National University of Science and Technology

Faculty of Industrial Technology

Department of Industrial and Manufacturing Engineering

Bachelor in Engineering Industrial and Manufacturing Engineering

Manufacturing Engineering Design TIE 3220

Second Semester Examinations August 2009

Duration: 3 hours
Answer: FIVE (5) Questions in all. ANY THREE from SECTION A and all in SECTION B

SECTION A

QUESTION 1

a) Explain briefly four properties expected on tooling and the elements that impart such properties. [8]

b) Briefly explain compression molding and injection molding. [8]

c) How do the two types of plastics differ and give one example of each type? [4]

QUESTION 2

a) Briefly explain the following terms with the aid of diagrams.

i) The direction of mold closure [2]

ii) External undercut [2]

b) In an effort to become more competitive a large automotive company has decided to expand its design for manufacturing group. Assume that you have applied for a position with that group. As part of the interview process you have been shown the proposed design of an injection molded part similar to the part shown in Figure 2.1. What suggestions would you make in order to reduce the cost to mold the part? [10]

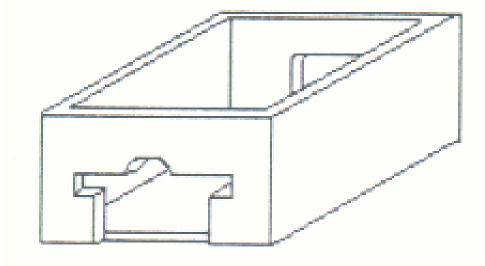


Figure 2.1: Proposed injection mold designs

c) Briefly explain three Design for Manufacture (DFM) guideline that you would keep in mind during plastic injection mould design. [6]

QUESTION 3

a) What comments would you make concerning the tooling costs for the part shown in Fig 3.1. (What suggestions in words would you make to reduce tooling cost?). [4]

b) Before you convince your MD that your suggested redesign of the part shown in Fig 3.1 will yield significant savings in tool cost, calculate the current tool costs assuming L= 70 mm, B=H=50 mm, the part has a textured surface finish and that tight tolerance are to be used. [16]

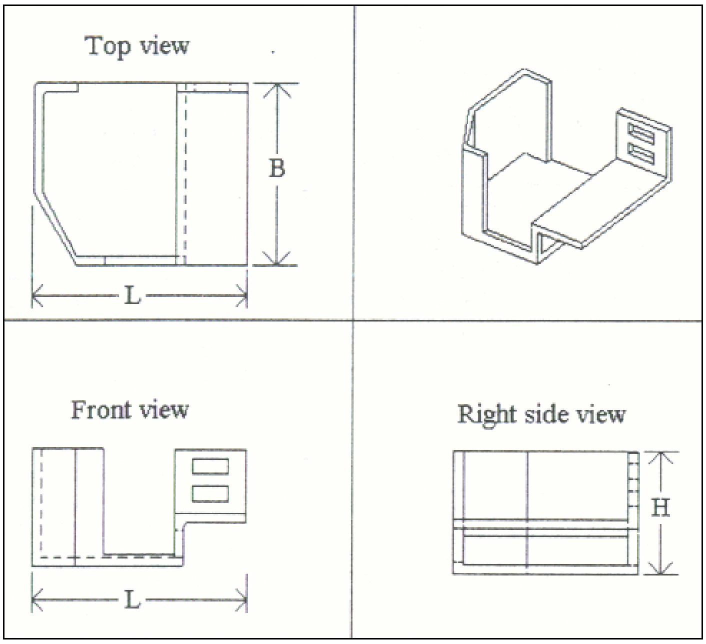


Figure 3.1:

QUESTION 4

For the file paper clamp shown in Figure Q4.1;

i) Apply Strip development process. [5]

ii) Create a strip layout [5]

iii) Sketch the progressive die set (punches and corresponding dies. [10]

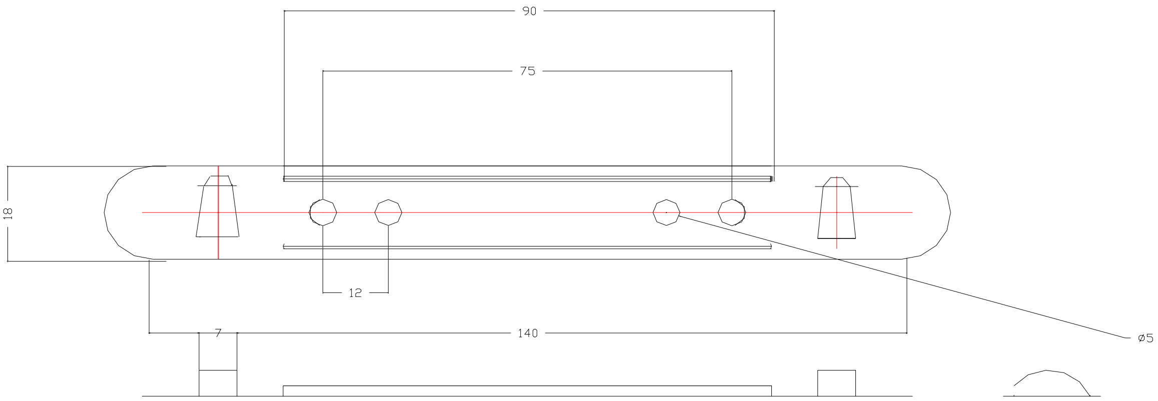


Figure Q4.1: File paper clamp

QUESTION 5

a) Briefly explain four aspects in the design for manufacturing guidelines for stamped parts. [8]

b) For a production volume of 50 000 parts determine the relative processing costs for part shown in Fig 4.1. Assume that the part is made of soft cold rolled steel. [12]

SECTION B

QUESTION 6

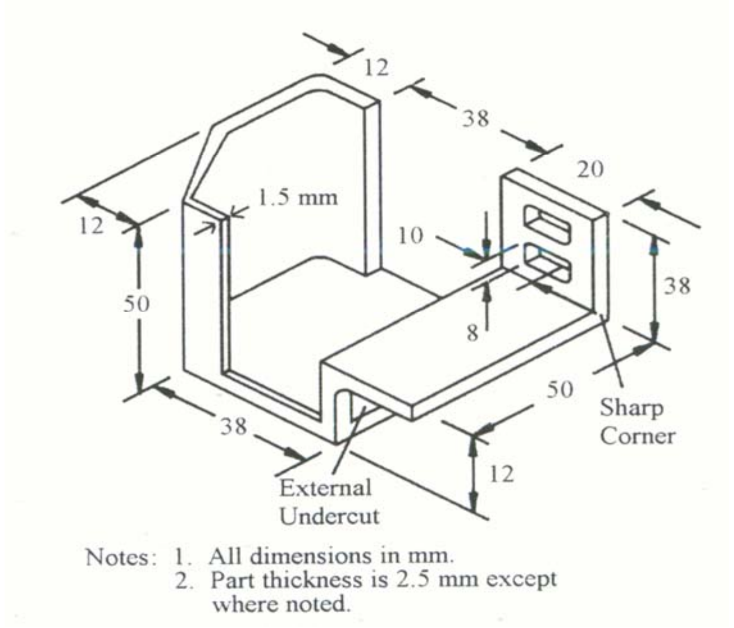
a) The part shown in Fig 4.1 is made of a soft cold rolled steel.. First suggest a redesign then determine:

i) The relative die construction cost for the part. [8]
ii) The relative die material cost for the part. [8]
iii) The overall die cost for the part. [4]

QUESTION 7

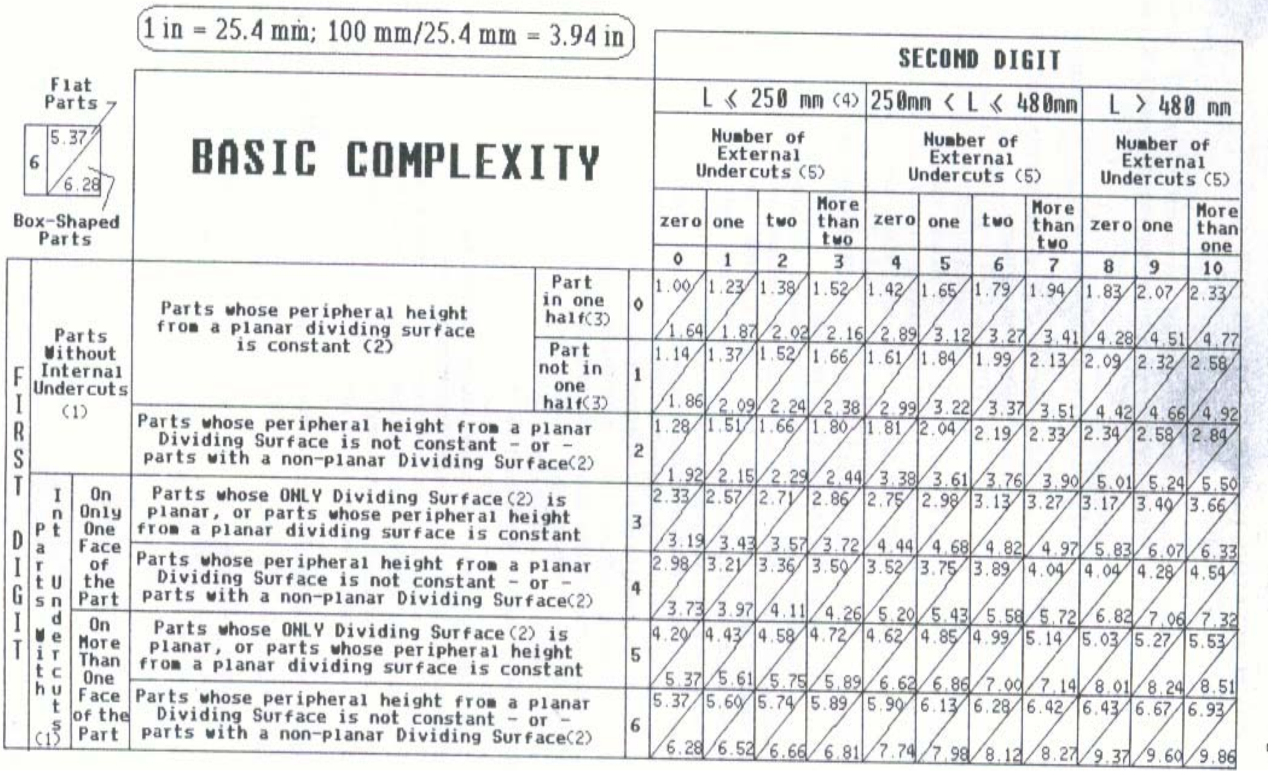
a) Imagine that you are part of the INDMFG team and you have been asked to roughly estimate the cycle time for the part shown in Fig 7.1. If it is to be produced with tight tolerances, what would you estimate the cycle time to be if the part is made of nylon 6 in a mold with a texture finish, given that the maximum wall thickness of the part is 2.5mm and the minimum wall thickness of the part is 1.5mm. [15]

b) In an effort to reduce processing costs, what redesign suggestions would you make for the part shown in Fig 7.1 so that the cycle time of the part is reduced? [5]



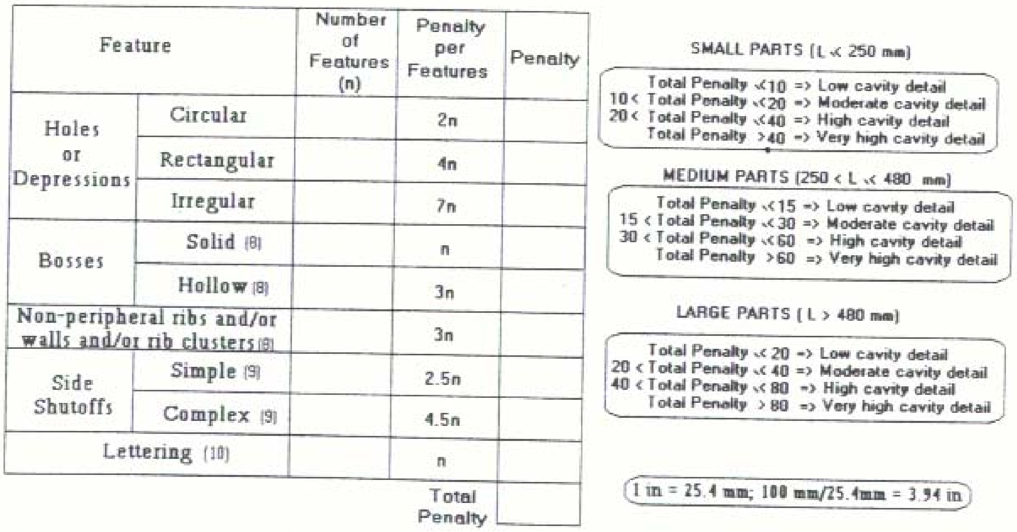
Notes: 1. All dimensions in mm.
2. Part thickness is 2.5 mm except where noted.

Figure 7.1



1 in = 25.4 mm; 100 mm/25.4 mm = 3.94 in

Flat Parts 6 5.37 / 6.28 Box-Shaped Parts			BASIC COMPLEXITY			SECOND DIGIT										
						L ≤ 250 mm (4)				250mm < L ≤ 480mm				L > 480 mm		
						Number of External Undercuts (5)				Number of External Undercuts (5)				Number of External Undercuts (5)		
						zero	one	two	More than two	zero	one	two	More than two	zero	one	More than one
						0	1	2	3	4	5	6	7	8	9	10
FIRST DIGIT	Parts Without Internal Undercuts (1)		Parts whose peripheral height from a planar dividing surface is constant (2)	Part in one half(3)	0	1.00 1.64	1.23 1.87	1.38 2.02	1.52 2.16	1.42 2.89	1.65 3.12	1.79 3.27	1.94 3.41	1.83 4.28	2.07 4.51	2.33 4.77
				Part not in one half(3)	1	1.14 1.86	1.37 2.09	1.52 2.24	1.66 2.38	1.61 2.99	1.84 3.22	1.99 3.37	2.13 3.51	2.09 4.42	2.32 4.66	2.58 4.92
			Parts whose peripheral height from a planar Dividing Surface is not constant - or - parts with a non-planar Dividing Surface(2)		2	1.28 1.92	1.51 2.15	1.66 2.29	1.80 2.44	1.81 3.38	2.04 3.61	2.19 3.76	2.33 3.90	2.34 5.01	2.58 5.24	2.84 5.50
	Parts With Internal Undercuts (1)	On Only One Face of the Part	Parts whose ONLY Dividing Surface (2) is planar, or parts whose peripheral height from a planar dividing surface is constant		3	2.33 3.19	2.57 3.43	2.71 3.57	2.86 3.72	2.75 4.44	2.98 4.68	3.13 4.82	3.27 4.97	3.17 5.83	3.40 6.07	3.66 6.33
			Parts whose peripheral height from a planar Dividing Surface is not constant - or - parts with a non-planar Dividing Surface(2)		4	2.98 3.73	3.21 3.97	3.36 4.11	3.50 4.26	3.52 5.20	3.75 5.43	3.89 5.58	4.04 5.72	4.04 6.82	4.28 7.06	4.54 7.32
		On More Than One Face of the Part	Parts whose ONLY Dividing Surface (2) is planar, or parts whose peripheral height from a planar dividing surface is constant		5	4.20 5.37	4.43 5.61	4.58 5.75	4.72 5.89	4.62 6.62	4.85 6.86	4.99 7.00	5.14 7.14	5.03 8.01	5.27 8.24	5.53 8.51
			Parts whose peripheral height from a planar Dividing Surface is not constant - or - parts with a non-planar Dividing Surface(2)		6	5.37 6.28	5.60 6.52	5.74 6.66	5.89 6.81	5.90 7.74	6.13 7.98	6.28 8.12	6.42 8.27	6.43 9.37	6.67 9.60	6.93 9.86



Feature		Number of Features (n)	Penalty per Features	Penalty
Holes or Depressions	Circular		2n	
	Rectangular		4n	
	Irregular		7n	
Bosses	Solid (8)		n	
	Hollow (8)		3n	
Non-peripheral ribs and/or walls and/or rib clusters (8)			3n	
Side Shutoffs	Simple (9)		2.5n	
	Complex (9)		4.5n	
Lettering (10)			n	
			Total Penalty	

SMALL PARTS (L ≤ 250 mm)

Total Penalty ≤10 => Low cavity detail
10 < Total Penalty ≤20 => Moderate cavity detail
20 < Total Penalty ≤40 => High cavity detail
Total Penalty >40 => Very high cavity detail

MEDIUM PARTS (250 < L ≤ 480 mm)

Total Penalty ≤15 => Low cavity detail
15 < Total Penalty ≤30 => Moderate cavity detail
30 < Total Penalty ≤60 => High cavity detail
Total Penalty >60 => Very high cavity detail

LARGE PARTS (L > 480 mm)

Total Penalty ≤ 20 => Low cavity detail
20 < Total Penalty ≤ 40 => Moderate cavity detail
40 < Total Penalty ≤ 80 => High cavity detail
Total Penalty > 80 => Very high cavity detail

1 in = 25.4 mm; 100 mm/25.4mm = 3.94 in

FIGURE 4.19 *Determination of cavity detail. (The numbers in parentheses refer to notes found in Appendix 4.A.)*

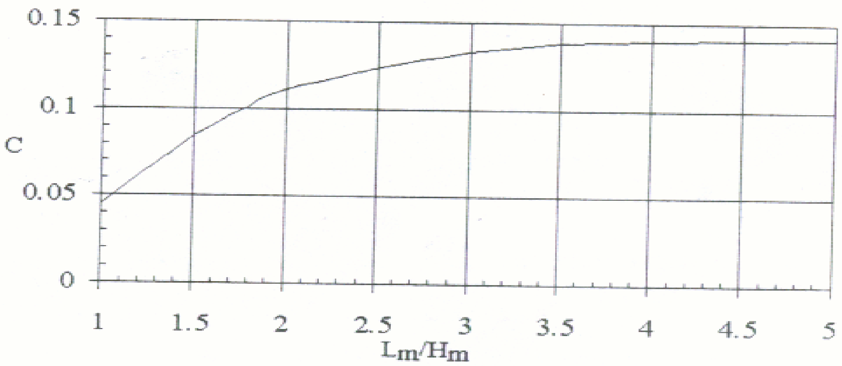


FIGURE 4.23 *Value of C for use in Equation 4.6. (If L_m/H_m <1, then use the value of H_m/L_m to determine C.)*

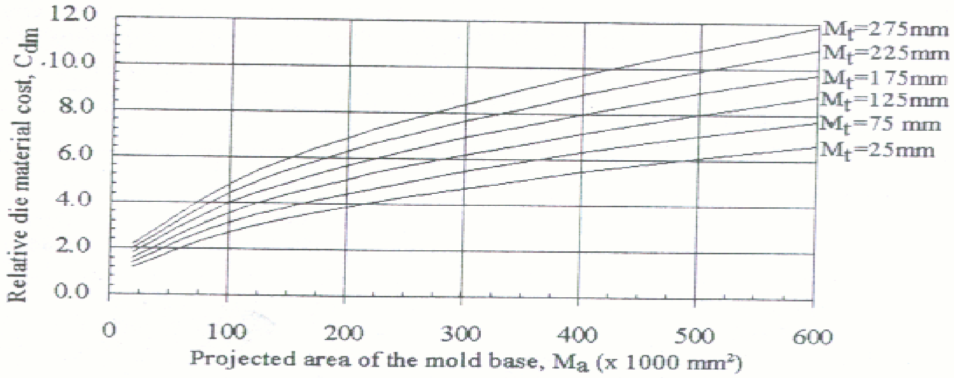


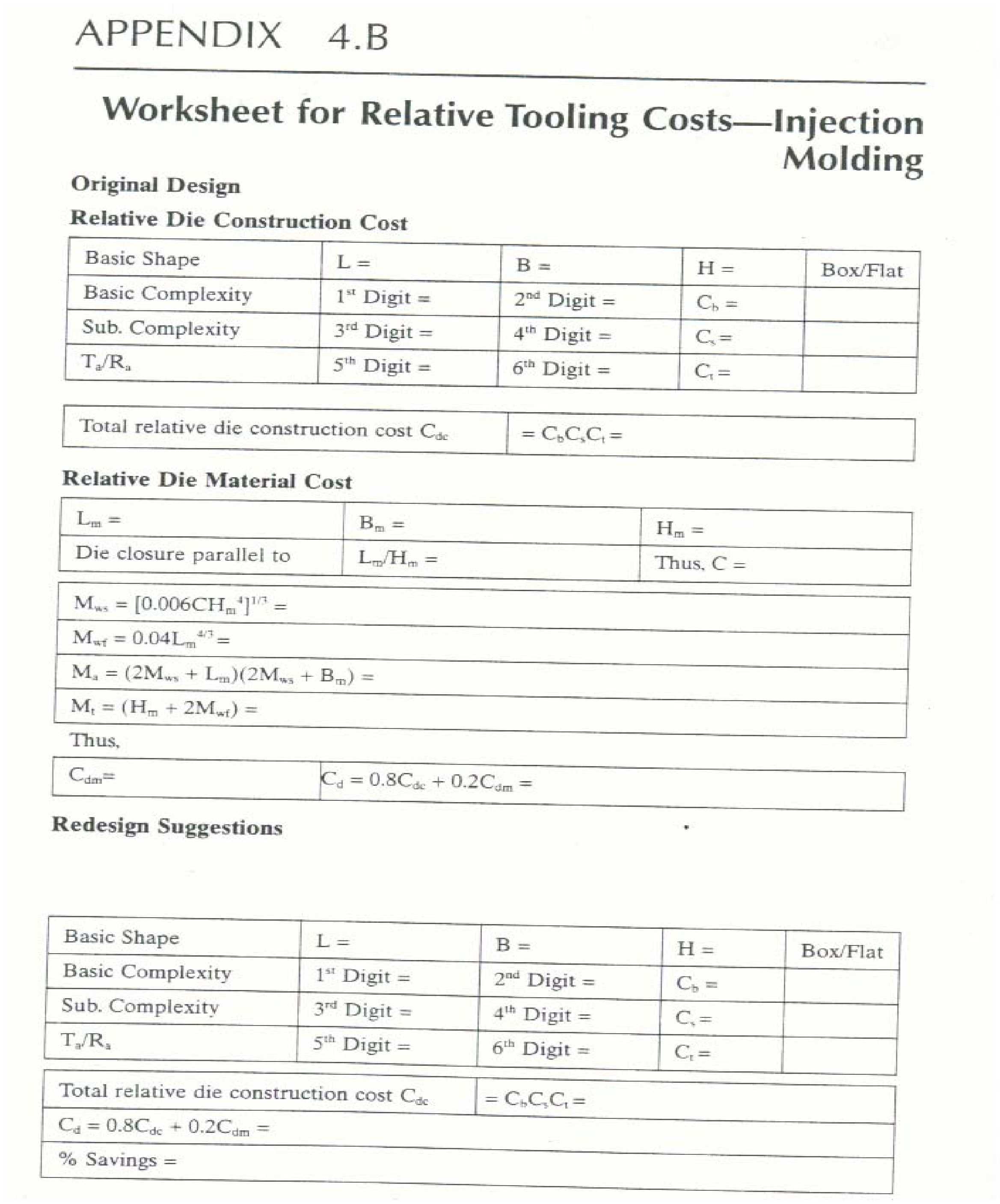
FIGURE 4.24 *Relative die material cost.*

Table 4.1 Subsidiary complexity rating, C_s. (The numbers in parentheses refer to notes found in Appendix 4.A.)

				Fourth Digit	
				Without Extensive (7) External Undercuts (5)	With Extensive (7) External Undercuts (5)
				0	1
Third Digit	Cavity Detail (6)	Low	0	1.00	1.25
		Moderate	1	1.25	1.45
		High	2	1.60	1.75
		Very High	3	2.05	2.15

Table 4.2 Tolerance and surface finish rating, C_t. (The numbers in parentheses refer to notes found in Appendix 4.A.)

				Sixth Digit	
				Commercial Tolerance, T_a	Tight Tolerance, T_a
				0	1
Fifth Digit	Surface Finish, R_a	SPI 5–6	0	—	—
		SPI 3–4	1	1.00	1.05
		Texture	2	1.05	1.10
		SPI 1–2	3	1.10	1.15



APPENDIX 4.B

Worksheet for Relative Tooling Costs—Injection Molding

Original Design

Relative Die Construction Cost

Basic Shape	L =	B =	H =	Box/Flat
Basic Complexity	1st Digit =	2nd Digit =	C_b =	
Sub. Complexity	3rd Digit =	4th Digit =	C_s =	
T_a/R_a	5th Digit =	6th Digit =	C_t =	

Total relative die construction cost C_{dc}	$= C_bC_sC_t =$

Relative Die Material Cost

L_m =	B_m =	H_m =
Die closure parallel to	L_m/H_m =	Thus, C =

$M_{ws} = [0.006CH_m^4]^{1/3} =$

$M_{wf} = 0.04L_m^{4/3} =$

$M_a = (2M_{ws} + L_m)(2M_{ws} + B_m) =$

$M_t = (H_m + 2M_{wf}) =$

Thus,

C_{dm}=	$C_d = 0.8C_{dc} + 0.2C_{dm} =$

Redesign Suggestions

Basic Shape	L =	B =	H =	Box/Flat
Basic Complexity	1st Digit =	2nd Digit =	C_b =	
Sub. Complexity	3rd Digit =	4th Digit =	C_s =	
T_a/R_a	5th Digit =	6th Digit =	C_t =	

Total relative die construction cost C_{dc}	$= C_bC_sC_t =$

$C_d = 0.8C_{dc} + 0.2C_{dm} =$

% Savings =

Appendix for Stamping Parts

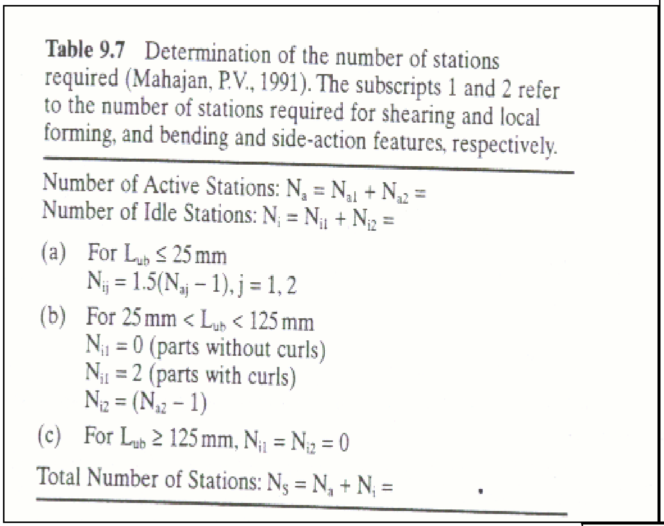


Table 9.7 Determination of the number of stations required (Mahajan, P.V., 1991). The subscripts 1 and 2 refer to the number of stations required for shearing and local forming, and bending and side-action features, respectively.

Number of Active Stations: $N_a = N_{a1} + N_{a2} =$

Number of Idle Stations: $N_i = N_{i1} + N_{i2} =$

(a) For $L_{ub} \leq 25\,\text{mm}$

$N_{ij} = 1.5(N_{aj} - 1), j = 1, 2$

(b) For $25\,\text{mm} < L_{ub} < 125\,\text{mm}$

$N_{i1} = 0$ (parts without curls)

$N_{i1} = 2$ (parts with curls)

$N_{i2} = (N_{a2} - 1)$

(c) For $L_{ub} \geq 125\,\text{mm}$, $N_{i1} = N_{i2} = 0$

Total Number of Stations: $N_S = N_a + N_i =$

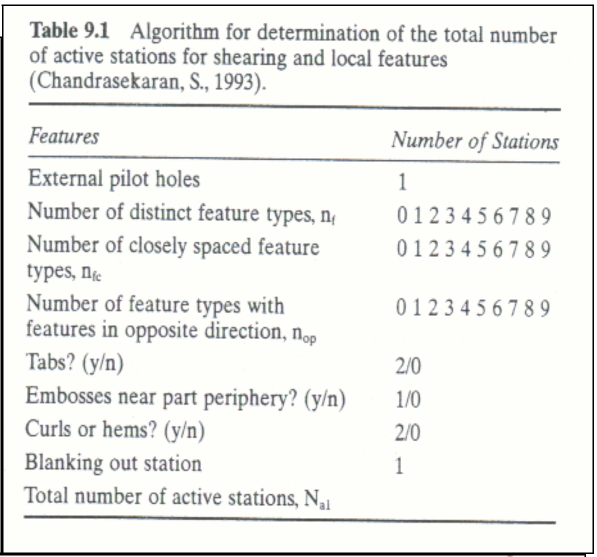


Table 9.1 Algorithm for determination of the total number of active stations for shearing and local features (Chandrasekaran, S., 1993).

Features	*Number of Stations*
External pilot holes	1
Number of distinct feature types, n_f	0 1 2 3 4 5 6 7 8 9
Number of closely spaced feature types, n_{fc}	0 1 2 3 4 5 6 7 8 9
Number of feature types with features in opposite direction, n_{op}	0 1 2 3 4 5 6 7 8 9
Tabs? (y/n)	2/0
Embosses near part periphery? (y/n)	1/0
Curls or hems? (y/n)	2/0
Blanking out station	1
Total number of active stations, N_{a1}	

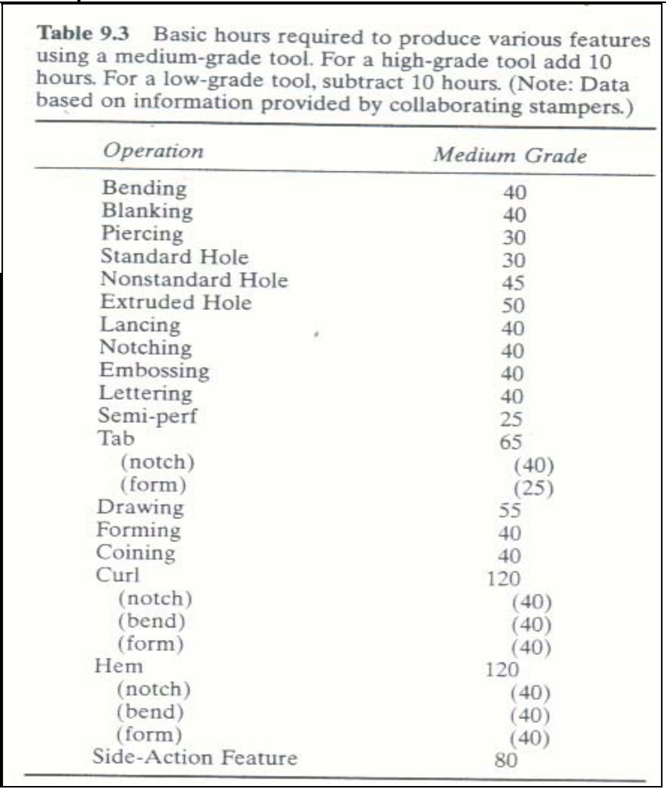


Table 9.3 Basic hours required to produce various features using a medium-grade tool. For a high-grade tool add 10 hours. For a low-grade tool, subtract 10 hours. (Note: Data based on information provided by collaborating stampers.)

Operation	*Medium Grade*
Bending	40
Blanking	40
Piercing	30
Standard Hole	30
Nonstandard Hole	45
Extruded Hole	50
Lancing	40
Notching	40
Embossing	40
Lettering	40
Semi-perf	25
Tab	65
(notch)	(40)
(form)	(25)
Drawing	55
Forming	40
Coining	40
Curl	120
(notch)	(40)
(bend)	(40)
(form)	(40)
Hem	120
(notch)	(40)
(bend)	(40)
(form)	(40)
Side-Action Feature	80

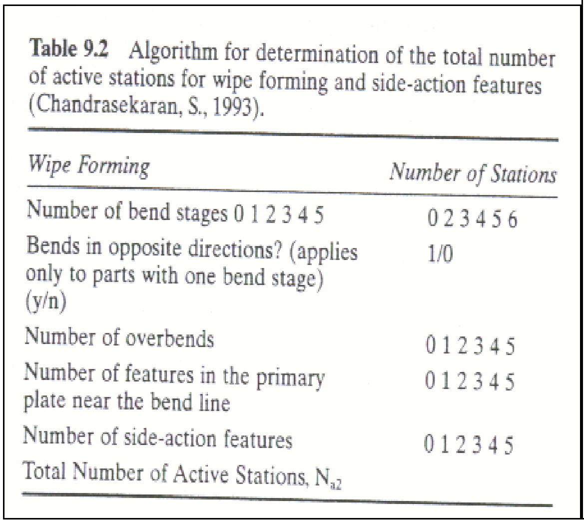


Table 9.2 Algorithm for determination of the total number of active stations for wipe forming and side-action features (Chandrasekaran, S., 1993).

Wipe Forming	*Number of Stations*
Number of bend stages 0 1 2 3 4 5	0 2 3 4 5 6
Bends in opposite directions? (applies only to parts with one bend stage) (y/n)	1/0
Number of overbends	0 1 2 3 4 5
Number of features in the primary plate near the bend line	0 1 2 3 4 5
Number of side-action features	0 1 2 3 4 5
Total Number of Active Stations, N_{a2}	

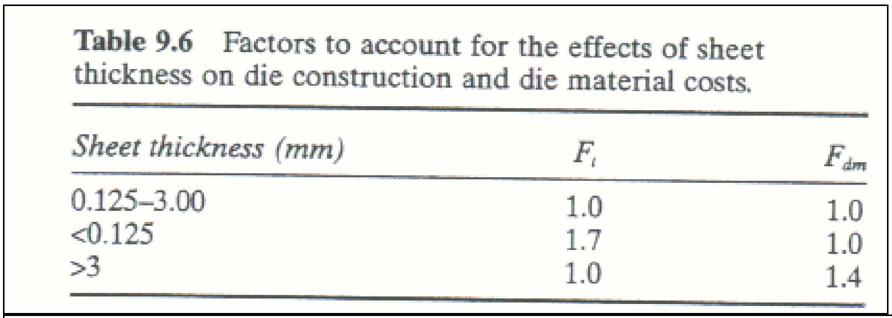
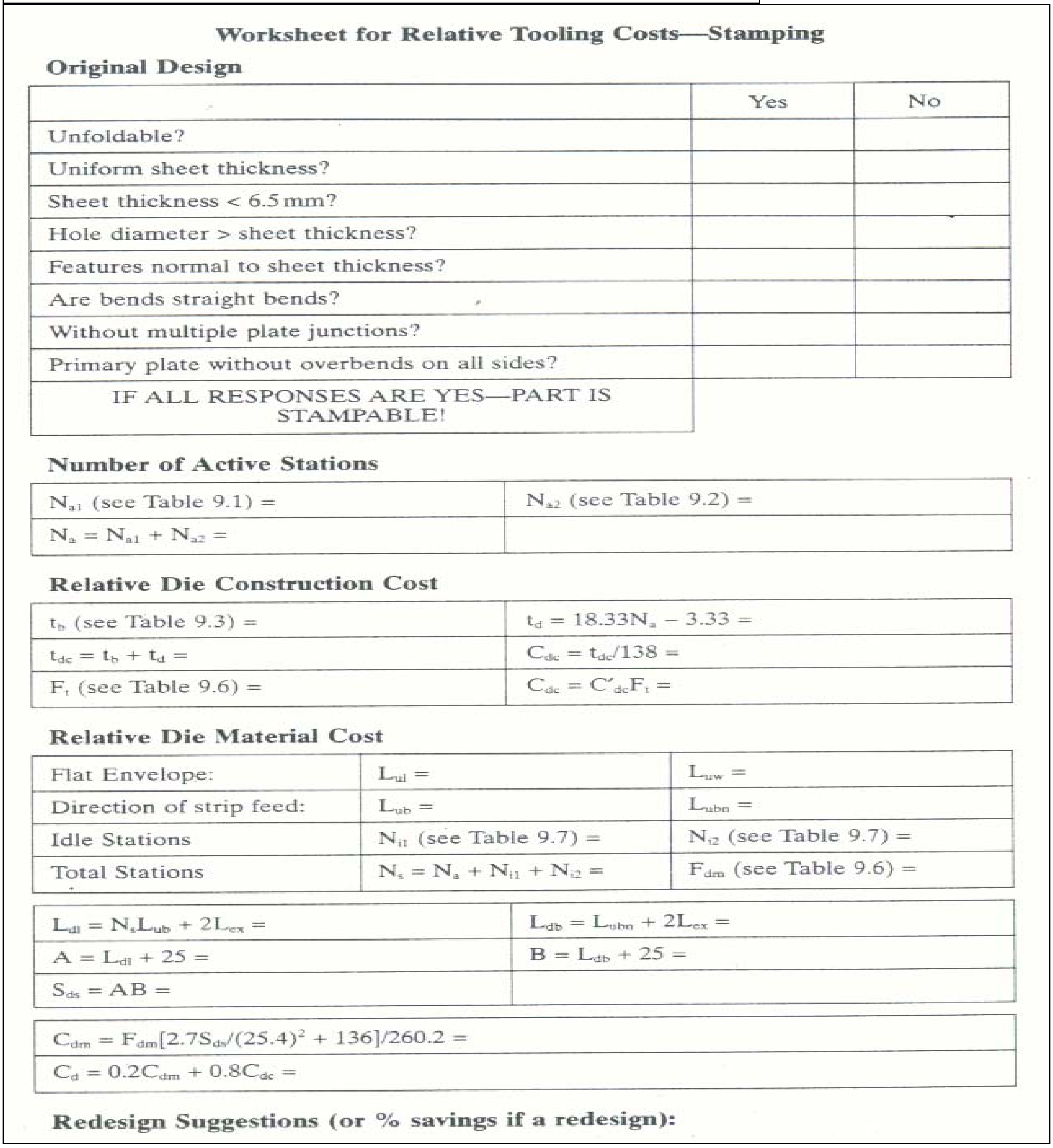


Table 9.6 Factors to account for the effects of sheet thickness on die construction and die material costs.

Sheet thickness (mm)	F_t	F_{dm}
0.125–3.00	1.0	1.0
<0.125	1.7	1.0
>3	1.0	1.4



Worksheet for Relative Tooling Costs—Stamping

Original Design

	Yes	No
Unfoldable?		
Uniform sheet thickness?		
Sheet thickness < 6.5 mm?		
Hole diameter > sheet thickness?		
Features normal to sheet thickness?		
Are bends straight bends?		
Without multiple plate junctions?		
Primary plate without overbends on all sides?		

IF ALL RESPONSES ARE YES—PART IS STAMPABLE!

Number of Active Stations

N_{a1} (see Table 9.1) =	N_{a2} (see Table 9.2) =
$N_a = N_{a1} + N_{a2} =$	

Relative Die Construction Cost

t_b (see Table 9.3) =	$t_d = 18.33N_a - 3.33 =$
$t_{dc} = t_b + t_d =$	$C_{dc} = t_{dc}/138 =$
F_t (see Table 9.6) =	$C_{dc} = C'_{dc}F_t =$

Relative Die Material Cost

Flat Envelope:	$L_{ul} =$	$L_{uw} =$
Direction of strip feed:	$L_{ub} =$	$L_{ubn} =$
Idle Stations	N_{i1} (see Table 9.7) =	N_{i2} (see Table 9.7) =
Total Stations	$N_s = N_a + N_{i1} + N_{i2} =$	F_{dm} (see Table 9.6) =

$L_{dl} = N_sL_{ub} + 2L_{ex} =$	$L_{db} = L_{ubn} + 2L_{ex} =$
$A = L_{dl} + 25 =$	$B = L_{db} + 25 =$
$S_{ds} = AB =$	

$C_{dm} = F_{dm}[2.7S_{ds}/(25.4)^2 + 136]/260.2 =$

$C_d = 0.2C_{dm} + 0.8C_{dc} =$

Redesign Suggestions (or % savings if a redesign):