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Chucks for machine tools and portable power tools —

**Part 5: Code of practice for the safe
operation of workholding chucks used
on lathes**

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- Advanced Manufacturing Technology Research Institute
- Cranfield Institute of Technology
- Department of Trade and Industry [Mechanical Engineering and Manufacturing Technology Division (Mmt)]
- Federation of British Engineers' Tool Manufacturers
- Health and Safety Executive
- Institution of Production Engineers
- Ministry of Defence
- University of Aston in Birmingham

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- Portable Electric Tool Manufacturers' Association

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Publications referred to	Inside back cover

Foreword

This Part of BS 1983 has been prepared under the direction of the Machine Engineers and Hand Tools Standards Committee and is based on a draft submitted by the Advanced Manufacturing Technology Research Institute (AMTRI).

This Part of BS 1983 will also be submitted as a UK proposal to the International Organization for Standardization (ISO) for consideration as an International Standard.

Lathe chucks operated at any speed are, potentially, very dangerous. They have to be suitably guarded in order to ensure that personnel do not come into contact with a moving chuck and that parts released from the chuck (for whatever reason) cannot be thrown at personnel either directly or after a ricochet. Power chuck controls also have to be suitably interlocked such that workpieces are not inadvertently released. These safety aspects are covered in BS 1983-4 *“Specification of criteria to be stated affecting performance of power operated workholding chucks at speed”* and in BS 5304 *“Code of practice for safeguarding of machinery”*.

However, because of the versatility of lathe chucks it follows that chuck designers and manufacturers cannot know the full range of uses to which their chucks will be put (i.e. range of machines on which a chuck may be mounted, type of jaws to be fitted, type of workpiece to be held). It is essential, therefore, for the user to take some responsibility for the application of a chuck. Further, in order that such duties can reasonably be undertaken by the user, it is essential that sufficient design data are available and that methods of calculation and/or of testing are specified. The machine tool manufacturer will also be involved in certain aspects of these problems.

This Part of BS 1983 attempts to outline the duties of, and to provide some of the necessary information needed by:

- a) the machine tool manufacturer;
- b) the chuck manufacturer;
- c) the chuck user.

However, because of the large number of chucks already in use it is necessary also to attempt to recommend the proper course of action regarding the application of existing chucks for which the required design data were not, in fact, passed over from manufacturer to user and which are now unobtainable.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 58, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of BS 1983 identifies and describes safe practices for design operation of workholding chucks used on turning machines.

The technical aspects covered by this code concern:

- a) the adequacy of the gripping force in the chuck;
- b) the fact that at excessive speed there may be failure of chuck components (fracture or excessive yielding);
- c) acceptable degrees of lack of balance and consequent vibration;
- d) the inertia loading imposed on the machine drive both by the chuck and by the workpiece;
- e) gravitational forces arising from the mass of the chuck and workpiece, together in some circumstances with cutting forces, and their effect on the machine;
- f) other aspects concerning the safe operation of lathe chucks.

Whilst primarily intended for application to lever and wedge type power chucks, including centrifugally compensated types, this code of practice can and should also be applied to manual chucks, but in such cases it is necessary to know the input torque.

NOTE 1 It should be recognized that even when a torque wrench or power driver is used, the grip is known to a lesser accuracy than, say, that of a power chuck having an hydraulically operated drawbar.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

2 Chuck grip

2.1 General

It should be recognized that there will be change of grip as the rotational speed increases even when the chuck has centrifugal compensation.

In the case of uncompensated, or only partially compensated, chucks set up for external grip, i.e. the jaws move inwards radially as the chuck is tightened, then an increase in rotational speed causes a loss of grip. However, when set up for internal grip an increase in rotational speed causes an increase in grip.

Over-compensation has the opposite effect, i.e. an external grip increases with speed. However over-compensation is not recommended in general because it may lead to progressive tightening if the speed is cycled up and down repeatedly.

It is essential that the chuck gripping condition is evaluated by the user or by tooling experts employed by him.

2.2 Forces applied to the chuck

2.2.1 General. The forces and torques applied via the workpiece to the jaws of the chuck can be represented by four terms:

ΣF_{ax} the total axial thrust;

ΣF_r the total radial force;

ΣM_d the total torque (about the spindle axis);

ΣM_k the total (tilting) moment (about an axis perpendicular to the spindle in the transverse centre plane of the jaws).

Each cutting tool, deadweight force and out-of-balance force and torque makes a contribution, usually to two or more of these total forces and torques, hence each contribution has to be calculated or measured.

Evaluation of mass induced forces requires values of density (see Table 1) unless components can be weighed. Evaluation of dynamic forces involves also the eccentricity, e (see clause 4).

Table 1 — Typical value of density, ρ

	kg/m ³
Magnesium alloy	1 800
Aluminium alloy	2 750
Iron	7 500
Steel	7 850
Zinc	7 000
Tin	7 290
Copper	8 780
Nickel	8 800
Brass	8 280 (on average)

2.2.2 Cutting forces and torques. There are many elaborate methods of calculating cutting forces and these methods are not precluded. Nevertheless the following simple methods are deemed to be sufficiently accurate.

a) For turning, facing and boring:

1) Estimate the tangential cutting force,

F_s (in N), as:

$F_s = \text{depth of cut (in mm)}$

$\times \text{feed (in mm)}$

$\times \text{specific cutting force (in N/mm}^2\text{)}$

where the specific cutting force is taken from Table 2.

Table 2 — Specific cutting forces, k_s , for turning, facing and boring

Material		Tensile strength	Brinell hardness number ^a	Specific cutting force, k_s			
				Feed per revolution			
				0.1 mm	0.2 mm	0.4 mm	0.8 mm
Carbon steels	low carbon (0.15 % C)	N/mm ² up to 490	HB up to 150	N/mm ² 3 600	N/mm ² 2 600	N/mm ² 1 900	N/mm ² 1 360
	low carbon (0.25 % C)	490 to 580	150 to 200	4 000	2 900	2 100	1 520
	medium carbon (0.4 % C)	580 to 680	180 to 250	4 200	3 000	2 200	1 560
	high carbon (0.55 % C)	680 to 830	200 to 300	4 400	3 150	2 300	1 640
Cast steel		290 to 490		3 200	2 300	1 700	1 240
		490 to 680		3 600	2 600	1 900	1 360
		680 +		3 900	2 850	2 050	1 500
Alloy steels		680 to 830		4 700	3 400	2 450	1 760
		830 to 970		5 000	3 600	2 600	1 850
		970 to 1 370		5 300	3 800	2 750	2 000
		1 390 to 1 750		5 700	4 100	3 000	2 150
Stainless steel		580 to 680		5 200	3 750	2 700	1 920
Tool steel		1 460 to 1 750		5 700	4 100	3 000	2 150
Manganese hardened steel				6 600	4 800	3 500	2 520
Cast iron			up to 200	1 900	1 360	1 000	720
Cast iron			200 to 250	2 900	2 080	1 500	1 080
Cast iron, alloy			250 to 400	3 200	2 300	1 700	1 200
Tempered cast iron				2 400	1 750	1 250	920
Copper				2 100	1 520	1 100	800
Copper with commutator mica (collectors)				1 900	1 360	1 000	720
Brass			80 to 120	1 600	1 150	850	600
Cast copper				1 400	1 000	700	520
Cast bronze				3 400	2 450	1 800	1 280
Zinc alloy Zn-Al 10-Cu2				940	700	560	430
Pure aluminium				1 050	760	550	400
Aluminium alloy with high Si content (11 % to 13 %, Si)				1 400	1 000	700	520
Piston alloy Al, Si (toughened) G Al-Si				1 400	1 000	700	520
				1 250	900	650	480
Other aluminium castings		up to 290		1 150	840	600	430
		290 to 420		1 400	1 000	700	520
Wrought aluminium alloys		420 to 579		1 700	1 220	850	640
Magnesium alloys				580	420	300	220
Hard rubber, ebonite				480	350	250	180
Rubber free insulating compound Novotex, Bakelite, Pertinaz				480	350	250	180
Hard paper, cardboard				380	280	200	140
Hard graphite (nuclear)				—	—	90	—

^a See BS 860.

NOTE When surfacing on a lathe, the depth of cut is measured radially and the feed axially but when facing the depth of cut is measured axially and the feed radially.

Alternatively estimate the power, P (in W), available as in Appendix A and derive the cutting force as follows:

Cutting speed,

$$V \text{ (in m/s)} = \pi \times \text{cutting diameter (in m)} \\ \times \text{spindle speed (in r/s)}$$

$$\text{Tangential cutting force, } F_s = \frac{P}{V}$$

2) Increase F_s by 1 % for each degree of top rake less than 10° , add 10 % to allow for tool wear.

3) Usually, feed force $\approx 0.6F_s$. (For difficult materials at slow speed, e.g. titanium, feed force = F_s .)

The feed force lies parallel to the spindle axis when cylindrical turning or boring, i.e. F_v in Figure 1 to Figure 3. It lies perpendicular to the spindle axis when facing, i.e. F_p in Figure 1 to Figure 3.

4) Separating force $\approx 0.25F_s$ and may usually be neglected. The separating force lies perpendicular to the spindle axis when cylindrical turning or boring, i.e. F_p in Figure 1 to Figure 3. It lies parallel to the spindle axis when facing, i.e. F_v in Figure 1 to Figure 3.

b) For drilling (and, approximately, for deep-hole boring):

1) Estimate the drilling torque, M (in N m), as:

$$M = 1.2k \times C_s$$

where:

k is the work material factor taken from Table 3;

C_s is the torque factor, taken from Figure 4, for the drill diameter and feed rate in use.

2) Estimate the feed force, F_a (in N), as:

$$F = k_f \times F_{s1}$$

where:

k_f is a work material factor taken from Table 4;

F_{s1} is a force factor taken either from Figure 5 (for drills of all sizes in brass and aluminium and for drills up to 12 mm diameter in steel and cast iron) or from Figure 6 (for drills of 16 mm and over in steel and cast iron).

NOTE 1 The information given in Table 4 and Figure 5 and Figure 6 is based on two separate series of tests and does, therefore, show small discrepancies in the region of 12 mm to 16 mm drill diameter.

NOTE 2 This calculation may be omitted if the workpiece is axially located by the chuck.

Table 3 — Work material factor, k , for drilling (and deep hole boring) torque

Description	Typical specification	k
Steels:		
Low carbon sulphurized (0.1 % C)	220 M 07 (En 1a) 240 M 07 (En 1b)	4 to 4.5
Low carbon low sulphur (0.2 % C)	080 A 22 (En 3)	5 to 5.5
(0.25 % C)	070 M 20 (En 4)	
(0.3 % C)	080 M 30 (En 5)	
(0.35 % C)	070 M 26 (En 6)	
(0.1 % C)	045 M 10 (En 32)	
Medium carbon (0.4 % C)	080 M 40 (En 8)	4 to 4.5
High carbon (0.55 % C)	070 M 55 (En 9)	6 to 6.5
Alloy steels	709 M 40 (En 19)	
	817 M 40 (En 24)	
	826 M 40 (En 26)	
Brass		2.0
Aluminium alloy (cast)		1.6
Cast iron: grey		
Feed rate > 0.7 mm/r		2.0
< 0.6 mm/r		3.0
Malleable iron		
Feed rate > 0.7 mm/r		2.7
< 0.6 mm/r		3.5

c) For tapping:

1) Estimate the torque, M (in N m), as:

$$M = k \times C_t \times C_d \times C_m$$

where:

k is the work material factor from Table 5;

C_t is the tap factor from Table 6;

C_d is the thread depth factor from Table 7;

C_m is the thread factor from Table 8.

Increase by 50 % to allow for tap wear.

2) Feed forces when tapping are not easy to estimate and are, in general small enough to be ignored.

**Table 4 — Work material factor, k_f , for drilling
(and deep hole boring) feed**

Material	k_f	
	Drill diameter	
	12 mm	16 mm
Low carbon steel (up to 0.25 % C) (all feed rates)	800	180
Medium carbon steel (over 0.3 % C) (all feed rates)	1 100	200
Grey cast iron feed rate > 0.7 mm/r < 0.6 mm/r	460 640	80 100
Malleable cast iron feed rate > 0.7 mm/r < 0.6 mm/r	380 500	90 120
Brass feed rate > 0.7 mm/r < 0.6 mm/r	170 300	
Aluminium feed rate > 0.7 mm/r < 0.6 mm/r	400 600	

Table 5 — Value of work material factor, k , for tapping

Material	Brinell hardness number ^a	k
	HB	
Grey cast iron	200	1.8
	300	1.9
Malleable cast iron	150	1.6
	250	1.8
Steels:		
low carbon (0.15 % C)	150	2.0
low carbon (0.25 % C)	200	2.4
high carbon (0.55 % C)	300	3.1
typical alloy steel	400	3.5
Aluminium alloys		0.7
Magnesium alloys		0.4
Brass		1.4
Leaded brass		0.7
Phosphor bronze		0.8

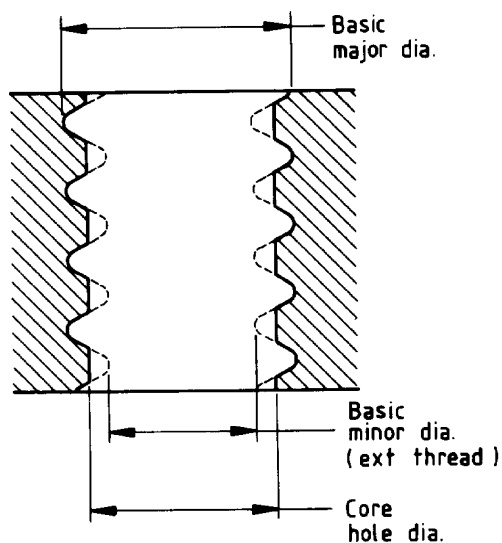
^a See BS 860.

Table 6 — Value of tap factor, C_t

Tap type	C_t
Spiral-point	1.0
Helical flute RH	1.3
Straight flute: in general	1.7
but over 40 mm dia. length of thread less than one diameter	1.3

**Table 7 — Values of thread depth factor, C_d ,
for tapping**

Depth of thread %	C_d
55	0.57
65	0.75
75	0.9
80	1.0
85	1.1



$$\text{Percentage depth of thread} = \frac{A}{B} \times 100$$

where:

A = basic major diameter – core hole diameter

B = basic major diameter – basic minor diameter

Table 8 — Values of thread factor, C_m , for tapping

a) ISO metric coarse pitch series

Diameter × pitch	C_m
M3 × 0.5	0.1
M4 × 0.7	0.22
M5 × 0.8	0.35
M6 × 1	0.63
M8 × 1.25	1.3
M10 × 1.5	2.2
M12 × 1.75	3.5
M16 × 2	6.0
M20 × 2.5	11
M24 × 3	19
M30 × 3.5	31
M36 × 4	48
M42 × 4.5	69
M48 × 5	96
M56 × 5.5	133
M64 × 6	179

b) ISO metric constant pitch series

Diameter	Pitch (mm)						
	1	1.25	1.5	2	3	4	6
mm	C_m	C_m	C_m	C_m	C_m	C_m	C_m
8	0.9	1.3					
10	1.1	1.6	2.2				
12	1.3	2.0	2.7	4.4			
16	1.8		3.7	6.0			
20	2.3		4.7	7.7			
24	2.8		5.6	9.3	19		
30	3.5		7.1	11.8	24		
36			8.6	14.3	29	48	
42			10.0	16.7	34	56	
48			11.5	19	39	65	
56			13.5	22	46	76	
64			15.5	26	53	88	179
72			17.5	29	60	99	202
80			19.0	32	66	111	226
90				36	75	125	256
100				40	83	139	285
110				45	92	154	315
125				51	105	175	360
140				57	118	196	404
160				65	135	225	463
180				73	152	253	522

c) B.S.W.

Diameter	threads per inch	C_m
in		
$\frac{1}{4}$	26	0.6
$\frac{5}{16}$	22	1.1
$\frac{3}{8}$	20	1.6
$\frac{1}{2}$	16	3.2
$\frac{5}{8}$	14	5.1
$\frac{3}{4}$	12	8.1
$\frac{7}{8}$	11	11
1	10	15
$1 \frac{1}{8}$	9	20
$1 \frac{1}{4}$	9	23
$1 \frac{1}{2}$	8	34
$1 \frac{3}{4}$	7	51
2	7	58
$2 \frac{1}{4}$	6	86
$2 \frac{1}{2}$	6	96
3	5	161
$3 \frac{1}{2}$	$4 \frac{1}{2}$	227
4	$4 \frac{1}{2}$	261

d) B.S.F.

Diameter	threads per inch	C_m
in		
$\frac{1}{4}$	20	1
$\frac{5}{16}$	18	1.5
$\frac{3}{8}$	16	2.3
$\frac{1}{2}$	12	5.2
$\frac{5}{8}$	11	7.7
$\frac{3}{4}$	10	11
$\frac{7}{8}$	9	16
1	8	22
$1 \frac{1}{8}$	7	32
$1 \frac{1}{4}$	$7 \frac{1}{2}$	35
$1 \frac{1}{2}$	6	56
$1 \frac{3}{4}$	5	91
2	$4 \frac{1}{2}$	126
$2 \frac{1}{4}$	4	175
$2 \frac{1}{2}$	4	196
3	$3 \frac{1}{2}$	300
$3 \frac{1}{2}$	$3 \frac{1}{4}$	402
4	3	532

e) B.S.P.

Nominal diameter	Outside diameter	threads per inch	C_m
in	in		
$\frac{1}{8}$	0.383	28	0.9
$\frac{1}{4}$	0.518	19	2.5
$\frac{3}{8}$	0.656	19	3.2
$\frac{1}{2}$	0.825	14	6.8
$\frac{5}{8}$	0.902	14	7.5
$\frac{3}{4}$	1.041	14	8.7
$\frac{7}{8}$	1.189	14	10
1	1.309	11	17
$1 \frac{1}{4}$	1.650	11	22
$1 \frac{1}{2}$	1.882	11	25
$1 \frac{3}{4}$	2.116	11	28
2	2.347	11	31
$2 \frac{1}{4}$	2.587	11	34
$2 \frac{1}{2}$	2.960	11	39
$2 \frac{3}{4}$	3.210	11	43
3	3.460	11	46

f) Inch-based constant-pitch series

Diameter	Pitch (threads per inch)			
	8	12	16	20
in				
1		11	6.6	4.5
$1 \frac{1}{8}$		12.4	7.5	5
$1 \frac{1}{4}$		13.8	8.3	5.6
$1 \frac{3}{8}$		15.3	9.2	6.2
$1 \frac{1}{2}$	34	16.7	10.1	6.8
$1 \frac{3}{4}$	40	19.6	11.8	7.9
2	46	23	13.5	9.1
$2 \frac{1}{4}$	52	25	15.2	10.2
$2 \frac{1}{2}$	58	28	17	11.4
$2 \frac{3}{4}$	64	31	19	12.5
3	70	34	20	13.7
$3 \frac{1}{4}$	76			
$3 \frac{1}{2}$	82			
$3 \frac{3}{4}$	88			
4	94			

2.2.3 Loading on the chuck: overhung workpiece, simple tooling. The loading on the chuck for an overhung workpiece, using simple tooling, is the easiest case to analyse.

Referring to Figure 1:

$$\begin{aligned}
 \text{Axially } \Sigma F_{ax} &= F_v + F_{vax} \\
 &\quad \text{axial thrust (drilling)} \\
 &\quad \text{longitudinal feed force (turning)} \\
 \\
 \text{Torque } \Sigma M_d &= F_s \frac{d_z}{2} + Wge + M_{dax} \\
 &\quad \text{drilling torque} \\
 &\quad \text{static unbalance torque} \\
 &\quad \text{(neglect if nominally symmetrical workpiece)} \\
 &\quad \text{cutting torque (turning)} \\
 \\
 \text{Radial force } \Sigma F_r^* &= \\
 &= (F_s - Wg)^2 + (F_p)^2 + W\omega^2 e \\
 &\quad \text{Dynamic out-of-balance} \\
 &\quad (\omega = 2\pi N/60 \text{ where } N \text{ is the spindle speed in r/min}) \\
 &\quad \text{(neglect if nominally symmetrical workpiece)} \\
 &\quad \text{r.m.s. of cutting forces + deadweight} \\
 \\
 \text{Tilting moment } \Sigma M_k^* &= \\
 &= \sqrt{\left\{ (F_s l_z - Wgl_s)^2 + \left(F_v \frac{d_z}{2} - F_p l_z \right)^2 \right\}} + W\omega^2 e l_s \\
 &\quad \text{Moments in } F_s \text{ plane} \\
 &\quad \text{Moments in } F_p \text{ plane} \\
 &\quad \text{Dynamic out-of-balance} \\
 &\quad \text{(neglect if nominally symmetrical workpiece)} \\
 &\quad \text{Non-rotating} \quad \text{Rotating}
 \end{aligned}$$

2.2.4 Loading on the chuck: vertical spindle, simple tooling. From Figure 2:

$$\begin{aligned}
 \Sigma F_{ax} &= F_v + F_{vax} + Wg \\
 \Sigma M_d &= F_s \frac{d_z}{2} + M_{dax} \\
 \Sigma F_r^* &= \sqrt{\{ (F_p^2 + F_s^2) + W\omega^2 e \}} \\
 \Sigma M_k^* &= \sqrt{\left\{ (F_s l_z)^2 + \left(F_v \frac{d_z}{2} - F_p l_z \right)^2 \right\}} + \\
 &\quad + W\omega^2 e l_s + Wge
 \end{aligned}$$

2.2.5 Inclined slides and multiple slides. When an inclined slide is used the cutting forces act at a different point and in different directions, see Figure 3, where they are denoted by F_{si} , F_{vi} , F_{pi} , for a slide rotated by angle, α , from the “horizontal” position.

The forces, torques and moments F_s , F_v and F_p then become:

Axial force, $F_v = F_{vi}$

Radial forces at the axis,

$$F_s = F_{si} \cos \alpha + F_{pi} \sin \alpha$$

and $F_p = F_{pi} \cos \alpha - F_{si} \sin \alpha$

NOTE 1 These terms replace F_s and F_p in the equations in 2.2.3.

$$\text{Torque about the axis} = F_{si} \frac{d_z}{2}$$

NOTE 2 This term replaces $F_s \frac{d_z}{2}$ in the equations in 2.2.3.

Moment in a vertical plane¹⁾

$$= F_s I_z - F_{vi} \frac{d_z}{2} \cos \alpha$$

NOTE 3 This term replaces $F_{si} I_z$ in the equations in 2.2.3.

Moment in a horizontal plane¹⁾

$$= F_p I_z - F_{vi} \frac{d_z}{2} \sin \alpha$$

NOTE 4 This term replaces $F_{pi} I_z$ in the equations in 2.2.3.

In the case of multiple slides, each slide is treated as inclined and the resultant values are summed as follows, where the suffix j indicates the slide:

Axially, $F_v = \Sigma F_{vij}$

Radially, $F_s = \Sigma F_{sj}$

and $F_p = \Sigma F_{pj}$

$$\text{Torque} = \Sigma F_{sij} \left(\frac{d_{zj}}{2} \right)$$

Moment in vertical plane¹⁾

$$= \Sigma \left\{ F_{sj} I_{zj} - F_{vij} \left(\frac{d_{zj}}{2} \right) \cos \alpha \right\}$$

Moment in horizontal plane¹⁾

$$= \Sigma \left\{ F_{pj} I_{zj} - F_{vij} \left(\frac{d_{zj}}{2} \right) \sin \alpha \right\}$$

2.2.6 Required grip. The values of ΣF_{ax} , ΣM_d are used as follows to establish the total grip, F_{sp} , needed to prevent slip:

$$\mu_{sp} F_{sp} \geq \sqrt{\left\{ \left(\frac{2 \Sigma M_d}{d_{sp}} \right)^2 + \left(\Sigma F_{sx} \right)^2 \right\}}$$

where μ_{sp} is the coefficient of friction given in Table 9

NOTE When the workpiece is axially located by the chuck ΣF_{ax} may be treated as zero provided it has a positive value initially.

¹⁾ These items can, at present, be used only subjectively in setting safety factors; no numerical criteria are available.

The choice between tangential and axial values in Table 9 is somewhat arbitrary. When there is no positive axial location tangential values for μ_{sp} should be used if the torque term ($2 \Sigma M_d/d_{sp}$) is predominant, i.e. for most turning operations. For drilling however when the term ΣF_{ax} predominates it is acceptable to select a value of μ_{sp} from the axial column of Table 9.

The grip F_{sp} then has to be increased by a factor, S_z , in order to provide for:

- a) a margin of safety to cater for values of ΣM_k ;
- b) any further margin of safety.

(The force of ΣF_r will cause radial deflection of the workpiece but no criteria are available, currently, to establish limits.)

A minimum of $S_z = 2$ is to be adopted, increased as necessary to cater for large values of ΣM_k (for which $l_z > d_{sp}$ probably) and other adverse factors, and a factor $S_{sp} = 1.5$ is used to provide a margin of safety when calculating the required total static grip, (F_{spo}) given by:

$$F_{spo} = S_{sp} (F_{spz} S_z + F_c)$$

for external grip (jaws moving radially inwards to grip)

$$F_{spo} = S_{sp} (F_{sp2} S_z + F_c)$$

for internal grip (jaws moving radially outwards to grip)

where F_c is the centrifugal force on jaws, see 2.3.

2.2.7 Effect of a tailstock centre. If a tailstock centre is used then the loading situation at the chuck becomes complex. Two approximate simplifications are possible.

- a) When the workpiece is not axially located by the chuck then an overestimate, and hence a safe estimate of the forces is obtained if the tailstock is ignored and the calculations made as for an overhung workpiece. This approach is justified on the basis that should the workpiece slip in the chuck then it may well slip off the tailstock centre.
- b) When the workpiece is axially located by the chuck then:

$$\Sigma F_{ax} = 0;$$

ΣF_r^a is evaluated after applying the multiplying factor given in Figure 7 to each component;

ΣM_d is evaluated as for an overhung workpiece;

ΣM_k^a is evaluated after applying the multiplying factor given in Figure 7 to each component.

^a These items can, at present, be used only subjectively in setting safety factors; no numerical criteria are available.

Thus the effect of a tailstock centre is to modify the values of $\Sigma F_v^{(2)}$ and $\Sigma M_k^{(2)}$ thus leading to the subjective choice of lower values for the safety factor S_z .

NOTE No guidelines are available to deal with this aspect; moreover the values of $\Sigma F_r^{(2)}$ and of $\Sigma M_k^{(2)}$ will usually be small. Hence, at present, it is recommended that $\Sigma F_r^{(2)}$ and $\Sigma M_k^{(2)}$ be neglected.

2.3 Change of grip at speed

It is essential that the chuck manufacturer provides graphs, Figure 8 being an example, showing the change of grip at various speeds when the chuck is fitted with standard jaws positioned flush with the outside diameter, inwardly stepped [see Figure 9 c)]. Supplementary data for outwardly-stepped jaws and for smaller radii would be acceptable, as additional curves or on separate graphs, as would comparable data for blank jaws. The information may be calculated or obtained experimentally using a stiff load transducer, e.g. one having a steel load path. Results obtained using a flexible load transducer, e.g. of the hydraulic type, are not acceptable.

NOTE 1 The transducer should, preferably, be some 10 times stiffer than the chuck.

The chuck manufacturer also has to state the masses of base jaws and any top jaws supplied and give the location of their centres of mass (both being marked, preferably, on the jaws).

²⁾ These items can, at present, be used only subjectively in setting safety factors; no numerical criteria are available.

The chuck user has to read off, from the graphs, the change in grip, F_c (in N), arising from the change in speed:

- a) an increase for internal gripping;
- b) a decrease for external gripping. (See 2.1.)

Unless an internal grip has to be limited by the need to avoid marking or distorting the workpiece, it is quicker and preferable to assume $F_c = 0$.

The loss of grip should not normally be allowed to exceed one half of its original value.

Where the conditions of use are not covered by the graphs available the chuck user has to calculate the change of grip, F_c , of uncompensated chucks as:

$$F_c = \omega^2 \Sigma(m_1 R_1)$$

where:

- $m_{1,2}$ etc. are the masses of the jaw components (in kg);
- $R_{1,2}$ etc. refer to the radii of their centres of mass (in m);
- ω is the angular velocity (in rad/s) = $2\pi N/60$ where N is the spindle speed in (r/min).

Figure 10 shows a log-log plot of F_c covering the range of chuck speeds, from 10 r/min to 10 000 r/min, and products of jaw mass (in kg) $\times$ radius of centre of mass (in m) from 0.001 kg m to 100 kg m.

For example, a 5 kg jaw set at 250 mm radius will have an mr value of $5 \times 0.25 = 1.25$ kg m and when rotated at 750 r/min will cause a loss of grip per jaw of $(2\pi \times 750/60)^2 \times 1.25 = 7\,711$ N.

NOTE 2 Where the jaw data are not available from the chuck manufacturer or where the user has designed and manufactured the jaw, the user has to determine the required information on the mass and the position of the centre of gravity by calculation or by measurement.