

SECTION 2, CHAPTER 3

LIMIT SYSTEMS

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Introduction

1. The correct functioning of the component parts of any mechanism depends on their size. Clearance must exist between a rotating part and its bearing to permit lubrication. A shaft that is too small for the bearing or that exceeds the diameter which ensures satisfactory clearance can cause extensive damage. Also, for ease of manufacture and replacement, it is essential that the components of similar mechanisms should be interchangeable. For these reasons, limit systems have been devised which give dimensions of parts most suitable for efficient operation of the mechanism.

2. It is not possible to make a part with theoretically correct dimensions because of imperfection of workmanship and inaccuracy of measurement, but the interchangeability of parts, which is an important feature of modern mechanisms, can be achieved if their dimensions are contained within certain limits.

3. Various limit systems have been devised. Many manufacturers work to limit systems of their own, but for general engineering use the two principal systems employed are the Newall and the British Standard.

4. Both the Newall and the British Standard systems are devised on the "Hole" basis, that is, the hole is made as near to the nominal size as the limits of workmanship demand, while the different types of fit are

obtained by varying the size of the shaft. (The term "shaft" is here used to include bolts, pins, etc.).

5. There are two grades of hole used in the Newall system termed Class A and Class B, the former being machined to finer limits than the latter. In the British Standard, there are four grades for bilateral holes (K.X.Y.Z.) and four grades for unilateral holes (B.U.V.W.), the letters in each case being arranged in decreasing order of limit fineness. (See para. 9 for definitions of unilateral and bilateral.)

Fits

6. There are three principal types of fit: "Interference", in which the shaft is larger than the hole; "Transition", where the shaft and the hole are approximately the same size; and "Clearance", where the hole is larger than the shaft. These are shown diagrammatically (Fig. 1).

7. Thus in the Newall System, for any nominal size, each of the six shafts may be associated with either the A or B hole to give six different fits with each. In the British Standard system for any nominal size, fourteen different shafts may be obtained and each of these may be associated with an appropriate hole in either the bilateral or unilateral range to give fourteen different fits with each. The difference between the high limit of the shaft and the low limit of the hole is called the "Allowance".

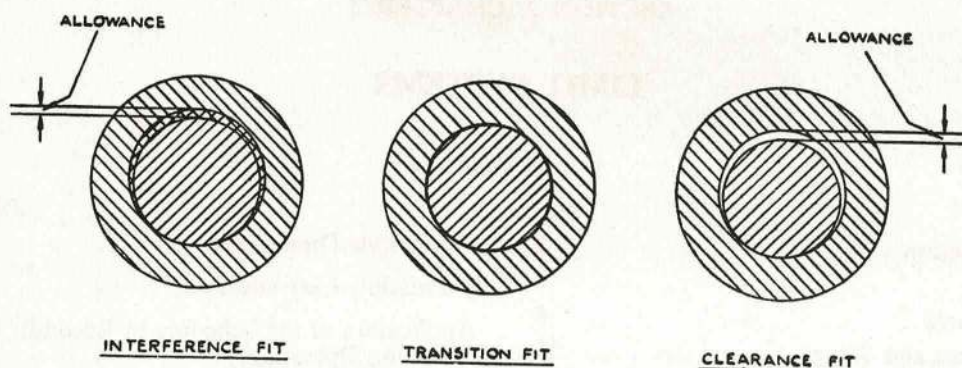


Fig. 1. TYPES OF FIT

The above types of fit are sub-divided in the Newall system as follows :—

Type of Fit	Class of Fit	Shaft Required	Remarks
Interference	Force	(F)	Mechanical pressure is required and once assembled no dismantling is likely to be required.
	Driving	(D)	These are a little less tight than Force Fits, and one part can be driven into the other.
Transition	Push	(P)	Slight manual effort is required to assemble the parts. Suitable for detachable or locating parts but not for moving parts.
Clearance	Running	(X) (Y) (Z)	Suitable for various types of moving parts.

Tolerances

8. As it is not possible to machine either the hole or shaft exactly to a definite size, it is necessary to allow for permissible variations on each. These variations are called "Tolerances". Thus the tolerance on a dimension is the variation tolerated on that dimension, and may be considered as a numerical expression of the desired quality of workmanship ; it is the difference between the high and low limits of size for that dimension. For example, a part that should be exactly 1 in. dia. (nominal size) will be accepted for a certain purpose if it is within the limits of 1.001 in. (high limit) and 0.999 in. (low limit) ; tolerance equals 0.002 in. The nominal size and the tolerance may be expressed as follows, i.e., 1.000 ± 0.001 in., but sometimes the nominal size is not given, only the low and high limits, e.g.

$$\begin{array}{r} 0.999 \text{ in.} \\ 1.001 \text{ in.} \end{array}$$

9. Tolerance may be allowed in one of two ways. For example, a 4 in. dia. hole with a tolerance of 0.004 in. could be produced within the following limiting sizes:—

$$\left\{ \begin{array}{l} 4.004 \text{ in. high limit} \\ 4.000 \text{ in. low limit} \end{array} \right\} \text{ or } \left\{ \begin{array}{l} 4.002 \text{ in. high limit} \\ 3.998 \text{ in. low limit} \end{array} \right\}$$

In the first instance, the tolerance is all in one direction, the low limit being the nominal size ; this is therefore called a "Unilateral" system. In the second instance, the nominal size of the hole is an intermediate figure, the limits going both above and below it ; this system is therefore called a "Bilateral" system.

10. The diagram shows the tolerance in addition to the limits and nominal dimension for a clearance fit using bilateral limits and a hole basis. The Newall system is a bilateral system ; the British Standard system can be used either as a unilateral or bilateral system.

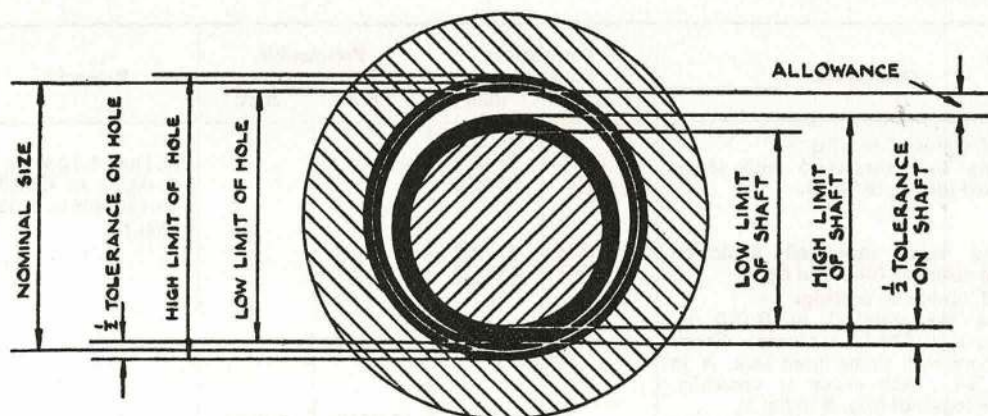


Fig. 2. DIAGRAM OF CLEARANCE FIT

11. Tables giving the limits for holes and shafts on the Newall system are found in A.P. 1464B, Vol. 1, Part 2, Sect. 5, Chap. 5. Similar tables for the British Standard system are in British Standard Specification No.1916, Part 4, 1953.

Clearance and Wear

12. When motion between two parts is required, e.g., a shaft rotating in a bearing the inner part must be smaller than the outer by a definite amount. This positive allowance, called clearance, also permits the use of a lubricant which will prolong the life of the moving parts. Eventually wear will reduce the size of one member (shaft) and increase the size of the other (bearing), which will cause the clearance to increase, and the shaft or bearing may become unserviceable because its size has worn beyond the "permissible worn dimension." If the clearance has

become too large because of wear on both parts, these parts may no longer be used together, although each individually may be within the permissible worn size. Therefore, both the size of a part and its clearance in the other part must be taken into consideration when determining serviceability.

Schedule of Fits and Clearances

13. A Schedule of Fits and Clearances for each mechanism is laid down in Volume 6, Part 3, of the relevant Air Publication, to which reference should be made as necessary. An extract from one such publication is set out below as an example. The diagrams referred to are included in the schedule to show exact details of the part concerned.

14. **Permissible Dimensions.** The figures given in the column 'Permissible Dimensions' represent the minimum and maximum dimen-

Description	Permissible dimensions		Permissible clearances		Remarks
	in.	mm.	in.	mm.	
<i>Crankpin and connecting-rod big-end</i>					
Crankpin, standard dia.	2.2485	57.112			
	2.249	57.125			
1st undersize (0.010 in., 0.254 mm.) ..	2.2385	56.858			Surface finish not to exceed 16 micro-inches.
	2.239	56.871			
2nd undersize (0.020 in., 0.508 mm.) ..	2.2285	56.604			
	2.229	56.617			
3rd undersize (0.030 in., 0.762 mm.) ..	2.2185	56.35			Crankpin width must not exceed 1.5785 in. (40.095 mm.) after re-grinding.
	2.219	56.363			
Crankpin radii of 5/32 in.—0.000, +1/64 in. (3.9687 to 4.3656 mm.) must be maintained.					
Crankpin, standard width	1.562	39.675	0.0095	0.2413	
	1.5635	39.713	0.013	0.3302	
Big-end bearing width	1.5505	39.383			
	1.5525	39.433			

Description	Permissible dimensions		Permissible clearances		Remarks
	in.	mm.	in.	mm.	
Big-end, standard bearing:— Boring size, measured with shims fitted (dia. A in fig. 3).	2.255 2.2565	57.277 57.314			Shim thickness 0.00275 to 0.00325 in. (0.0698 to 0.0825 mm.)
Finished bore, measured vertically, shims removed (dia. B in fig. 3).	2.25225 2.25325	57.207 57.232			
Big-end, undersize bearings:— These are supplied in 0.010 in. stages to 0.030 in. undersize. Check the bore with shims fitted (dia. A in fig. 3); then check it vertically, shims removed (dia. B in fig. 3).					
Crankpin running clearance in big-end bearings.			0.00325 0.00475	0.0825 0.1206	
Tightening torque for big-end nuts is 70 lb. ft. (9.7 kg./m.).					

sions of new parts; the difference between these dimensions is known as the manufacturing tolerance.

15. Permissible Clearances. The figures given in the column 'Permissible clearances' represent the minimum and maximum clearances obtainable when new parts are assembled. For example, if a new shaft made to the maximum dimension of 0.499 in. is assembled in a new bush bored to the minimum dimension of 0.500 in., the clearance will be 0.001 in. Conversely, if a new shaft made to the minimum dimension of 0.498 in. is assembled in a new bush bored to the maximum dimension 0.5015 in., the clearance will be 0.0035 in.

16. Application of the Schedule to Reconditioning Operations. The dimensions of new parts, together with the clearances between

these parts, should be used by the tradesman as standards with which he can compare the dimensions and clearances of the parts he is viewing. For example, if the tradesman is viewing a bush and its corresponding shaft, he may find, by comparison with the 'new' dimensions, that most of the wear has taken place in the bush and therefore it is necessary to renew the bush only. Conversely, if most of the wear has taken place on the shaft, it may be necessary to renew the shaft only.

17. The question of whether or not to renew a part, is one on which the tradesman must exercise his discretion, except in cases where it is laid down that mating parts must both be renewed. Only those parts that may be regarded as having a reasonable expectation of life should be refitted.



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