

A GUIDE TO THE SELECTION OF CAM AND FOLLOWER TYPE

1. INTRODUCTION

1.1 Introductory Notes

This document is one of the comprehensive series of Engineering Sciences Data Items (see References 2 to 17) that deals with the design of cam and follower systems and gives a guide to the selection of cam and follower type. The user is presented with the various types of cam and follower configurations available, and is then guided into selecting the configuration which best suits his own particular application. The selection of a suitable cam and follower type, along with the selection of a suitable cam law (see Reference 3), forms the basis of the mechanism design process.

A cam, rotating or translating, is a mechanical member which by direct contact transmits a desired motion to a follower by virtue of its profile shape. In general the cam drives the follower and the arrangement of a cam and its follower constitutes a conjugate pair and for most practical purposes must be considered together.

The selection of a cam and follower configuration is governed by several factors; two fundamental factors are the type of input motion available and the type of output motion required. The input motion may be rotating or translating and the output motion may be translating or swinging, or for example in the case of indexing configurations the output motion may be a uni-directional intermittent rotation. This Item only deals with rotating cams which produce straight line or oscillatory follower motion. Other factors governing choice are the machine space available, the rate of follower lift and total lift requirement, the cam operating speed and lubrication requirements.

Having decided on a particular cam and follower configuration the user must then choose a suitable cam law (see Reference 3) to obtain the correct performance of the follower output motion. A cam law is the term given to a mathematical expression which defines follower motion and hence is a major factor in determining the shape of the cam profile. However, it must be noted that for the same cam law different followers will give rise to different cam shapes. If a particular cam law produces the required performance over only part of the motion segment, other cam laws can be used as required for other parts of the motion segment to meet the complete requirement. References 1, 6, 11 and 13 give comprehensive approaches to combining cam laws.

For a cam and follower configuration to achieve its designed performance, contact between the two must be maintained at all operating speeds. To achieve this there are two means available, force closure and body or desmodromic closure. Force closure relies on an external force to maintain the contact between the follower and the cam, applied to the follower by gravity or more commonly a spring. Body closure is provided by having contact between the cam and follower for both directions of their relative motion. There are specific cases, during a dwell, where it may be desirable to have clearance between the cam and follower.

It must be noted that the performance of any of the cam laws discussed within the series of Items on cam design will not be achieved in practice if the manufacturing facilities and techniques available to the user are not able to produce the accuracy required (Reference 18).

1.2 Use of this Item

The cam and follower configurations covered by this Item are classified according to the nature of the output motion they produce and the user decides which class is required according to the cam input motion and the required follower output motion. Having decided on the class, this Item may well present the user

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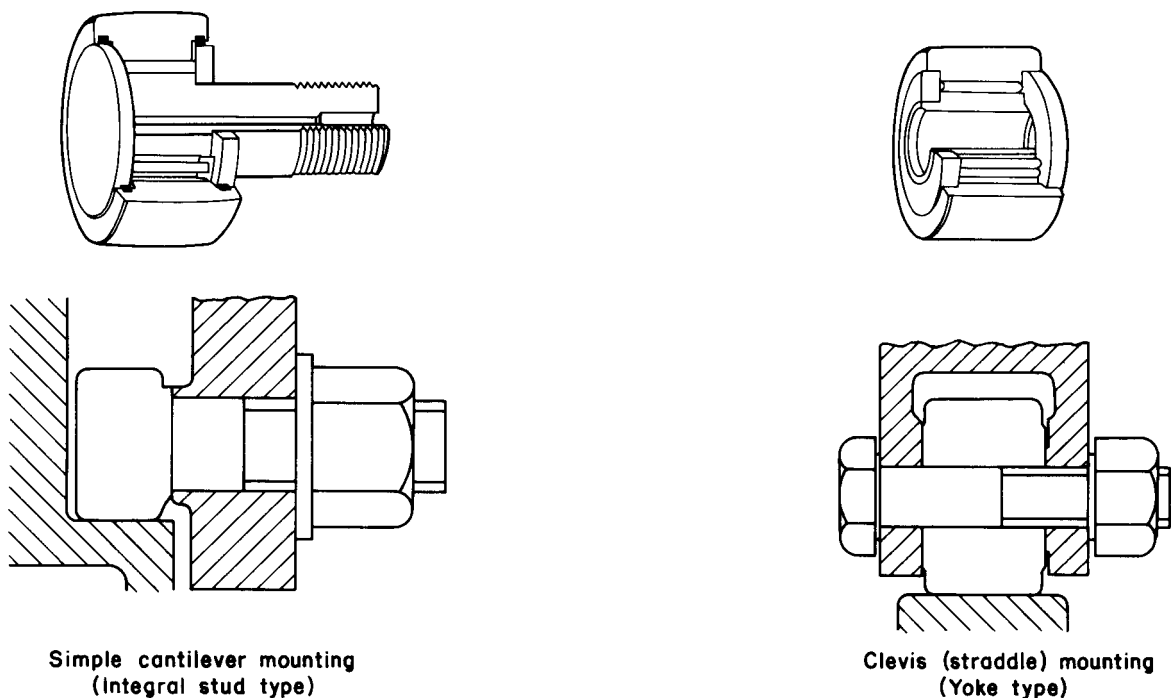
with more than one cam and follower configuration capable of carrying out the required task. Further guidance towards the most suitable configuration is then given by the consideration of a variety of factors, and any problems which might arise from the configuration selected are then highlighted.

The cam and follower configurations have been divided into two main classes; translating follower motion (Section 2) and swinging follower motion (Section 3).

2. TRANSLATING FOLLOWER MOTION

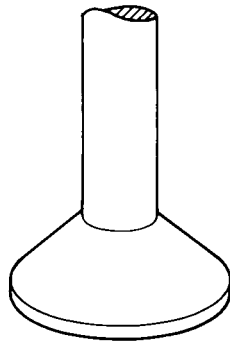
A follower is termed 'translating' if it is constrained to move in a straight line throughout the cycle of the cam. There is a choice between curved foot (usually roller) followers and flat faced followers. Three types of roller followers available for use are those with crowded needle bearings, caged needle bearings and plain bearings.

The features which govern the choice of a roller follower or a flat faced follower are discussed in this Section of the Item. Sketch 2.1 shows two different ways of mounting a track roller onto a follower. Sketch 2.2 shows a flat faced follower and a curved faced follower which must not rotate.

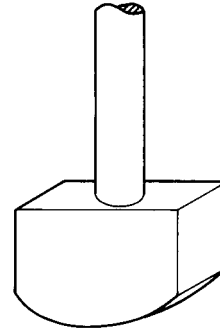


Sketch 2.1

The cam and follower configurations which produce translating follower motion can be further classified into two groups, those which produce follower motion in a plane perpendicular to the cam axis of rotation and those which produce follower motion in a plane parallel to or in-line with the cam axis of rotation.



(a) Flat faced follower



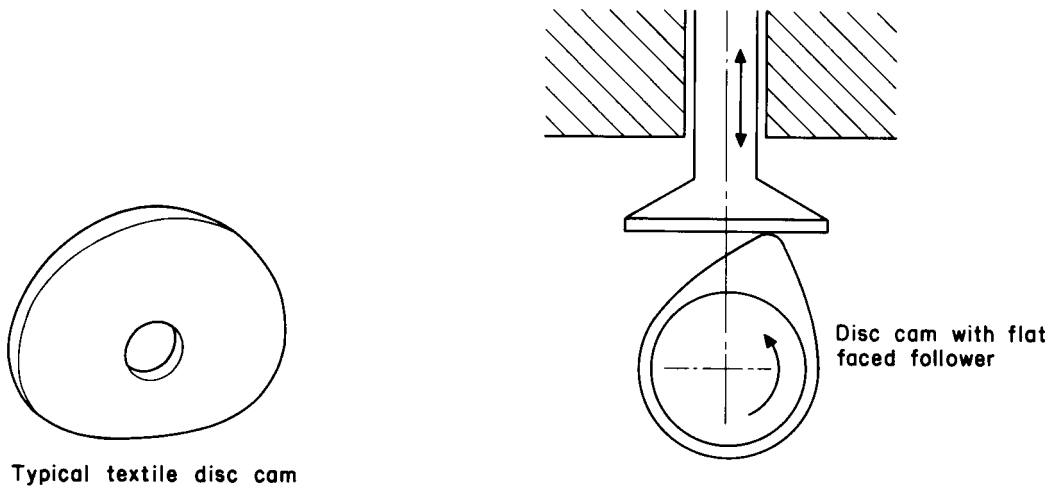
(b) Curved faced follower

Sketch 2.2

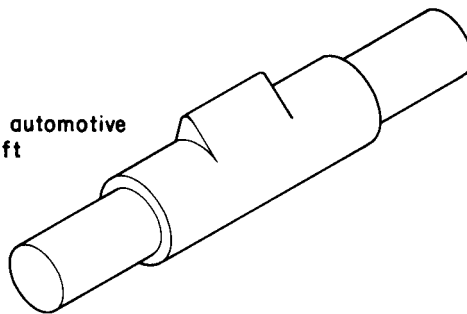
2.1 Translating Follower Motion in a Plane Perpendicular to the Cam Axis of Rotation

2.1.1 Disc cam

Sketch 2.3 shows typical disc cams and a disc cam in conjunction with a flat faced follower. The cam is shown together with a flat faced follower but in fact can be used in conjunction with any of the follower types shown in Sketches 2.1 and 2.2 or with swinging followers (see Section 2.2.1). To maintain contact between the cam and follower, force closure (generally by a spring) must be used. The disc cam is commonly used.



Typical automotive camshaft



Sketch 2.3

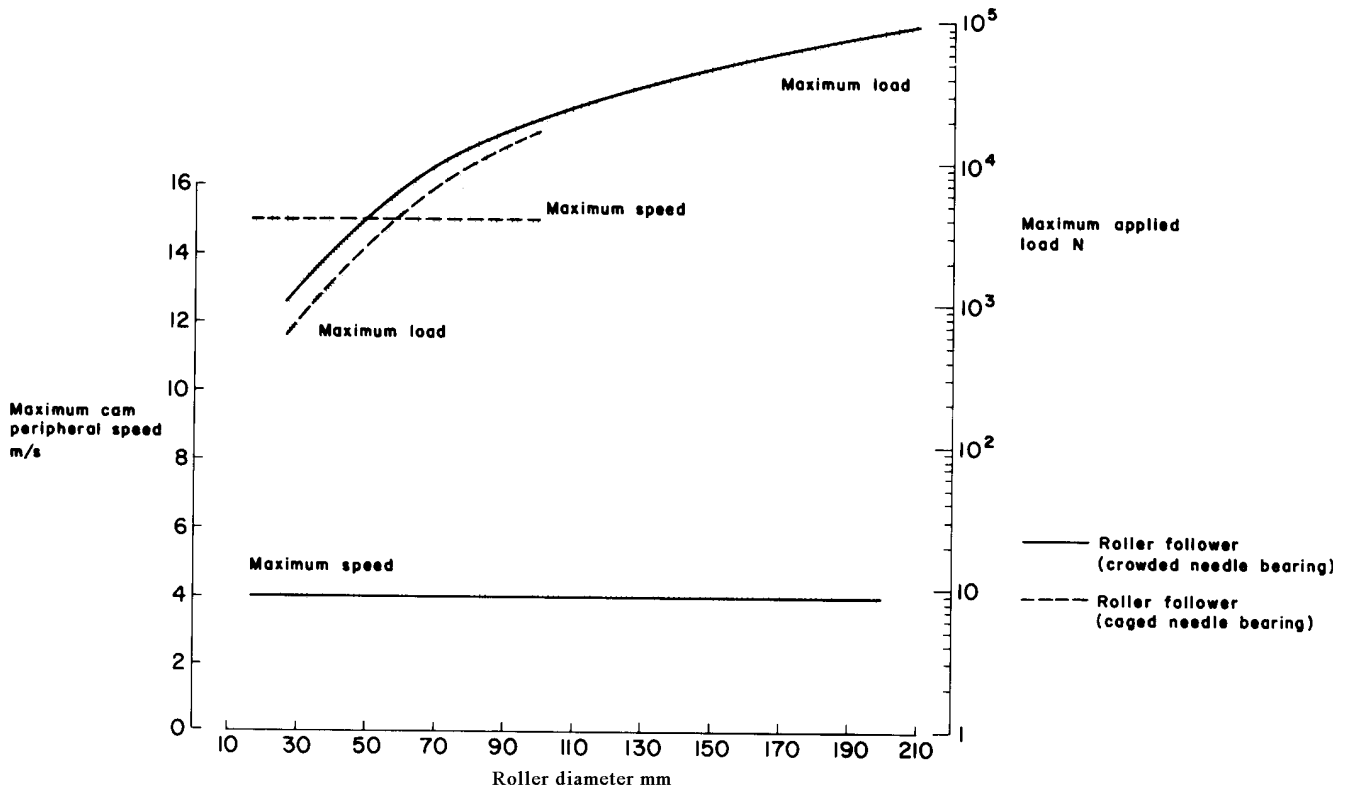
2.1.2 Follower selection

Table 2.1 gives a comparison between the design criteria of roller and flat faced followers for the same lift and segment angles for rise and fall.

TABLE 2.1

	ROLLER FOLLOWER	CURVED FOOT FOLLOWER	FLAT FACED FOLLOWER
CAM SPEED	Sketch 2.4 shows the speed and load limits recommended by one supplier for roller followers (crowded needle and caged needle bearings).	There is no theoretical upper limit to the cam speed provided that lubrication is adequate to limit temperature rise (see below). Automobile and aircraft engines provide examples of high speed applications that have proved reliable.	
LOAD	Comparison with other suppliers shows these to be typical.	The maximum allowable loads for sliding followers are dependent upon the material used, the working width of the follower and the lubrication available.	
LUBRICATION	With needle bearings a roller is capable of operating under conditions of intermittent lubrication.	Essential to prevent high local temperature and metal to metal contact which cause wear. Lubrication must be available on starting up and needs replenishing during operation. Generally, a high working oil viscosity is desirable with a copious supply of lubricant for the best results. Scuffing (see Section 2.1.3) is liable to occur when the local metal temperature exceed about 200°C. Additives improve the overall performance of an oil. Viscosity index improvers, anti-oxidant and detergent additives are the main types of anti-scuffing additives. Reference 10 shows the effect of these on cam performance. For the best results, oil should be supplied at the lowest practical temperature.	
MACHINE SPACE	Require the most machine space.	For the same application, generally weigh less and take up less space.	
AVAILABILITY	Available 'off the shelf'.	Can readily be made an integral part of the machine, easy to manufacture.	
PRESSURE ANGLE [†]	High values of pressure angle may cause poor performance and the possibility of jamming of the follower in its guide.	Pressure angle is constant and this type of follower can accommodate steep cam profiles without risk of jamming.	
CAM PROFILE	Can result in cams having reverse curvature, though care must be taken in selecting the radius of the roller or curved foot to avoid undercutting (inability of the roller to follow the cam profile).	Not suitable for use with cams having reverse curvature. However, when designing cams from cam laws this problem will not occur. Gives rise to a larger cam.	
MISALIGNMENT AND STRESSES	Surface stresses tend to be much higher, however there is a reduction in sliding wear when using a roller follower. Rollers and curved foot followers generally have a slightly crowned surface. This slight barrelling allows for small misalignments of the follower and also reduces contact stress at the follower or cam edge. Barrelled roller followers give a much better correlation between calculated and achievable contact stresses than cylindrical roller followers.	To avoid edge loading, a large radius spherical crown may be used instead of a flat face. The follower centre line may be slightly displaced from the axial centre line of the cam to encourage rotation of the follower, resulting in the wear being spread evenly and life being prolonged.	
		A curved foot follower may be used in place of a roller follower, but as with the roller follower it must be constrained against rotation in its guide.	

[†] Angle between the direction of motion of the follower and normal to the cam profile at the point of contact.



Sketch 2.4

2.1.3 Common modes of failure

When using a roller follower on a cam operating at low speeds the motion of the roller is in general pure rolling. At higher speeds of cam rotation it is essential to make the roller as light and with as small a diameter as practicable, giving minimum moment of inertia of the roller thus reducing the danger of sliding between the roller and the cam during changes in velocity.

When using flat faced followers three main forms of failure occur: pitting, scuffing and polish wear.

Pitting is a failure of the surface, manifested initially by the breaking-out of small roughly triangular portions of the material surfaces. This failure is primarily due to high contact stresses.

Scuffing is the local welding together of two heavily loaded surfaces, particularly when a high degree of relative sliding occurs under poor lubrication conditions, followed by the tearing apart of the welded material. Surface treatments are available which reduce the likelihood of scuffing.

Polish wear is the general erosion of the contacting surfaces. If the conditions which cause pitting and scuffing are avoided (see Table 2.1) polish wear will be small, but occasionally very rapid wear can occur.

Roller followers are much less prone to polish and scuffing wear than flat faced followers.