The present invention relates to variable speed friction gears and, more particularly, those of the kind basically employing a rotary driving disc, a rotary driven disc spaced therefrom, and a rotary intermediate disc arranged to contact frictionally the driving and driven discs to transmit the drive between them, the speed transmission ratio being variable by moving the position of the intermediate disc relatively to the others so that these latter will each contact the working face of the intermediate disc at an adjusted position. It is to be noted that where reference is made above, and in the following specification, to a "disc" this term is intended to include equivalent rotary members, e.g. spoke-provided or other forms of annulus, capable of fulfilling the functions to be hereinafter explained.

The improved gear according to the present invention is of the kind set forth above and is characterised by the fact that the contact face of the intermediate disc is of domed form (i.e. is of curved convex form in all diametral planes thereof) and that the driving and driven discs are arranged to make point contact with this domed face.

In constructing such a gear to operate under optimum conditions, the intermediate disc is mounted for rocking about a predetermined center, when moved for varying the transmission ratio, and it is arranged so that the points of contact between the driving and driven discs and the intermediate disc are maintained in the same plane as this center, in all positions.

An intermediate disc contact face fulfilling the required function is a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about the said center, each in turn with successive, equi-angularly-spaced radii from said center, and an appropriate shape can therefore be obtained following this requirement.

The aforesaid center may be a pivot point or fulcrum on which the intermediate disc is mounted for rocking movement in any direction (thus, in universal fashion).

An equivalent arrangement comprises the provision of the disc with a part-spherical seating on a corresponding mounting, the center of the sphere representing, in this latter case, the center referred to.

Other alternative mountings fulfilling the requisite condition, which may be employed are, for instance, spring mountings of various forms, resilient mountings in rubber or like material, and trunnion mountings.

It will also be understood that various forms of gear can be developed from the above principles (and examples will hereinafter be described) including the use of a pair of intermediate discs in conjunction with one driving and one driven disc, and a plurality of transmission sets in a single gear.

Other constructional features of the invention will be described hereinafter.

Several constructional forms of the invention are shown, by way of example, on the accompanying drawings, wherein:

Figure 1 is an elevation of a simple construction and is intended mainly to illustrate the principle of the invention;
Figure 2 is an end elevation;
Figure 3 is a section on the line A—A in Figure 1, showing the intermediate disc adjusted laterally to a different working position;
Figure 4 illustrates a method of determining the contour of the working face of the intermediate disc;
Figure 5 is an elevation of a modified construction which comprises a single pair of opposed, cooperating intermediate discs between which the driving and driven discs are frictionally engaged;
Figure 6 is a sectional on the line B—B in Figure 5;
Figure 7 is a part sectional plan view of a modified construction which comprises a number of driving/drawn disc pairs, each associated with two opposed, cooperating intermediate discs;
Figure 8 is an elevation, partly in section, of a construction of epicyclic type.

Figure 9 is a section on the line C—C in Figure 8 but with a portion of the end plate of the driving machine included.

Referring first to Figures 1 to 3:

The simple constructional form of the invention shown in these figures comprises an angle support 1, in the vertical flange 2 of which two parallel, spaced shafts 3 and 4 are rotatably carried. A driving disc 5 is fixed upon one of the shafts, say the shaft 3, and a driven disc 6 is fixed upon the other shaft 4. The base of the support is provided with longitudinal guideways 7 which are disposed at right angles to the axes of the two shafts. A carriage 8 is slidably mounted upon the guideways and can be adjusted to and fro along the same by means of a longitudinal threaded rod which is fitted with an operating handle 9 and is engaged in a nut (not shown) carried by the carriage.

The externally-threaded shank 10 of an intermediate shaft 11 is engaged in a threaded hole formed in the vertical flange 12 of the carriage, the axis of the shaft being parallel to the axes of the driving and driven shafts 3 and 4, and the axes of the three shafts lying in the same plane. Means, such as a nut 13, are provided for locking the intermediate shaft in its axially-adjusted position in the carriage. The inner end 14 of the intermediate shaft is pointed and is engaged in a tapered bearing 15 of a larger angle formed in the concave face 16 of the concave-convex intermediate or drive-transmission disc 17, wherefore the latter is capable of a degree of universal rocking movement on the pointed tip 14 of its support.

The contact face 18 of the disc 17 is domed and in order to obtain the desired point contact between this face 18 and the peripheral edges of the driving and driven discs 5 and 6, and to fulfill certain other conditions set out below, this contact face should represent the surface of revolution of a particular curve. A method of determining this curve is illustrated in Figure 4 which gives the shape of the working face of the disc on a section through the center taken at 90 degrees to the face. It also gives the relative position of the pivot point. It is most important that this should be adhered to in order that the point whilst holding the discs in frictional contact, falls on a line drawn between the points of contact on the peripheral edges of the driver/drawn discs with the intermediate disc. This must hold true throughout the adjustment range. Any divergence of the pivot point from this line would cause a load on the drive to exert a tipping effort on the intermediate disc. It is equally important that the point should at all times lie in the plane between the driver/drawn shafts. Unless these conditions are fulfilled true rolling action between the
discs cannot be secured. It will be apparent from the foregoing that no axial movement of the pivot point occurs as the speed ratio is altered, and in those forms of construction later to be described wherein the pivot point is replaced by a part spherical seat, sliding of discs and settings along these shafts is limited to that occasioned by inaccuracies and wear.

The method used in laying-out the curve is very similar to that used in laying-out a uniform motion cam, differences being that it is started from two arbitrary points on a diametrical line, which points are spaced apart in accordance with the gap between the points of contact of the intermediate disc with the driven/shaft discs, and is produced for only a few degrees on either side of this line. The “rise” per degree of angular motion is very great.

Thus, referring to Figure 4, in laying out the curve, assuming that H is the center of the tapered bearing in the concave face of the intermediate disc, a diametrical line a—b, c—c, d—d. About the center H there is drawn a circle e of a diameter G which is equal to the width of the gap between the points of contact on the adjacent peripheral edges of the driving and driven discs 5 and 6 with the intermediate disc 17, and on the outside and inside of this circle, respectively, three equi-distantly spaced concentric circles f, f', g, g', and h, h', are drawn. Thus, there are seven radial lines radiating from the center H and from the points of intersection lettered from j to p and j' to p' of these lines and the seven concentric circles are points upon the curve of the convex working surface 18 of the intermediate disc. The total cross travel of the carriage carrying the intermediate disc is equal to the radial distance between the innermost (h') and the outermost (g') of the said concentric circles and the overall ratio of the speed adjustment is equal to the square of the ratio between the radius of the innermost circle and that of the outermost circle.

Whilst in some of the constructions according to this invention the use of springs between adjacent pairs of intermediate discs is unnecessary, the use of at least one spring within a disc assembly on the intermediate shaft is needed in order to compensate for inaccuracies in the contours of the discs and eventual wear of the several parts of the drive.

It is therefore desirable to keep the curvature of the intermediate disc to the minimum consistent with "point" contact between these and the driver/driven discs. The hardness, accuracy, and finish of the mating surfaces will be controlling factors in determining this curvature.

Moreover, as in nearly all practical applications of the drive those portions of the driver/driven discs making contact with the intermediate disc will be in the form of a rounded rather than a square corner, a slight modification of the curvature of the intermediate discs will be needed to offset the change in the point of tangency which takes place as between one extreme of adjustment and the other.

From a consideration of Figures 1 to 3 it will be apparent that the intermediate disc could equally well be supported on a part-spherical surface provided such surface were concentric about the position of point 14. This has been done in a second constructive form of the invention, shown in Figures 5 and 6, which comprises a casing 19 in the front and back walls 20 and 21 of which two parallel, spaced shafts 22 and 23 are rotatably mounted, one of these shafts being the driving shaft and the other the driven shaft. The cover 20 is, in Figure 5, assumed removed. Between the two shafts there is an intermediate shaft 24 which is parallel to the other shafts and is supported by ball bearings 25 and 26 in such manner that its axis lies in the same plane as the axis of the driving and driven shafts. The driving and driven shafts are provided respectively with driving and driven discs 29 and 30, each of which is splined for axial movement along its shaft. The discs are formed with peripheral edges 31 and 32 of substantially circular section. Two intermediate concave-convex discs 33 and 34, having domed surfaces 35 and 36, are constructed like that of the intermediate discs described above, encircle the intermediate shaft. The intermediate discs are formed respectively with central, apertured bosses 37 and 38, having part-spherical outer surfaces 39 and 40 which are rotatably mounted in part-spherical bearing surfaces 41 and 42 formed respectively in the body parts of hollow sleeves 43 and 44, the shanks 45 and 46 of which are slidably arranged upon the intermediate shaft. The peripheral edges 31 and 32 of the driving the driven discs 29 and 30 are engaged between the domed contact or working faces 35 and 36 of the two intermediate discs, and these are thrust into contact with the two peripheral edges by springs 47 and 48 which surround the intermediate shaft and react respectively between the sleeves 43 and 44 and nuts 49 and 50 adjustably threaded upon the shaft. The part-spherical surface formed upon each intermediate disc is so related to the domed contact face thereof that the center of the sphere of which the form it makes a part is coincident with the datum point (H Figure 4) of said said disc. As a consequence the behavior of each intermediate disc will be as if supported at this point.

The bearings 25 and 26 of the intermediate shaft 24 are supported in housings 27 and 28, and in order to obtain the desired lateral movement of the intermediate shaft in the plane containing the axes of the driver/driven shafts, these housings are each carried by a swinging link 51, 52 pivotally mounted on cross-spindles 53 and 54 parallel to shaft 24. The swingings of the housings 27 and 28 and consequent variation of the transmission ratio is effected by an arm 55 connected to a spindle 54 and forked at 56 to receive a pin on a nut 57 carried by a threaded spindle 58 having an operating handle 59 at its outer end.

It will be understood that the gear may include a number of axially-spaced driving discs all mounted upon the same driving shaft and a number of intermediate discs all mounted upon the same driven shaft, a co-operating pair of intermediate discs being associated with each driving and driven disc pair.

As shown in Figure 7, a number of driving discs 60 may be splined upon it a driving shaft 61 and an equal number of driven discs 62 may be splined upon a driven shaft 63 which is parallel to the shaft 61. The construction comprises an intermediate shaft 64 which is parallel to the shafts 61 and 63, the axes of the three shafts lying, as before, in the same plane.

A number of intermediate disc-pairs are mounted upon the intermediate shaft, each such pair comprising two axially-spaced concave-convex discs 65 and 66, the peripheral edges of two of the discs 60 and 62 being engaged between the domed contact surfaces 67 and 68 of the corresponding intermediate discs. Each intermediate disc is formed with a part-spherical central aperture 69, the center point of which corresponds to the center H shown in Figure 4, the working surface 67 and 68 of each pair of discs being formed in accordance with the curve shown in that figure. Within the bore of each intermediate disc there is a sleeve 70 which is a sliding fit on the shaft 64 and which is shaped externally to form a part-spherical seating 71 for the bore 69 of the disc. In assembling each intermediate disc and its sleeve, the latter is inserted into the bore of the disc whilst at right angles to the plane of the latter until the centers of curvature of the bore and the seating coincide, and then rocked back through 90°. Pressure of contacts between the driving/driven discs and the co-operating parts of the intermediate disc is maintained by springs 72 which are fitted between the pairs of intermediate discs and springs 73 fitted between nuts 74 screwed upon and near to the ends of the intermediate shaft and the adjacent intermediate disc.
In this construction the speed adjustment may be effected by adjusting mechanism comprising swinging links 75 and housing 76 like those included in the construction shown in Figures 5 and 6, the ends of the intermediate shaft 64 being supported by ball bearings in the housings.

Where it is desired to keep the mechanism as compact as possible an epicyclic type of construction may advantageously be used. In this manner, the drive may be spread over a large number of elements without unduly lengthening the shafts.

As shown in Figures 8 and 9, such mechanism may comprise a central splined driving shaft 77 on which are slidable mounted a number of driving discs 78, each of which is adapted to engage with the working faces of the two concave-convex discs 79 of a number of pairs of such discs. Thus, for example, four sets of pairs of cooperating intermediate discs may, as shown in Figure 8, be arranged around the driving shaft 77 and each set carried upon a shaft 80, the four shafts being angularly spaced at 90° from each other. At its two ends each shaft 80 is mounted in ball bearings 81 fitted in arms 82 which extend from the ends of a sleeve 83 which is free to rotate about a stud 84, the four studs being fixed in a plate 84a (not seen in Figure 8). A plate 85 is carried at one end of the four studs and is provided internally with a ball bearing 86 for one end of the driving shaft 77 and externally with another ball bearing 87 upon which a driven drum 88 of cup shape is turnably mounted.

The drive from the driving disc 78 to the sets of pairs of intermediate discs 79 is transmitted from the latter to axially spaced driving rings 89 which are slidable mounted on longitudinal keys 90 on the inside of the drum. Each driven ring is engaged in the space between the intermediates discs of four co-planar sets of intermediate discs.

In order to vary the speed ratio, one end of a control lever 91 is pivotally mounted upon the driving shaft 77 and is coupled by links 92 to four of the aforesaid arms 82 which carry the four shafts 80 upon which the four sets of intermediate discs 79 are mounted. By pivoting the control lever 91 in one or the other the direction the intermediate discs 79 are carried towards or away from the driving shaft and the ratio of the drive consequently is altered.

The intermediate discs may be constructed like those included in the above described constructions shown in Figures 5 and 6 or Figure 7. It will be understood that, as with other epicyclic transmissions, the role of the three main components of the drive i.e., central (sun) discs, intermediate (planetary) disc carrier, and outer rings (annulus) may be interchanged to suit the requirements of any particular application. As an example, the drum 88 may be made the driving member, and the shaft 77 may be fixed, the plate 84a then becoming the driven member. Furthermore, if a spring is fitted to this plate 84a acting to turn the boss of lever 91 in an anti-clockwise direction a simple form of self-regulating drive will be provided, whereas the spring, holding the gear in low ratio, is opposed by centrifugal forces which will be generated in the intermediate (driven) assembly tending to move it to high ratio.

The material most generally suitable for the discs appears to be hardened steel, which may be improved by such special hardening as nitriding or hard facings such as Ceramite or Stellite. For light drives and certain feed motions softer metals or “plastics” material may be found suitable.

What I claim then is:

1. A variable speed friction gear comprising a rotatable driving member, a rotatable driven member spaced from said driving member, and an intermediate disc for transmitting rotary motion between said driving and driven members by frictional contact of a face of said disc with both said members, such intermediate disc having a contact face of domed shape arranged for point contact with each of said members, the contact face of the intermediate disc being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametrical lines through said center.

2. A variable speed friction gear comprising a rotatable driving member, a rotatable driven member spaced from said driving member, an intermediate disc for transmitting rotary motion between said driving and driven members by frictional contact of a face of said disc with both said members, such intermediate disc having a contact face of domed shape arranged for point contact with each of said members, the contact face of the intermediate disc being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametrical lines through said center and means for mounting this intermediate disc for universal movement about said center, when moved for varying the transmission ratio, with the points of contact between the driving and driven members and the intermediate disc in the same plane as this center.

3. A gear according to claim 2, characterised by the fact the mounting means includes an element whereby the intermediate disc may rock about said center.

4. A variable speed friction gear comprising a rotatable driving member, a rotatable driven member spaced from said driving member, an intermediate disc for transmitting rotary motion between said driving and driven members by frictional contact of a face of said disc with both said members, such intermediate disc having a contact face of domed shape arranged for point contact with each of said members, the contact face of the intermediate disc being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametrical lines through said center, and a pivot rockably supporting said intermediate disc centrally in relation to the domed contact surface thereof, said pivot being adjustable along a straight line in a plane containing the points of contact with the driving and driven members.

5. A variable speed friction gear comprising a rotatable driving member, a rotatable driven member spaced from said driving member, an intermediate disc for transmitting rotary motion between said driving and driven members by frictional contact of a face of said disc with both said members, such intermediate disc having a contact face of domed shape arranged for point contact with each of said members, the contact face of the intermediate disc being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametrical lines through said center, and a movable mounting for said intermediate disc, such mounting having a paraspherical seating receiving a part of interfitting paraspherical contour on the intermediate disc.

6. A variable speed friction gear comprising a rotatable driving member, a rotatable driven member spaced from said driving member, and a pair of opposed intermediate discs for frictional contact each with said driving and driven members to transmit the drive between these latter, each of said intermediate discs having a domed face making point contact with the driving and driven members the contact face of the intermediate disc being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametrical lines through said center.

7. A variable speed friction gear comprising at least one rotatable driving disc, at least one rotatable driven
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disc, a pair of opposed intermediate discs for frictional contact each with said driving and driven discs to transmit the drive between these latter, said intermediate discs having domed confronting faces engaging between them, and making point contact with, a peripheral portion of each of the driving and driven discs, the contact face of the intermediate discs being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametral lines through said center, a shaft on which said intermediate discs are both rockably mounted and axially spaced, said means acting on said intermediate discs to maintain them in contact with the driving and driven discs and means for effecting lateral adjustment of said shaft for varying the speed-transmission ratio.

8. A variable speed friction gear comprising at least one rotatable driving disc, at least one rotatable driven disc, a pair of centrally-apertured, opposed intermediate discs for frictional contact each with said driving and driven discs to transmit the drive between these latter, said intermediate discs each having a part-spherical bearing surface at the aperture thereof, and said intermediate discs having domed confronting faces engaging between them, and making point contact with, a peripheral portion of each of the driving and driven discs, the contact face of the intermediate discs being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametral lines through said center, a shaft for carrying both the intermediate discs of the said pair, a pair of sleeves on said shaft each having a bearing surface interfitting and carrying the part-spherical bearing surface of the corresponding intermediate disc, spring means acting on said intermediate discs to maintain them in contact with the driving and driven discs, means for effecting lateral adjustment of said shaft for varying the speed-transmission ratio and shafts parallel to the first-mentioned shaft and respectively having the driven and driving discs splined thereon.

9. A variable speed friction gear comprising a driving shaft, a driving disc splined on said driving shaft, a set of pairs of axially-spaced cooperating intermediate discs having domed contact surfaces engaging the driving disc, the contact face of the intermediate discs being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametral lines through said center, the discs of each pair of intermediate discs being mounted for universal movement upon an intermediate shaft and the intermediate shafts being spaced radially from, and angularly around, said driving shaft, a cage rotatable around, and concentric with, the driving shaft, a driven ring in said cage and having its inner peripheral edge engaged between the contact surfaces of the cooperating pairs of intermediate discs and means for moving said intermediate discs simultaneously between the peripheral edges of the driving disc and driven ring.

10. A gear according to claim 9, in which each intermediate shaft is supported by pivotally-mounted arms one at least of which is connected by a link to a common control member rotatable upon said driving shaft.

11. A variable speed friction gear comprising a driving shaft, a plurality of axially-spaced driving discs splined on said shaft, a set of pairs of axially-spaced cooperating intermediate discs having domed contact surfaces engaging the driving discs, the contact face of the intermediate discs being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametral lines through said center, the discs of each pair of intermediate discs being mounted for universal movement upon an intermediate shaft and the intermediate shafts being spaced radially from, and angularly around, said driving shaft, said driving shaft, a cage rotatable around, and concentric with, the driving shaft, a plurality of driving rings in said cage each having its inner peripheral edge engaged between the contact surfaces of the cooperating pairs of intermediate discs, and means for moving said intermediate discs simultaneously between the peripheral edges of the driving discs and driving rings.

12. A variable speed friction gear comprising a rotatable driving member, a rotatable driven member spaced from said driving member, an intermediate disc for transmitting rotary motion between such members, said intermediate disc having a contact face of domed shape arranged for point contact with one of said members, a drive connection between the intermediate disc and the other of said members, the contact face of the intermediate disc being defined by a surface of revolution produced by a curve representing the intersection of a series of equally spaced arcs, described about a predetermined center, each in turn with successive, equi-angularly spaced diametral lines through said center and means for mounting said intermediate disc for universal movement about said center so that movement of the disc varies the transmission ratio.

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