM (even though it's slightly bouncing)
- The **lower cam** collides w/ the **hook** @ 16 SPM:
- A design review of the cam system is necessary to increase the SPM.

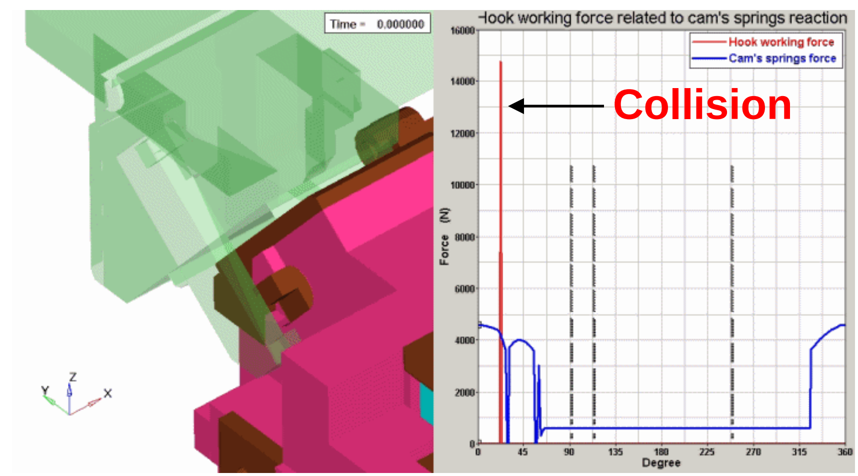


Typical lower cam representation (Section)

10 strokes/min



16 strokes/min



Courtesy of Altair Engineering Chrysler - USA

The Problem Implementing Die Engineering Strategies

The creation of the engineering building blocks necessary to design a metal forming system based on scientific principles is not a formal process, it is not recognized as worthy of academic credit, and is usually ceded to industry technical societies and companies with a product to sell