Curvic® Coupling Design

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Rochester, New York

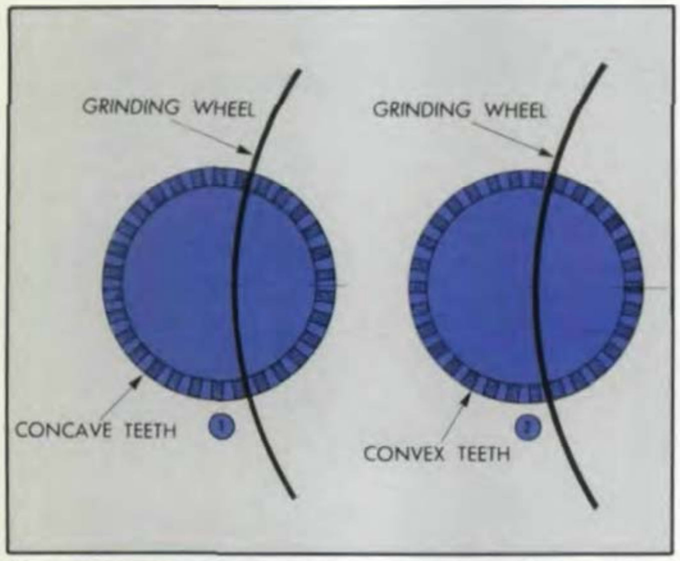


Fig. 1 – Left, a cross-section view taken perpendicular to the axis of a concave Curvic Coupling. Right, the mating convex Curvic Coupling. Note the curved teeth.

Introduction

Curvic Couplings were first introduced in 1942 to meet the need for permanent couplings and releasing couplings (clutches), requiring extreme accuracy and maximum load carrying capacity, together with a fast rate of production. The development of the Curvic Coupling stems directly from the manufacture of Zerol® and spiral bevel gears since it is made on basically similar machines and also uses similar production methods. The Curvic Coupling can therefore lay claim to the same production advantages and high precision associated with bevel gears.

The term "Curvic Couplings" refers to toothed connection members with the teeth spaced circumferentially about the face and with teeth which have a characteristic curved shape when viewed in a place perpendicular to the coupling axis (see Fig. 1.). This curvature exists because the members are machined with a face-mill cutter or a cup-type grinding wheel. One member is made with the outside edge of the cutter or wheel as shown at the left of the figure, and a concave, or an hour-glass shaped tooth is produced. The mating member ing a convex, or barrel-shaped tooth. The radius of the cutter or the grinding wheel surface is chosen in such a way that the teeth will either mate along the full face width of the tooth or along only a section of the face width, as desired.

The three basic types of Curvic Couplings are (1) the Fixed Curvic Coupling, (2) the Semi-Universal Coupling, and (3) the Releasing Coupling (or clutch). The coupling provides a positive drive along with precision centering and high load carrying capacity.

Fixed Curvic Couplings

The Fixed Curvic Coupling is a precision face spline for joining two members, such as two sections of a shaft, to form a single operating unit.

The fixed Curvic Coupling is used extensively in the construction of built-up turbine and compressor rotors for air-

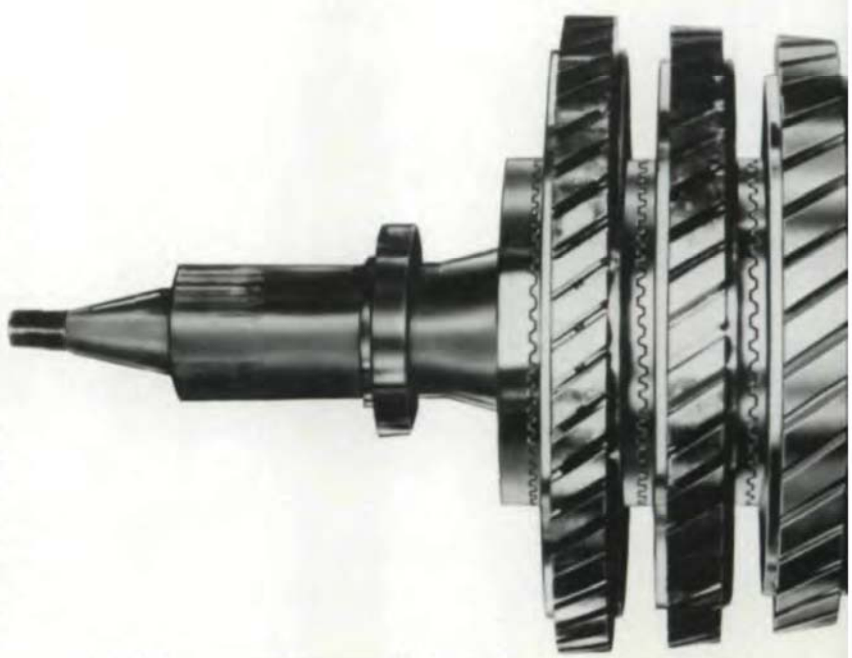


Fig. 2 – A compressor rotor assembly for an aircraft jet engine. The Fixed

craft and industrial gas or steam turbine engines as shown in Figs. 2, 3, and 4. Figs. 5 and 6 show a method of joining a turbine impeller or a bevel gear to a shaft. Crankshafts can be made of separate, interchangeable parts by means of a coupling as shown in Fig. 7.

The Fixed Curvic Coupling is also used today by many major machine tool manufacturers for precision indexing mechanisms as illustrated in Figs. 8 and 9.

Semi-Universal Couplings

The Semi-Universal Coupling is also a precision face spline loosely coupled to permit up to 2° misalignment of shafts together with axial freedom. The teeth of one member usually have a curved profile to keep the load localized in the middle of the tooth and to transmit more nearly uniform motion.

Fig. 10 illustrates an application of semi-universal couplings and shows the typical tooth shape.

Releasing Couplings (Clutches)

The Releasing Couplings are designed and made so that the proper tooth contact is maintained while the clutch engages and disengages. In the larger sizes, a helical surface is used to accomplish this. On small clutches, this action is approximated by a special localized tooth bearing. The two members of a shift or overload clutch are usually held in position by spring pressure. By adjusting the amount of pressure, the amount of torque which can be transmitted without disengagement of the clutch can be controlled. Shift clutches are used today in a wide variety of applications including aircraft, automotive, farm equipment and power tools.

The application shown in Fig. 11 can be produced by cutting or grinding, depending on accuracy required.

Design Features

The basic geometry of the Curvic Coupling has been given in Fig. 1. The grinding wheel sweeps across the face of the coupling contacting one side of one tooth and the opposite side of another tooth in a single engagement. During one complete revolution of the work, the machining of the Curvic Coupling is completed.

The radius of the grinding wheel, the number of teeth, and

Fig. 3 – A turbine rotor assembly for a stationary gas turbine. Note the Fixed Curvic Coupling teeth between each disc.

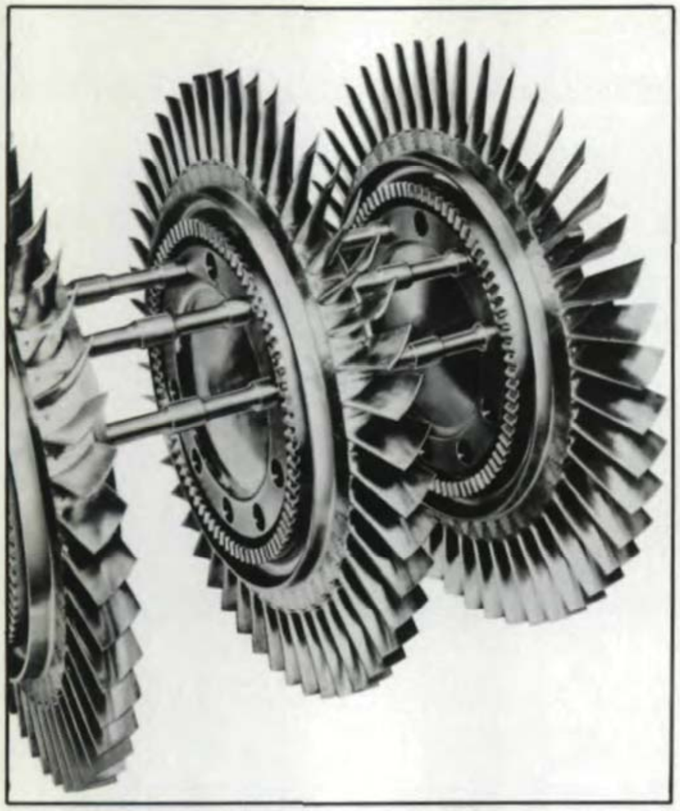


Fig. 4 – A stationary gas turbine rotor showing the through bolts used for clamping the Fixed Curvic Coupling members together.

Fig. 6 – Curvic Couplings are used to enable separate manufacture of bevel gear and long shaft.

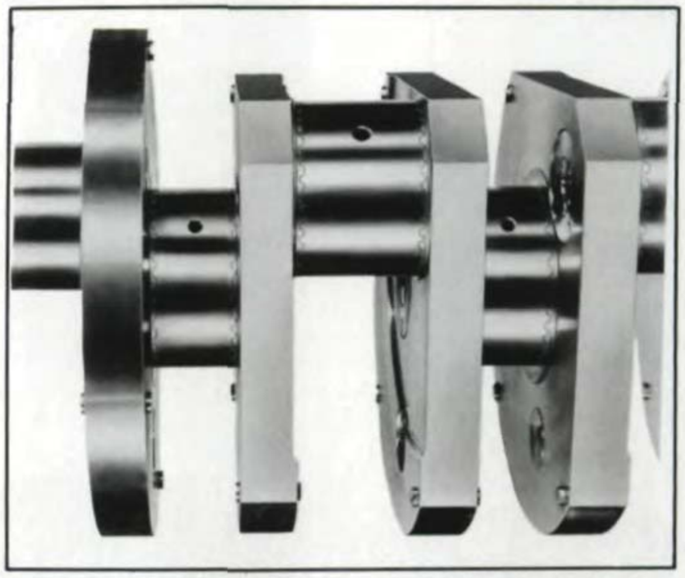


Fig. 7 – A section of a crankshaft showing the Fixed Curvic Coupling. Crankpins, crankwebs and journals were made separately for ease of manufacture and handling.

The basic relationship is as follows:

n_x = number of half pitches included between two engagements of grinding wheel.

N = *number of teeth in Curvic Coupling.*

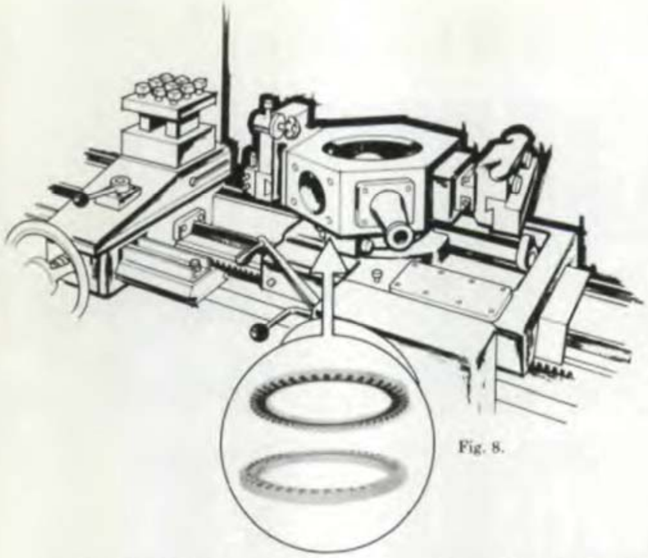
r = radius of grinding wheel.

A = mean radius of Curvic Coupling.

$$\text{then } \beta = \frac{90° \times n_x}{N}$$

$$\text{and } r = A \tan \beta.$$

The radius of the grinding wheel can be changed by changing n_x as well as by changing N and A. The diameter of the



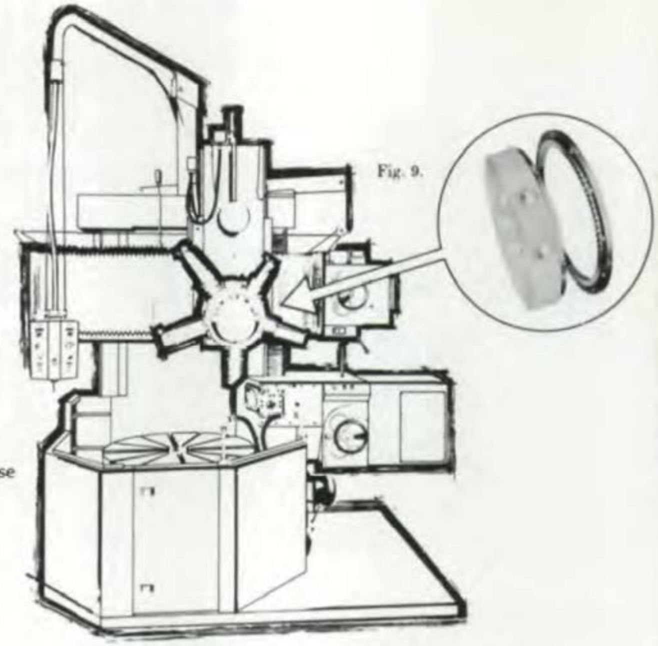


Fig. 8 and 9—The precision accuracy of Fixed Curvic Couplings permits the precise indexing and repeatability required on this horizontal turret lathe (Fig. 8) and vertical turret lathe (Fig. 9).

and 21". The maximum Curvic Coupling diameter produced is 50" and the smallest diameter is 0.375".

Curvic Coupling teeth can be produced with a wide range of pressure angles to suit the application.

A view of ground Fixed Curvic Coupling teeth at the outside diameter is shown in Fig. 13. The chamfer on the top of the teeth is automatically ground as the tooth slot is being ground. The chamfer permits a larger fillet radius to be used, thus strengthening the teeth. Also shown is the characteristic gable bottom which eliminates any possibility of forming a stress-raising step in the root of the tooth. Fig. 14 shows the tooth configuration of a typical Curvic Coupling.

As can be seen in Figs. 1 and 12, the space between two adjacent Curvic teeth is ground at two different locations on the wheel to obtain the proper taper of the tooth toward the coupling center. The grinding wheel then must be wide enough to cover at least half of the tooth space width at the outside diameter and still be narrow enough to pass through the space at the inside.

To do this, the inside diameter of the coupling must be equal to, or greater than, 75% of the outside diameter.

Another design feature of Fixed Curvic Couplings permits localization of the tooth contact area. The tooth contact for most applications should be centrally located and the length of contact should be approximately 50% of the face width when checked with the mating control coupling under light pressure. The type of application and method of bolting determine the tooth bearing length which should be used. Under pressure of the bolting load the tooth bearing area will increase, thus insuring a uniform distribution of contact over

coupling, it is usually necessary that the blank design contain no projections beyond the root line of the teeth. For proper clearance, the nearest projection should be at least $^{1}/_{32}$" below the root line.

In designing a Fixed Curvic Coupling it is essential to consider the method of bolting or clamping the two members. The tension in the bolt or bolts must be sufficient to keep the coupling teeth in full engagement under all conditions of operation. Furthermore, the bolts must have clearance throughout their entire length so that centering is accomplished only by the Fixed Curvic Coupling teeth.

In selecting the required coupling size, three items determine the load which the coupling teeth will carry. The teeth must (1) be strong enough so they will not shear, (2) have sufficient surface area to prevent pitting, galling, and fretting corrosion, and (3) be supported by adequate material to withstand tension across the root of the tooth space.

The shear strength is dependent upon the cross-sectional area of all the teeth. Since there is no backlash in a Fixed Curvic Coupling, the teeth are in intimate contact so that half of the metal is ordinarily removed in both members, regardless of the number of teeth or their depth. With this condition, the torque load is carried over a shear area approximately half as large as in a one-piece hollow shaft.

The allowable surface loading will depend on the contact area of the coupling teeth. Standard tooth proportions are used to maintain a constant area for a given coupling diameter regardless of the number of teeth. This area is sufficient to carry a load corresponding to the safe load in shear, and the proportions are varied only in special cases.

Fig. 10 – A Curvic Coupling of the semi-universal type is employed at both ends of this intermediate drive shaft.

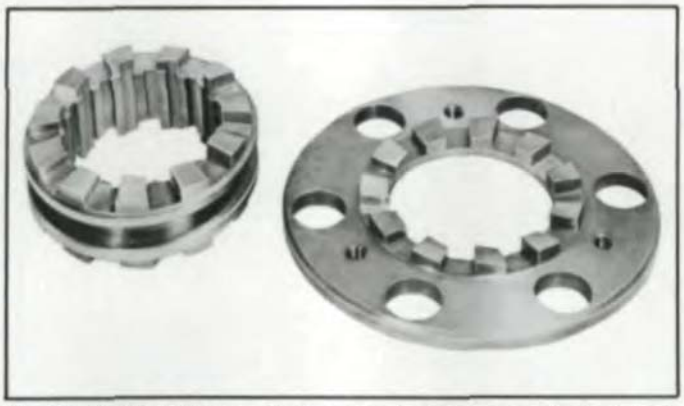


Fig. 11 – A shift clutch for a truck application. The tops of the teeth have generated helical surfaces.

forces the coupling members together causing a wedging effect between the mating teeth. This wedging effect creates a tensile stress in the blank under the tooth space. An increased amount of backing material will decrease this stress within limits.

Design Procedure

After considering the type of Curvic Coupling required to meet the needs of a given application, it is possible to determine the approximate size which is necessary to transmit a specified load.

For initial size determination on Fixed Curvic Couplings either Graph 1 or the following formula can be used:

$$D = \sqrt[3]{\frac{T}{1310}} \quad \text{where } D = \text{coupling diameter (inches)}, \; T = \text{torque (lb-inches)}$$

This assumes that the face length is .125 times the coupling diameter or .875", whichever is smaller, and a material with an ultimate strength of 150,000 P.S.I. is employed. Graph 2 applies to Semi-Universal Curvic Couplings and

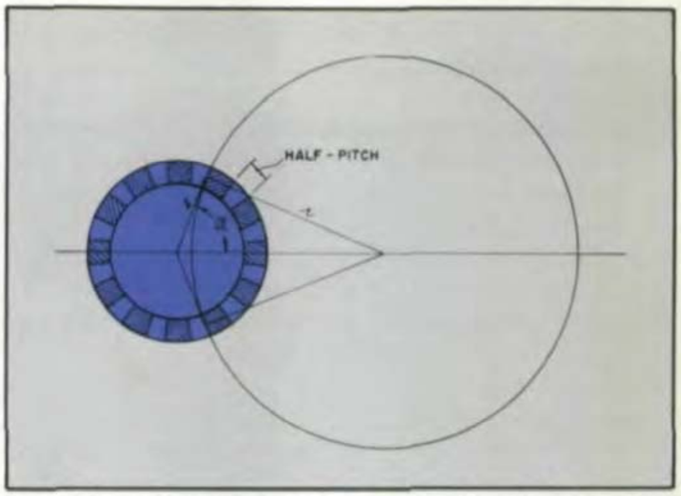


Fig. 12 – Diagram illustrating the basic geometry of the Curvic Coupling.

disengaged only while standing still, use the Graph 1. Graphs 2 and 3 are based on the use of case-hardening steel at 60 Rockwell "C".

The maximum torque value during operation should be used in the above determination. If, however, there is a peak starting torque or other peak overload torque which occurs very infrequently during the life of the unit and does not exceed 5 seconds duration at any one time, this peak value should be divided in half and compared with the maximum operating torque. The higher of these two values should be used to determine coupling size.

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