

DESIGN OF PARALLEL AXIS STRAIGHT SPUR AND HELICAL GEARS – CHOICE OF MATERIALS AND PRELIMINARY ESTIMATE OF MAJOR DIMENSIONS

1. NOTATION AND UNITS

The notation used in this Item follows as far as possible that proposed in Draft ISO Recommendation No. 889 and followed in British Standard 436: Part 1: 1967, and thus differs from that used in Item No. 77002.

		<i>Familiar British Units</i>	<i>SI Units</i>
a	centre distance	in	m
b	facewidth	in	m
d	reference diameter of gear	in	m
F_t	tangential load per unit facewidth	lbf/in	N/m
f_u	tensile strength of gear material at core	lbf/in ²	N/m ²
f_{us}	effective strength of tooth flank surface (case hardened and surface hardened gears only)	lbf/in ²	N/m ²
M	torque	lbf in	Nm
u	gear ratio (taken as negative for internal gears)	–	–
v_p	tooth speed relative to common perpendicular to axes of mating gears	ft/min	m/s
β	helix angle	degrees	degrees

Subscripts

1	refers to a pinion
2	refers to a wheel

2. INTRODUCTION

This Item is complementary to Item No. 77002 “Design of parallel axis straight spur and helical gears – geometric design”.

Section 4 gives data for gears generated from the 20° flank rack form given in BS 436: Part I: 1967, which enable an initial estimate to be made of the major gear dimensions required for a specified torque and gear ratio.

General guidance only is given on the choice between metallic and non-metallic gear materials.

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3. CHOICE OF MATERIAL

Figure 1 gives guidance on practical limits for torque and speed for different types of material. Table 3.1 gives strength data, other properties and general comments, for materials normally used for gears. Those materials which are most widely used in general engineering are printed in bold type.

Gears of wrought or cast steel, iron, bronze and brass materials have good dimensional stability and large load carrying capacity over a wide temperature range. Unless special considerations such as resistance to corrosion or good bearing properties dictate the choice, ferrous materials are best used.

If tooth failure is caused by bending stress, the relative load capacity of gears made from different steels having the same heat treatment can be obtained from the tensile strength of the core material. Surface fatigue damage is due to a combination of mechanical and thermal stresses. Within each of the groups of metals given in Table 3.1, the resistance of a material to this damage is nearly proportional to the surface hardness of the metal. Because of the relatively shallow hardened layer of nitride hardened components, it is important that sub-surface stresses do not exceed those allowable for the core material. Direct comparisons should not be made between materials having different heat treatment or between different types of materials. Guidance on the relative fatigue strengths of different types of material can be obtained from Reference 7.

Special care should be taken when comparing the load capacity of flame hardened steels. Inconsistencies in the flame hardening process will produce variable load capacities. Although the case strength may be increased the bending strength could be much lower than for similar materials in the normalised condition. Specialised techniques may be necessary to give acceptable results.

Advantages and disadvantages of the different materials used for gears are given in Table 3.1.

3.1 Material Combination

Table 3.1 gives some suitable materials for mating gears.

The use of dissimilar metals for wheel and pinion gives less chance of instantaneous welding of the mating teeth if there is a breakdown of the lubricant. This is not, however, so important when using case hardened materials. If the pinion is made of the material with the higher load capacity the life of the two gears will often be closely matched.



TABLE 3.1 Suitable Materials

Material and Condition	Representative Type or Specification	f_u		f_{us}		Min. Core Hardness B.H.N.	Min. Flank Hardness V.H.N.	Limiting Ruling Section		Comments				
										Economics	Suitable Wheel Material when Pinion Material is from Col. 2	Advantages	Disadvantages	
		10 ³ lbf/in ²	10 ⁶ N/m ²	10 ³ lbf/in ²	10 ⁶ N/m ²			in	mm					
CAST IRON														
As cast	B.S. 821 Ordinary Medium High Grade	26.9 35.8 49.3	185 247 340	– – –	– – –	165 210 220	– – –	¾	20	Cheapest of the ferrous materials. Economic for large gears	Cast Iron	Cheapest for large gears	Should not be used where there are severe shock loads	
CAST STEEL														
As cast	B.S. 3100	78.4	541	–	–	145	–	–	–	About twice the cost of high grade cast iron	Cast Iron	May be cheaper than machining or fabricating large heavy duty gears	Load capacity is less than forged steels of comparable material cost	

TABLE 3.1 (Continued) Suitable Materials

Material and Condition [†]	Representative Type or Specification	f_u		f_{us}		Min. Core Hardness B.H.N.	Min. Flank Hardness V.H.N.	Limiting Ruling Section		Comments					
		10 ³ lbf/in ²	10 ⁶ N/m ²	10 ³ lbf/in ²	10 ⁶ N/m ²			Economics		Suitable Wheel Material when Pinion Material is from Col. 2	Advantages	Disadvantages			
								in	mm						
NORMALISED AND THROUGH HARDENED STEELS															
Carbon steel Normalised	En 8	78.4	541	—	—	145	—	6	150	As cheap as high grade CI but machining cost to be considered	Cast Iron	Cheapest forged steel generally used for gears; easily machined; can be welded	Lowest load capacity of generally-used gear steel		
	En 9	101	696	—	—	201	—	4	100	Slightly dearer than En 8			Cast Steel En 8 En 14B	Not easily welded	
Carbon-manganese steel Normalised	En 14B	85	586	—	—	180	—	6	150	About 1½ times the cost of En 9	Cast Steel En 8	Suitable for welding	Cost more than En 9 but has lower load capacity		
Carbon-chromium steel Hardened and Tempered	En 11	123	848	—	—	250	—	2½	64	About twice the cost of En 9	En 9 En 14B En 21	50 per cent increase in load capacity over carbon steels	Hard to machine accurately. Unsuitable for high class gears or gears with helix angles > 10°		
		146	1010	—	—	290	—	—	—						
Nickel steel Hardened and Tempered	R En 21	105	724	—	—	201	—	4	100	Cheapest of the through hardened steels; 1½ times the cost of En 9	En 9 En 14B	Slightly higher load capacity than carbon steels	Lowest load capacity of the generally-used hardened gear steels		
Nickel-chromium-molybdenum steels		En 24 (S 95) (S 119)	123	848	—	—	250	—	6	150	About 1½ times cost of En 21	En 9 En 14B En 21	Easily machined in this condition		
Hardened and Tempered	T En 27		123	848	—	—	250	—	6	150	Over twice the cost of En 21				En 19
	W En 27		157	1080	—	—	310	—	4	100	Dearest through-hardened steel				En 9 En 14B En 21 En 24 En 27
	Z En 30B (3S28)		224	1540	—	—	440	—	6 (Oil hardened) 2½ (Air hardened)	64					

[†] Letters refer to tensile range symbols for hardened and tempered material as given in B.S. 970 "Wrought steels En Series".
