39

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Code of practice for the safe operation of work-holding chucks used on lathes

Lignes directrices pour l'utilisation sûre des mandrins porte-pièce de tour

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Contents

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Appendices

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 13618, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 39, *Machine tools*, Sub-Committee SC 8, *Chucks*.

This document is being issued in the type 2 Technical Report series of publications (according to subclause G.4.2.2. of part 1 of the ISO/IEC Directives, 1992) as a "prospective standard for provisional application" in the field of work-holding chucks for machine tools because there is an urgent need for guidance on how standards in this field should be used to meet an identified need. This Technical Report reproduces practically verbatim British Standard BS 1983-5:1989 and implements it as an ISO Technical Report. For the user's convenience, where possible, references to national standards have been changed to refer to International Standards.

This document is not to be regarded as an "International Standard". It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this type 2 Technical Report will be carried out not later than two years after its publication with the options of: extension for another two years; conversion into an International Standard; or withdrawal.

Appendices A to E of this Technical Report are for information only.

Introduction

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 ISO 13046.

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 Technical Report 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, transmitted from manufacturer to user and which are now unobtainable.

Code of practice for the safe operation of work-holding chucks used on lathes

1 Scope

This Technical Report identifies and describes safe practices for design and 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. Publications referred to in this Technical Report are listed in Appendix E.

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	1800
Aluminium alloy	2750
Iron	7500
Steel	7850
Zinc	7000
Tin	7290
Copper	8780
Nickel	8800
Brass	8280 (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***	**Specific cutting force, k_s**			
				Feed per revolution			
				0.1 mm	0.2 mm	0.4 mm	0.8 mm
		N/mm^2	HB	N/mm^2	N/mm^2	N/mm^2	N/mm^2
Carbon steels	low carbon (0.15 % C)	up to 490	up to 150	3600	2600	1900	1360
	low carbon (0.25 % C)	490 to 580	150 to 200	4000	2900	2100	1520
	medium carbon (0.4 % C)	580 to 680	180 to 250	4200	3000	2200	1560
	high carbon (0.55 % C)	680 to 830	200 to 300	4400	3150	2300	1640
Cast steel		290 to 490		3200	2300	1700	1240
		490 to 680		3600	2600	1900	1360
		680+		3900	2850	2050	1500
Alloy steels		680 to 830		4700	3400	2450	1760
		830 to 970		5000	3600	2600	1850
		970 to 1370		5300	3800	2750	2000
		1390 to 1750		5700	4100	3000	2150
Stainless steel		580 to 680		5200	3750	2700	1920
Tool steel		1460 to 1750		5700	4100	3000	2150
Manganese hardened steel				6600	4800	3500	2520
Cast iron			up to 200	1900	1360	1000	720
Cast iron			200 to 250	2900	2080	1500	1080
Cast iron, alloy			250 to 400	3200	2300	1700	1200
Tempered cast iron				2400	1750	1250	920
Copper				2100	1520	1100	800
Copper with commutator mica (collectors)				1900	1360	1000	720
Brass			80 to 120	1600	1150	850	600
Cast copper				1400	1000	700	520
Cast bronze				3400	2450	1800	1280
Zinc alloy Zn-Al 10-Cu2				940	700	560	430
Pure aluminium				1050	760	550	400
Aluminium alloy with high Si content (11 % to 13 %, Si)				1400	1000	700	520
Piston alloy Al, Si (toughened)				1400	1000	700	520
G Al-Si				1250	900	650	480
Other aluminium castings		up to 290		1150	840	600	430
		290 to 420		1400	1000	700	520
Wrought aluminium alloys		420 to 579		1700	1220	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	—

***See ISO 4964.**

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 (in m/s) = π × cutting diameter (in m) × spindle speed (in r/s)

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

(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 ≈ $0.6F_s$. (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 figures 1 to 3. It lies perpendicular to the spindle axis when facing, i.e. F_p in figures 1 to 3.

(4) Separating force ≈ $0.25F_s$ and may usually be neglected. The separating force lies perpendicular to the spindle axis when cylindrical turning or boring, i.e. F_p in figures 1 to 3. It lies parallel to the spindle axis when facing, i.e. F_v in figures 1 to 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 figures 5 and 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 specifications**	***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)	
Alloy steels		709 M 40 (En 19) 817 M 40 (En 24) 826 M 40 (En 26)	6 to 6.5
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)	1100	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***	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

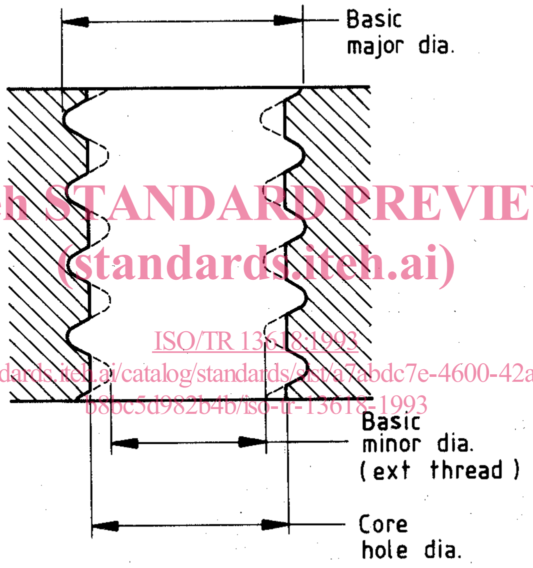
*See ISO 4964.

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 x 0.5	0.1
M4 x 0.7	0.22
M5 x 0.8	0.35
M6 x 1	0.63
M8 x 1.25	1.3
M10 x 1.5	2.2
M12 x 1.75	3.5
M16 x 2	6.0
M20 x 2.5	11
M24 x 3	19
M30 x 3.5	31
M36 x 4	48
M42 x 4.5	69
M48 x 5	96
M56 x 5.5	133
M64 x 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		
1/4	26	0.6
5/16	22	1.1
3/8	20	1.6
1/2	16	3.2
5/8	14	5.1
3/4	12	8.1
7/8	11	11
1	10	15
1 1/8	9	20
1 1/4	9	23
1 1/2	8	34
1 3/4	7	51
2	7	58
2 1/4	6	86
2 1/2	6	96
3	5	161
3 1/2	4 1/2	227
4	4 1/2	261

(d) B.S.F.

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

(e) B.S.P.

Nominal diameter	Outside diameter	threads per inch	C_m
in	in		
1/8	0.383	28	0.9
1/4	0.518	19	2.5
3/8	0.656	19	3.2
1/2	0.825	14	6.8
5/8	0.902	14	7.5
3/4	1.041	14	8.7
7/8	1.189	14	10
1	1.309	11	17
1 1/4	1.650	11	22
1 1/2	1.882	11	25
1 3/4	2.116	11	28
2	2.347	11	31
2 1/4	2.587	11	34
2 1/2	2.960	11	39
2 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 1/8		12.4	7.5	5
1 1/4		13.8	8.3	5.6
1 3/8		15.3	9.2	6.2
1 1/2	34	16.7	10.1	6.8
1 3/4	40	19.6	11.8	7.9
2	46	23	13.5	9.1
2 1/4	52	25	15.2	10.2
2 1/2	58	28	17	11.4
2 3/4	64	31	19	12.5
3	70	34	20	13.7
3 1/4	76			
3 1/2	82			
3 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:

Axially $\Sigma F_{ax} = F_v + F_{vax}$

axial thrust (drilling)

longitudinal feed force (turning)

Torque $\Sigma M_d = F_s \dfrac{d_z}{2} + Wge + M_{dax}$

drilling torque

static unbalance torque (neglect if nominally symmetrical workpiece)

cutting torque (turning)

Radial force $\Sigma F_r{}^* =$

$(F_s - Wg)^2 + (F_p)^2 + W\omega^2 e$

Dynamic out-of-balance ($\omega = 2\pi N/60$ where N is the spindle speed in r/min) (neglect if nominally symmetrical workpiece)

r.m.s. of cutting forces + deadweight

Tilting moment $\Sigma M_k{}^* =$

$$\sqrt{\left\{(F_s l_z - Wg l_s)^2 + \left(F_v \frac{d_z}{2} - F_p l_z\right)^2\right\}} + W\omega^2 e l_s$$

Moments in F_s plane

Moments in F_p plane

Dynamic out-of-balance (neglect if nominally symmetrical workpiece)

Non-rotating

Rotating

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

$$\Sigma F_{ax} = F_v + F_{vax} + Wg$$

$$\Sigma M_d = F_s \frac{d_z}{2} + M_{dax}$$

$$\Sigma F_r{}^* = \sqrt{\{(F_p{}^2 + F_s{}^2) + W\omega^2 e\}}$$

$$\Sigma M_k{}^* = \sqrt{\left\{(F_s l_z)^2 + \left(F_v \frac{d_z}{2} - F_p l_z\right)^2\right\}} + W\omega^2 e l_s + Wge$$

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**.

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

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

Moment in a vertical plane*

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

NOTE 3. This term replaces $F_s l_z$ in the equations in **2.2.3**.

Moment in a horizontal plane*

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

NOTE 4. This term replaces $F_p l_z$ 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 $F_p = \Sigma F_{pj}$

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

Moment in vertical plane*

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

Moment in horizontal plane*

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

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:

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

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.

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*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:

$\Sigma F_{ax} = 0$;

$\Sigma F_r{}^*$ is evaluated after applying the multiplying factor given in figure 7 to each component;

ΣM_d is evaluated as for an overhung workpiece;

$\Sigma M_k{}^*$ is evaluated after applying the multiplying factor given in figure 7 to each component.

Thus the effect of a tailstock centre is to modify the values of $\Sigma F_v{}^*$ and $\Sigma M_k{}^*$ 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 $\Sigma F_r{}^*$ and of $\Sigma M_k{}^*$ will usually be small. Hence, at present, it is recommended that $\Sigma F_r{}^*$ and $\Sigma M_k{}^*$ 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).

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) × 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 $(2\pi \times 750/60)^2 \times 1.25 = 7711$ 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.

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