Forging design

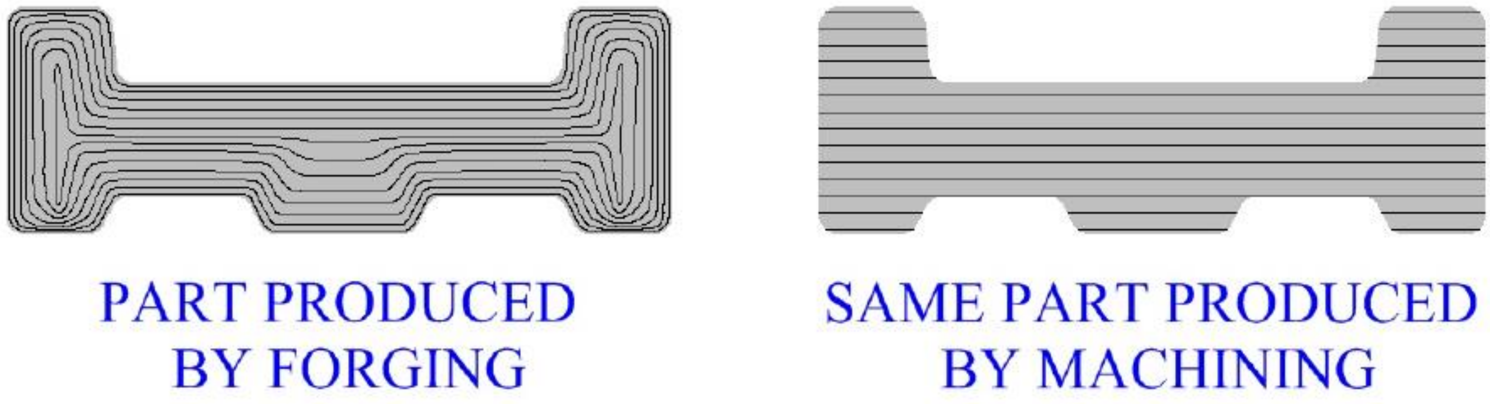
When designing a complex metal forging process, great consideration should be taken with each step and how it relates to the final product.

Also, design the chosen path for the redistribution of the work material from the start of the process to the end of the last step, concentrating on smooth metal flow.

Forging design, in general, should first accomplish a rough redistribution of the material, then the more detailed impression die forging operations, and finally finishing operations.

In addition to providing a smooth transition of material the forging processes, as a whole, should be designed to produce a controlled grain structure in the final product.

Grain Structure



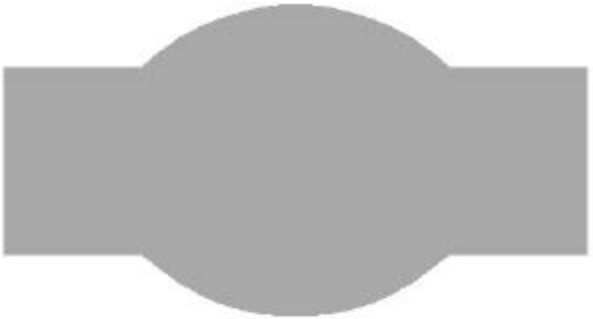
When choosing a path for material redistribution, a metal forging design should consider how this particular method of metal deformation will effect and change the grain structure of the part.

It is desirable that the final product contain a favourable grain orientation throughout the structure of its material. Such a grain structure should strengthen the part, particularly with respect to that part's application

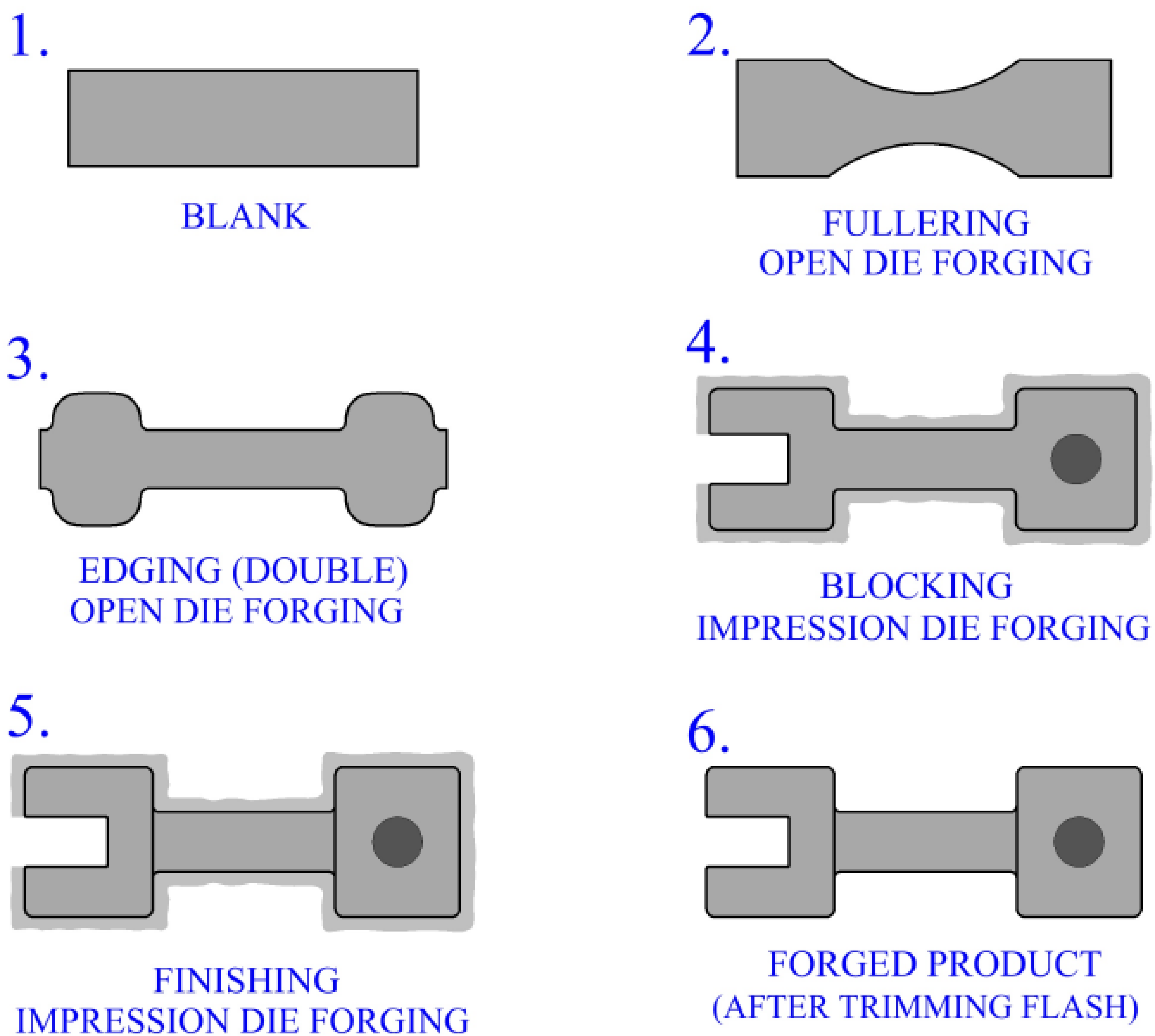
PREFORMING

A series of preforming operations are required to gradually bring the stock material closer to the finished shape before the last forming operation.

FULLERING



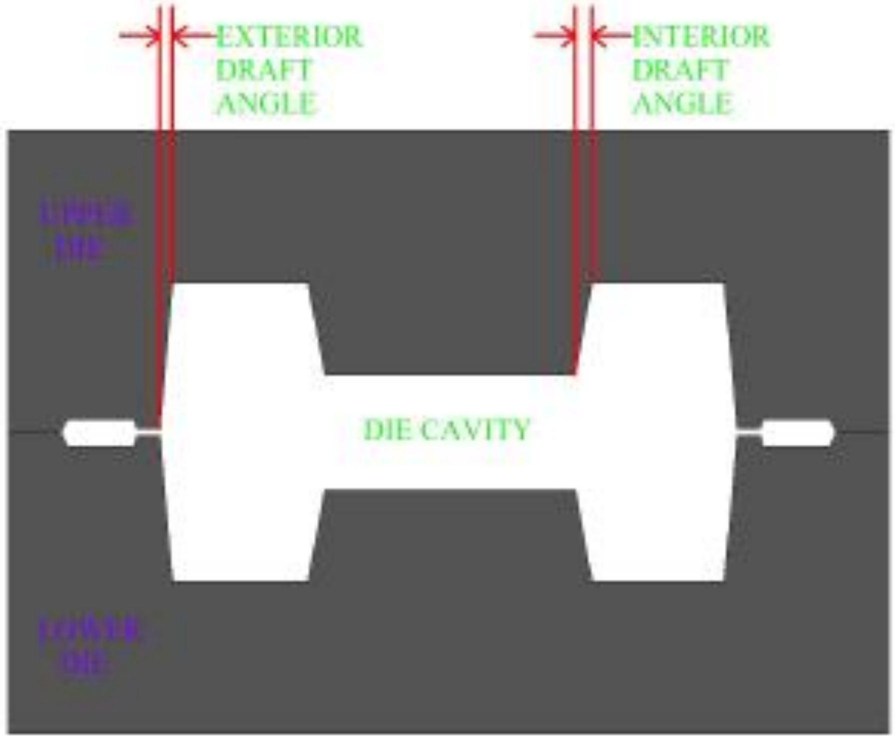
EDGING


1.
BLANK
2.
FULLERING
OPEN DIE FORGING
3.
EDGING (DOUBLE)
OPEN DIE FORGING
4.
BLOCKING
IMPRESSION DIE FORGING
5.
FINISHING
IMPRESSION DIE FORGING
6.
FORGED PRODUCT
(AFTER TRIMMING FLASH)

Forging allowances

- Machining allowance
- Oxidation allowance
- Draft – Angle allowance to facilitate release of the part from the die after forging.
- Inside draft allowances are greater than that for outside.
- All edges shall have radius added in the corners – ensures good material flow and die filling .

Draft In forgings



Draft Angle

Draft angle is the taper around the internal and external sides of a part.

Draft angle is necessary to include in the forging die design in order to allow the removal of the work from the die after the part has been forged.

The larger the draft angle, the better it will facilitate the metal forging's removal.

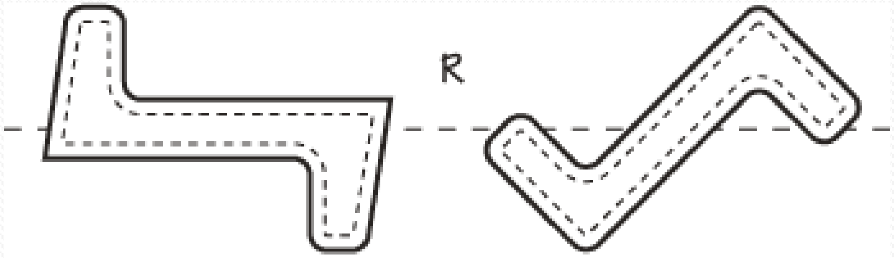
Some precision forging operations produce a forged part with no draft angle.

Common draft angles used in manufacturing industry are 3, 5, 7, and 10 degrees.

Draft

Draft angle of 1 ½º to 7º is normally added to all surfaces perpendicular to the forging plate, allowing for easy removal of the forged part from the die.

But sometimes the part can be tilted in the die to produce "natural draft" without angling its surfaces.



Tilting part in die gives natural draft.

Draft angles

Material	Draft Angle (°)
Aluminum	0 - 2
Copper Alloys (Brass)	0 - 3
Steel	5 - 7
Stainless Steel	5 - 8

Fillet Radii and Corner Radii

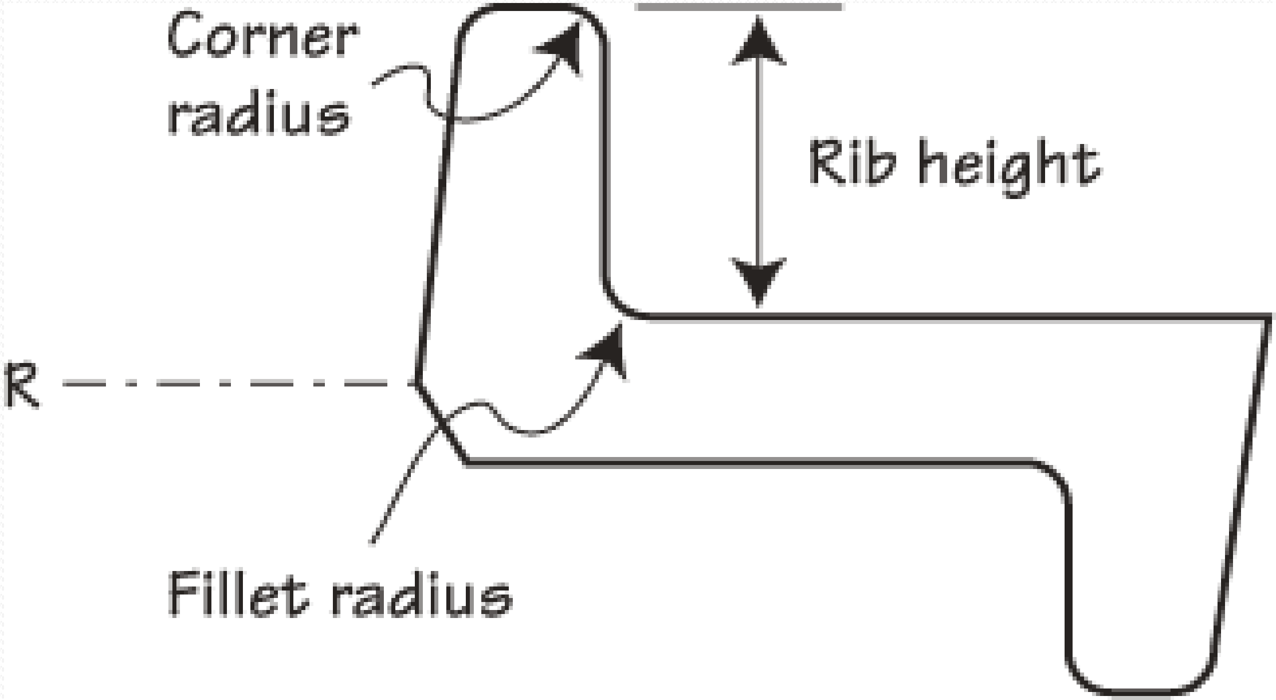
When necessary, forging can produce radii as small as any other metal forming process.

But smaller radii are more costly to machine in the die, and can cause checking of the die surface and reduced wear life.

Fillet radii should be as large as practical to ease metal flow and avoid laps and cold shuts.

Like fillet radii, corner radii should be as large as possible to ease metal flow during forging and reduce die wear.

But absolute minimums for corner radii are usually about half the minimums for fillet radii.


Corner radius
Rib height
R
Fillet radius

Height of Protrusion mm (in)	**Min. Corner Radius** mm (in)	**Min. Fillet Radius** mm (in)
12.5 (0.5)	1.5 (0.06)	5 (0.2)
25 (1.0)	3 (0.12)	6.25 (0.25)
50 (2.0)	5 (0.2)	10 (0.4)
100 (4.0)	6.25 (0.25)	10 (0.4)
400 (16)	22 (0.875)	50 (2.0)

Tolerances

- ***Dimension tolerances*** *are usually positive and are approximately 0.3 % of the dimension, rounded off to the next higher 0.5 mm (0.020 in).*
- ***Die wear tolerances*** *are lateral tolerances (parallel to the parting plane) and are roughly +0.2 % for Copper alloys to +0.5 % for Aluminum and Steel.*
- ***Die closure tolerances*** *are in the direction of opening and closing, and range from 1 mm (0.040 inch) for small forgings, die projection area < 150* cm^2 *(23* in^2*), to 6.25 mm (0.25 inch) for large forgings, die projection area > 6500* cm^2 *(100* in^2*).*
- ***Die match tolerances*** *are to allow for shift in the upper die with respect to the lower die. This is weight based.*

DIE MATCH TOLERANCE IN mm

Material	**Finished forging weight in kg**		
	<10	< 50	>500
Aluminium, copper alloy and steel	0.75	1.75	5
Stainless steel and Titanium	1.25	2.5	6.5

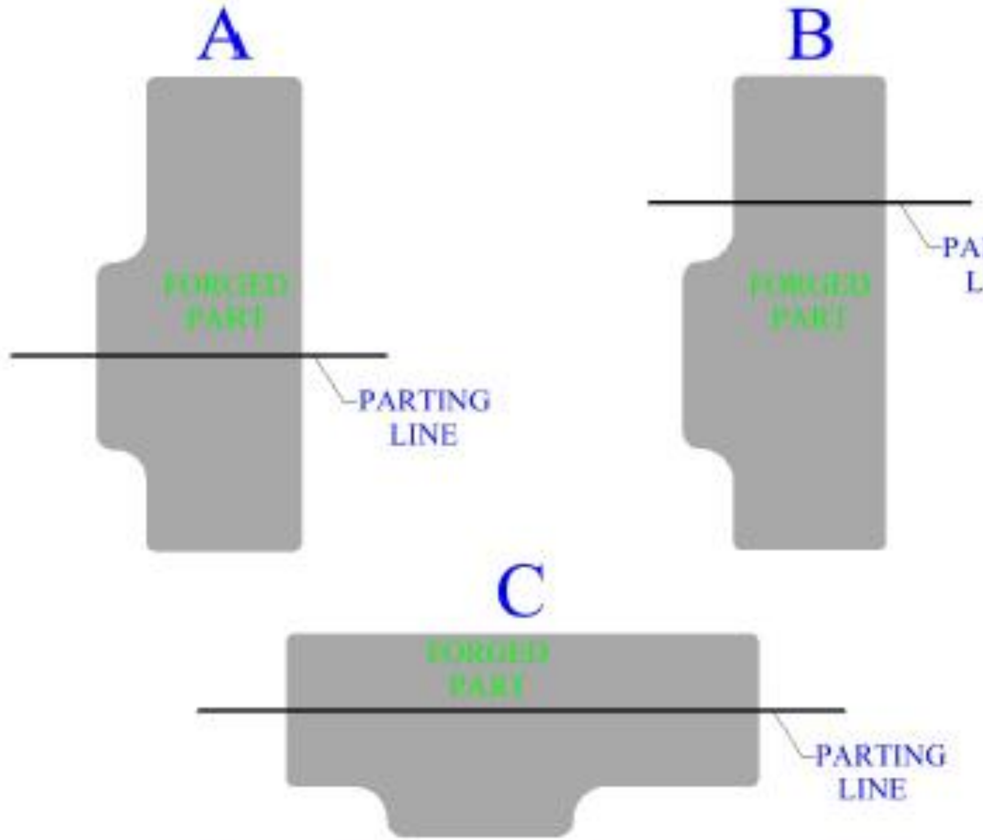
Flash Tolerance for finished forgings after trimming in mm

Material	Finished casting weight in KG		
	<10	<50	>500
Aluminium, copper alloy and steel	0.8	3.25	10
Stainless steel and Titanium	1.6	5	12.5

PARTING LINE

Location of the parting line is of primary importance in metal forging die design.
The parting line, which defines the forging plane of the operation, is a large determinant in how metal flows through the die during the forging's compression.
The parting line dictates where flash will be formed, and effects the grain structure of the manufactured part.
It is easier to fill sections closer to the parting line than further away.
In determining a parting line the maximum periphery of the metal forging should be considered.

PARTING LINE



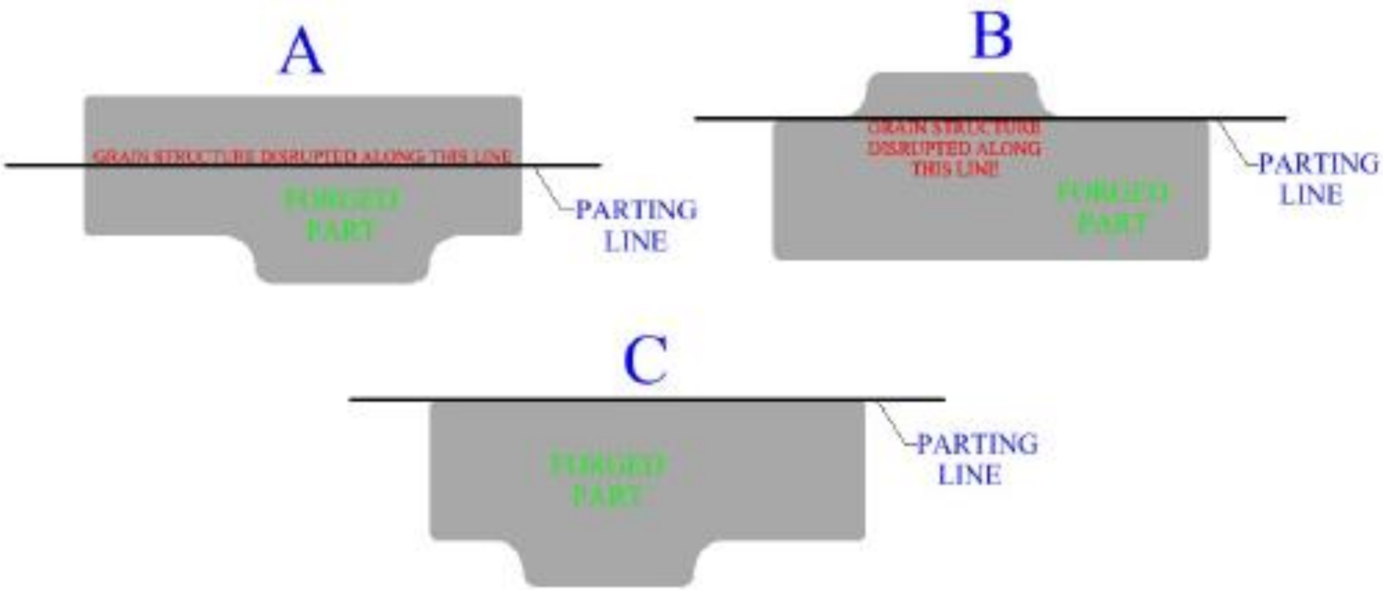
*UNLIKE [A] OR [B] PARTING LINE LOCATION [C] MAKES USE OF THE MAXIMUM PERIPHERY OF THE FORGING

The location of the parting line of C will better facilitate the flow of metal through the die cavity, since unlike A or B, location C makes use of the maximum periphery of the forging.

PARTING LINE

It is easier to fill material near the forging plane than in the further recesses of the die cavity. In addition to being a major factor in the flow of metal during the forging process, the location of the parting line is also critical in the formation of the grain structure of the forged work. **The parting line acts to disrupt the metal's grain Structure.**

PARTING LINE



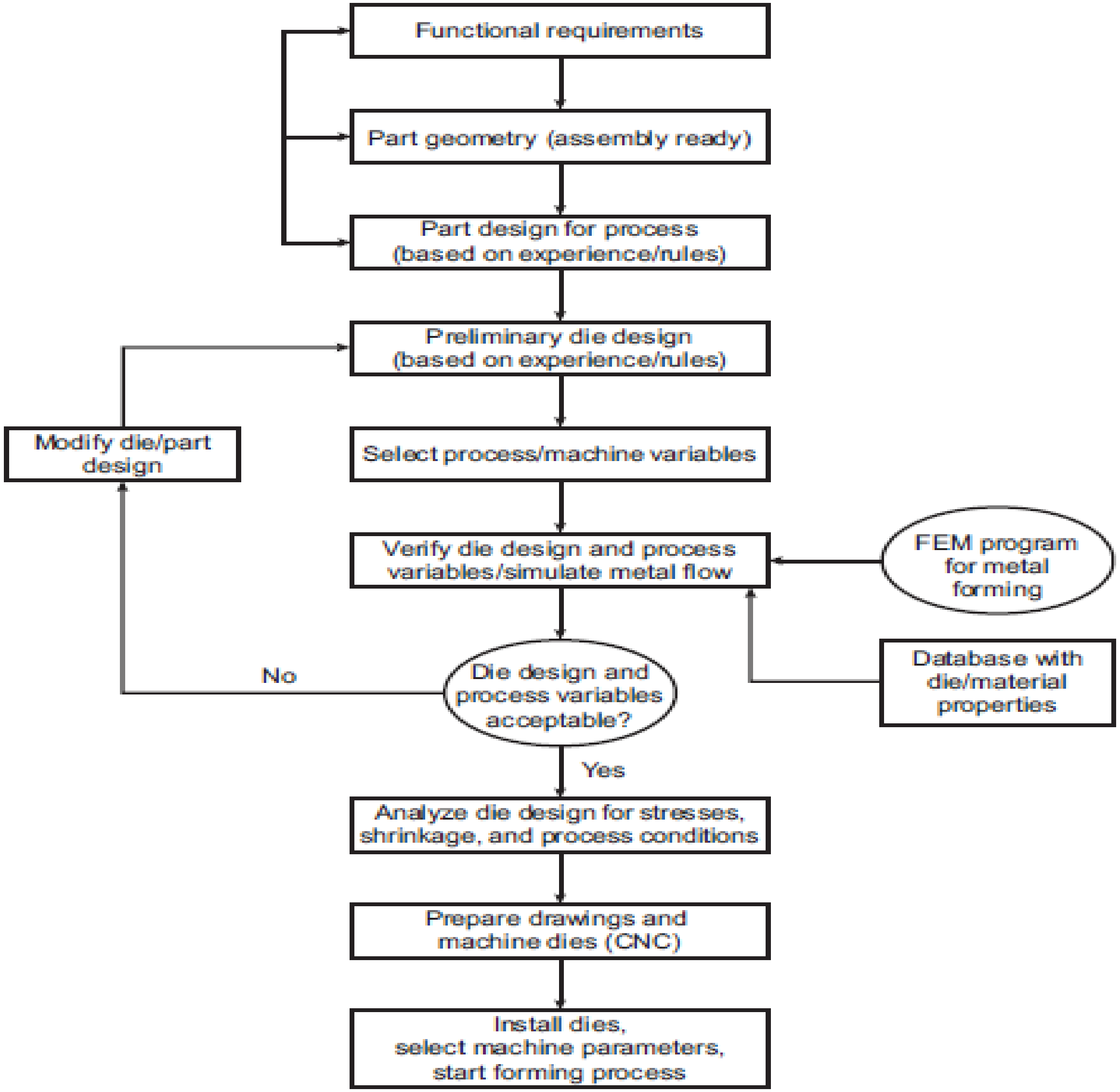
*UNLIKE [A] OR [B] PARTING LINE LOCATION [C] DOES NOT DISRUPT THE GRAIN STRUCTURE OF THE FORGING

The placement of the parting line in A and B acts to disrupt the grain structure of the metal at the plane through which it passes.

Locating the parting line at the top of the forging as in C eliminates the rupture of the forging‘s grain structure.

Also this particular location of the parting line will allow for the entire impression to be formed in one die, while the other die can be flat. Design of the die as in C is both more economical and provides superior grain structure of the metal forging.

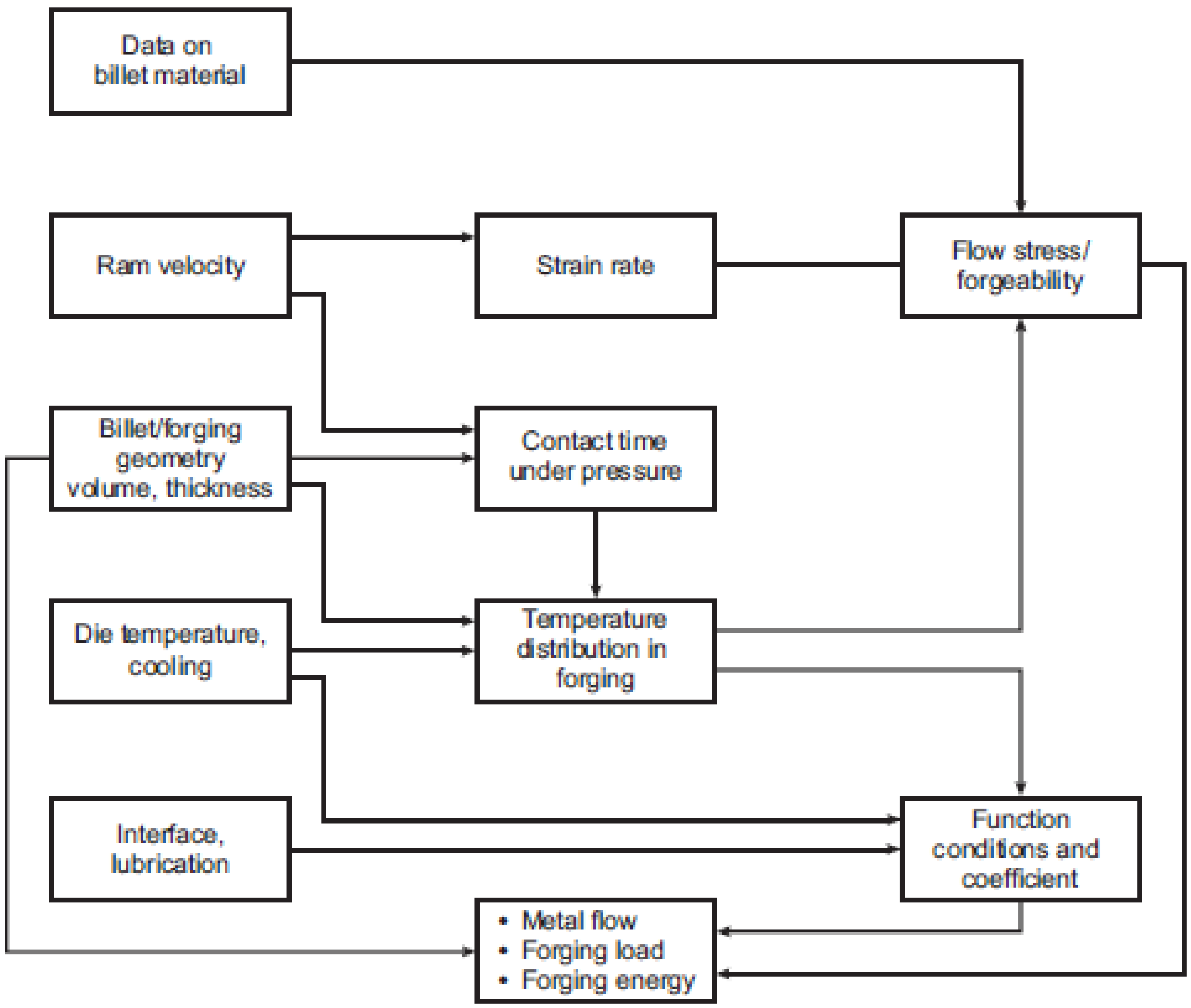
FORGING PROCESS DESIGN

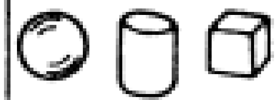
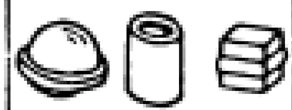


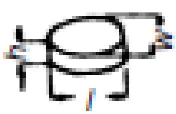
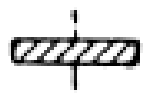
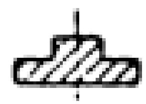
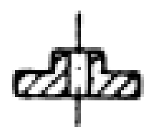
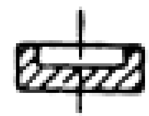
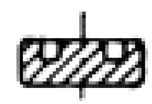
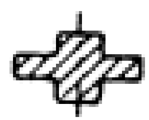
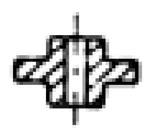
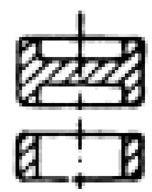
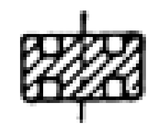
HOT FORGING TEMPERATURES OF VARIOUS MATERIALS

Metal or alloy	Approximate range of forging temperature, °C (°F)
Aluminum alloys (least difficult)	400–500 (750–930)
Magnesium alloys	250–350 (480–660)
Copper alloys	600–900 (1110–1650)
Carbon and low-alloy steels	850–1150 (1560–2100)
Martensitic stainless steels	1100–1250 (2010–2280)
Maraging steels	1100–1250 (2010–2280)
Austenitic stainless steels	1100–1250 (2010–2280)
Nickel alloys	1000–1150 (1830–2100)
Semiaustenitic PH stainless steels	1100–1250 (2010–2280)
Titanium alloys	700–950 (1290–1740)
Iron-base superalloys	1050–1180 (1920–2160)
Cobalt-base superalloys	1180–1250 (2160–2280)
Niobium alloys	950–1150 (1740–2100)
Tantalum alloys	1050–1350 (1920–2460)
Molybdenum alloys	1150–1350 (2100–2460)
Nickel-base superalloys	1050–1200 (1920–2190)
Tungsten alloys (most difficult)	1200–1300 (2190–2370)

VARIABLE S IN FORGING PROCESS



Shape class 1, compact shape  Spherical and cubical	Sub-group	101 No subsidiary elements 	102 Unilateral subsidiary elements 	103 Rotational subsidiary elements 	104 Unilateral subsidiary elements 

Shape class 2, disc shape  Parts with circular, square, and similar contours; cross piece with short arms; upset heads; and long shapes (flanges, valves, etc.)	Sub-group / Shape group	No subsidiary elements	With hub	With hub and hole	With rim	With rim and hub
	21 Disc shape with unilateral element	211 	212 	213 	214 	215 
	22 Disc shape with bilateral element	...	222 	223 	224 	225 

<table>
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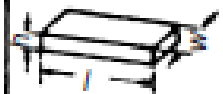


$l > w \geq h$

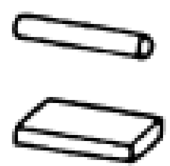
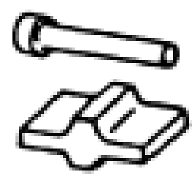
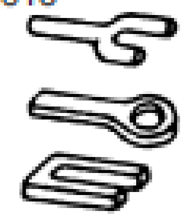
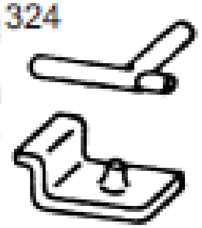
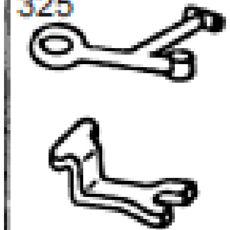
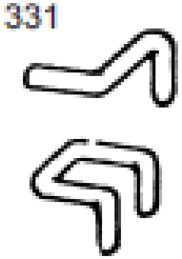
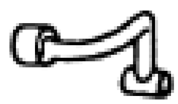
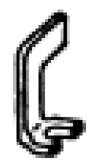
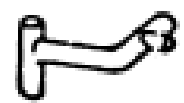
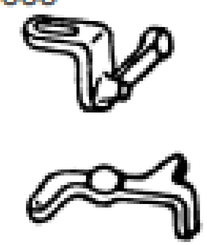
Parts with pronounced longit. axis length groups:

1. Short parts $l < 3w$

2. Avg. length $l = 3w$ to $8w$

3. Long parts $l = 8w$ to $16w$

4. Very long parts $l > 16w$

Length group numbers added behind bar, e.g., 334/2</td><td>Sub-group / Shape group</td><td>No subsidiary elements</td><td>Subsidiary elements parallel to axis of principal shape</td><td>With open or closed fork element</td><td>With subsidiary elements asymmetrical to axis of principal shape</td><td>With two or more subsidiary elements of similar size</td></tr>
<tr><td>31
Principal shape element with straight axis</td><td>311
</td><td>312
</td><td>313
</td><td>314
</td><td>315
</td></tr>
<tr><td>32
Longit. axis of princial shape element curved in one plane</td><td>321
</td><td>322
</td><td>323
</td><td>324
</td><td>325
</td></tr>
<tr><td>33
Long. axis of princial shape element curved in several planes</td><td>331
</td><td>332
</td><td>333
</td><td>334
</td><td>335
</td></tr>
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