Steering a Motor Car

A Meccano Demonstration of the Mechanical Principles Involved

By Edgar Wright

This article describes not only the more important mechanical principles involved in steering a motor car, but also a Meccano model that clearly demonstrates the working of Ackermann steering gear. The model is quite simple to construct and is so designed that it may be incorporated without alteration in the existing Meccano motor chassis (Model No. 701).

THE design of motor car steering gear is not nearly as simple as it may seem to the casual observer. Many people appear to think that it is only necessary to twist the front axle round upon a pivot and the car will promptly describe a graceful curve or take sharp turns to right or left at the bidding of the driver. This idea of course is very far from the truth. In designing a car a great deal of care is given to this important part of the control, and there are many variations in the different steering gears in use at the present time. Every steering gear, however, must fulfil three very important requirements, which may be briefly dealt with here.

First, it is necessary that there should be as little play as possible between the road wheels and the steering wheel—that is to say, the smallest movement of the steering wheel should produce almost instantaneous movement of the road wheels. On the other hand, allowance must be made for small irresponsible movements of the road wheels themselves. These movements are due to surface inequalities in the road, and must not transmit undue shocks or vibrations to the hands of the driver.

Second, after a car turns a corner the wheels should tend of their own accord to return to the straight. The rear driving wheels naturally tend to travel in a straight line and in a well-built car this tendency can usually be relied upon to bring the front wheels back to their normal position. In this connection it should be stated, however, that many conflicting opinions have been held in the past on the subject of "irreversibility" of steering gear.

The "Irreversible" Control

The "irreversible" type of control is that in which the steering wheel can easily turn the front wheels, but the latter can with difficulty turn the steering wheel. This result is effected by worm gearing fitted between the steering wheel and the linkage and the degree of irreversibility obtained depends on the pitch of the worm.

It has been decided that the completely irreversible steering gear is not satisfactory, because the steering wheel becomes "dead" and the driver loses his "feel" of the road. In addition, great stresses are introduced in the linkage, for every shock to the front wheels is opposed by a completely rigid mechanism.

Owners of Meccano outfits will understand these points better if they construct the Meccano model of a motor chassis and experiment with different types of steering gear. For example, if worm gearing is used between the steering column and the transverse shaft that conveys movement to the front stub axles, it will be found that, while the wheels can be turned quite easily by the steering wheel, their position cannot be altered by grasping the wheels themselves with the intention of turning their axles about the pivots. The pitch of the Meccano Worm is so small that the gear is completely irreversible.

But suppose we substitute for the worm gear a Pinion and Contrate Wheel. The road wheels can now be moved either by turning the steering wheel or by touching the wheels themselves. In practice the "reversibility" of such a steering gear would be too great; the road wheels would be deflected by the smallest shock or bump, and the steering wheel would be difficult to hold while the car turned a corner. Therefore a happy medium between these two results is obtained by employing a worm of moderately large pitch. The greater portion of any shock to the wheels is then absorbed in friction, but a slight tendency to twist is imparted through the pinion and worm to the steering wheel. Such a compromise in the gear arrangement also allows the wheels to "straighten out" if the wheel is released after the car has turned a corner. At the same time the wheel is not difficult to hold while the car is actually cornering.

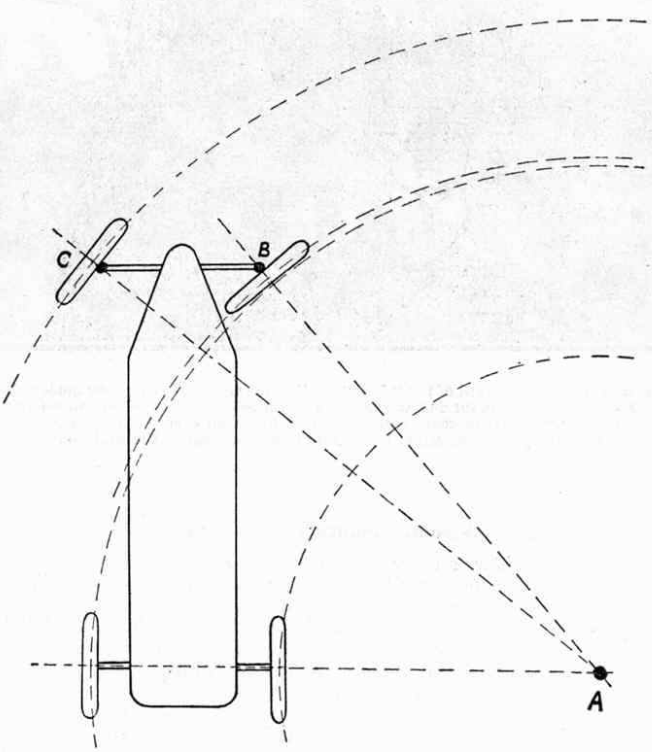


Fig. 1

What Happens when Turning

Third, and this is an important point—the wheels must not remain parallel when negotiating a curve. Many readers may not have given much consideration to this point—indeed, some may not have given it even a thought, but a reference to Fig. 1 should make the statement clear.

The drawing is intended to represent a car turning a corner, and in doing so it will be apparent that the wheels must describe an arc or portion of a circle whose centre point is shown at A. Now although both front wheels must turn about this centre, they are situated at varying distances from it. This means to say that the right hand front road wheel must follow an arc of a circle having a radius equal to A B, and the left hand wheel must follow an arc struck from a larger radius A C. For the wheels to describe an arc of a circle with the least possible friction on the road surface each must be situated at a tangent to its respective circle. But it is obvious that both wheels cannot lie at their respective tangents and at the same time remain parallel with each other.

Hence it becomes necessary to incorporate in the steering gear some method by means of which a greater angle can be given to the wheel nearer the centre of the circle, whether the car be turning to right or left.

The principle by which this object is achieved is known as Ackermann steering. This interesting apparatus can be reproduced perfectly in Meccano, and its operation should be made clear by reference to Figs. 2 and 3. The model shown therein is designed for incorporation in the Meccano motor chassis (Model No. 701 in the Meccano Complete Manual). Fig. 3 is a plan view of the fixed front axle and stub axle mountings, while Fig. 2 is a general view of the complete steering gear. Two short levers, 1 and 2, are rigidly connected to the stub axles. In practice these levers may project either forward or backward; in the model they project backward or *behind* the road wheels. They are connected one to the other by the tie rod 3.

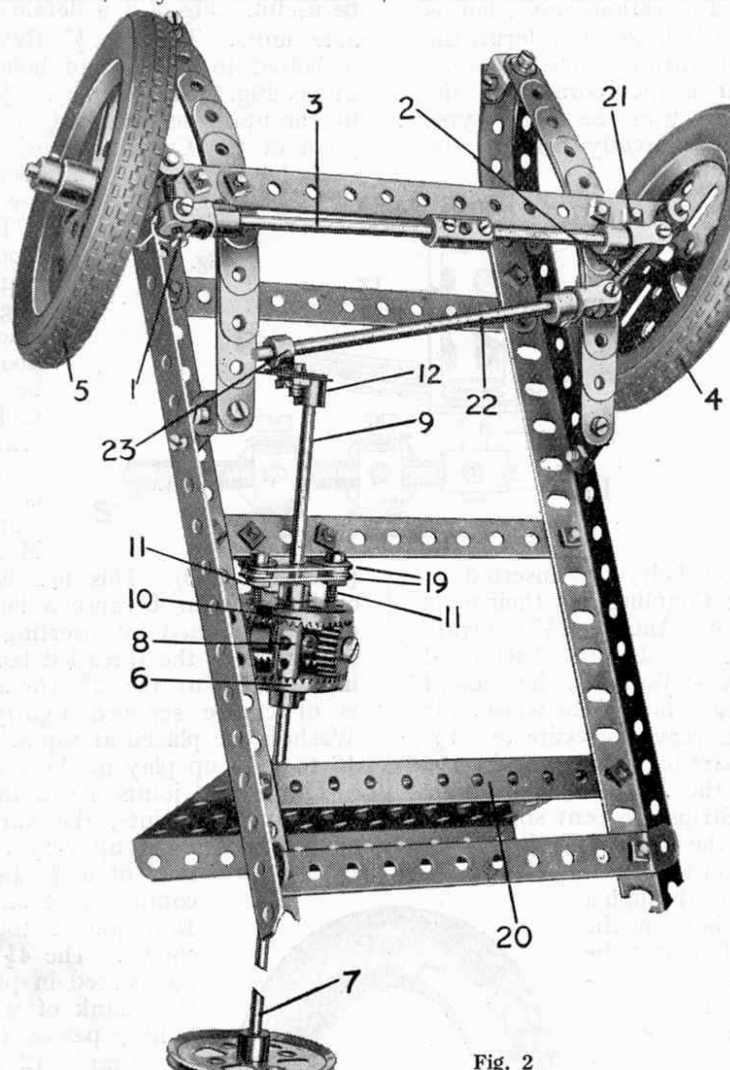


Fig. 2

Principle of Ackermann Steering

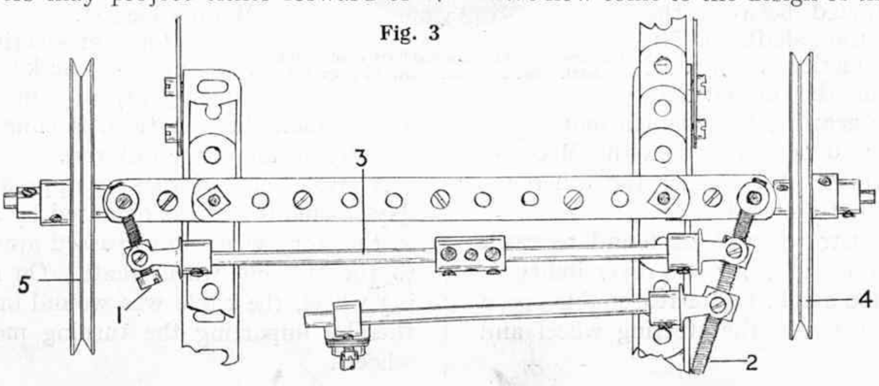
It will be noticed that the levers 1 and 2 lie at a slightly obtuse angle to the stub axles (see Fig. 3). This angularity is most important, for on it rests the whole principle of Ackermann steering. The correct angle for the levers is arrived at by placing them so that their centre lines, if produced, would meet on the centre line of the car. The exact meeting place varies according to the proportions of the car and length of the levers, but as a rule it is found to be just in front of the back axle.

Now if the car is to be turned to the right the road wheel 4 (Fig. 3) must be deflected in that direction and the lever 2 will be moved through a certain number of degrees to the left. In doing so it pushes the lever 1 in the same direction but owing to the difference in angularity between the two levers, lever 1 (and therefore the road wheel 5), moves through a lesser number of degrees. If the car moves to the left, exactly the opposite occurs, the lever 1 moving through a greater number of degrees than the lever 2.

Therefore this arrangement of the linkage fulfils the third requirement of the steering gear, that is, it imparts a greater angular movement to the inner road wheel when the car turns to right or left. As a matter of fact Ackermann gear does not fulfil all the requirements of the ideal steering gear, for when it is used the outer wheel is turned a trifle too much at "small lock" (that is slight deviation from the straight). The error diminishes however until at a certain angle of the wheels the steering is perfect, but at still greater lock the inner wheel is turned a little too far in proportion to the angle of the outer wheel.

We now come to the design of the gearing between the steering wheel and the road wheels. The gear ratio, or extent of movement of the road wheels to a given movement of the steering wheel depends largely on the particular type of car. If the ratio is too high, however, a slight twist of the wheel will result in a considerable

Fig. 3



deflection of the car which would be dangerous and might easily cause accidents. On the other hand, if the ratio is too low the car would be slow to respond to the wheel and therefore difficult to manage in dense traffic.

Epicyclic Reduction Gear

The gear reduction is effected in various ways, but as already indicated a worm of fairly large pitch forms the basis of the more usual types of gearing. In some cars a small epicyclic reduction gear is incorporated in the steering column. The Ford car uses the latter type, the gear casing being mounted directly beneath the steering wheel.

The reduction gear adopted in the Meccano model is based on the epicyclic principle, and to make its operation quite clear the photograph may be supplemented by the following brief explanations :—

The 1½″ Contrate Wheel 6 is bolted rigidly to the steering post 7, the extreme end of which is free to rotate in the Coupling 8. The latter is secured to a 3″ Rod 9 and carries two 25-teeth Pinions journalled on Pivot Bolts. These bolts are inserted in opposite threaded holes of the Coupling and their ends grip the extremity of the Rod 9. Another 1½″ Contrate Wheel 10 (without set-screw) is placed on the shaft 9 and prevented from turning by the ½″ Bolts 11, the ends of which enter two of the holes in the face of the wheel. It will be noticed that these bolts serve to secure two 1½″ Strips 19, which are spaced apart by Washers and serve as a reinforced bearing for the Rod 9. The Angle Brackets supporting the 1½″ Strips are bent slightly to conform with the angle of the steering column. A Collar and set-screw is placed on the steering post 7 where the latter passes through a further bearing, formed by a hole in the plate 20. The Collar is placed against the inner side of the bearing—i.e., the side nearest the Contrate Wheel 6—and so serves to hold the various components of the reduction gear in position.

Rotation of the steering wheel causes the ¾″ Pinions to roll round the teeth of the fixed Contrate Wheel 10, and the movement of the Pinions imparts motion, in turn, to the Coupling 8 secured to the Rod 9 (which carries the steering drop lever 12, consisting of a Meccano Crank reinforced by a Flat Bracket). With this particular gearing a reduction ratio of one in two is obtained between the steering wheel and the shaft 9. In actual practice the reduction is greater, owing to variations in the design and number of teeth in the gearing, but a much more complicated mechanism would be required in the Meccano model in order to increase still further the difference in speed between the shafts 4 and 9.

The steering gear illustrated will be found to work very well in Meccano models, for its reversibility is neither too great nor too small, and a reasonable speed reduction is provided between the steering wheel and the road wheels.

Further Details of the Model

The construction of the remainder of the Meccano model of Ackermann steering gear will no doubt be clear from the illustrations, but further particulars regarding the mounting of the front wheels, etc., may be useful. Fig. 4 is a detailed view of one of the stub axle units. The 1″ × ½″ Reversed Angle Bracket 13 is bolted to the second hole of the fixed front axle 21 (see Fig. 2) and supports a ½″ Bolt 14, which is gripped by the upper set-screw of the Coupling 16. The lower pivot of the Coupling consists of a 1″ Axle Rod 15, secured by means of the lower set-screw.

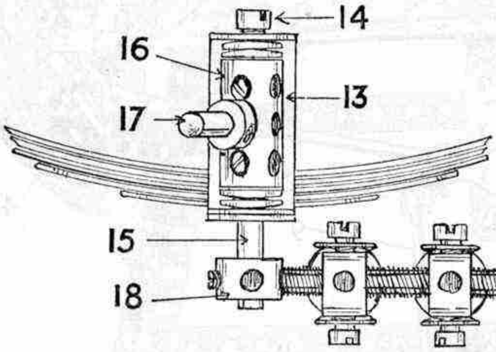
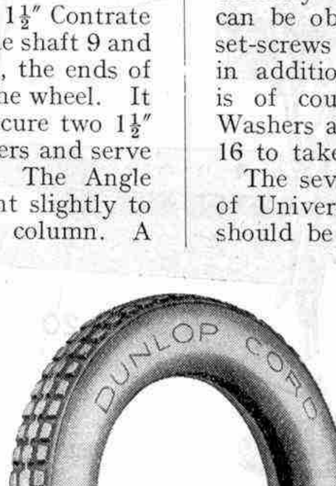


Fig. 4

The stub axle 17 (a 1½″ Rod) is fixed in the centre transverse hole of the Coupling 16. Each front road wheel must be free to turn about its axle but should be held in place by two Collars, mounted one on either side of the wheel boss.

It will be noted that 18 is the centre collar, or "spider," extracted from a Meccano Universal Joint (Part No. 140). This has been used in place of an ordinary Collar because a better grip on the Rod 15 can be obtained by inserting one, two, or even three set-screws in the threaded borings of the special collar in addition to the 2″ Threaded Rod 2. The latter is of course screwed tightly into the collar. Two Washers are placed at top and bottom of the Coupling 16 to take up play in the bearings.

The several joints in the linkage consist of portions of Universal Joints, the various set-screws of which should be screwed up very tightly. The lever 1 consists of a ¾″ Bolt, and the tie-rod 3 is composed of one 3½″ and one 2½″ Axle Rod joined together by the Coupling shown. The 4½″ Rod 22 carries a Collar 23 secured in place by an ordinary bolt, the shank of which, before entering the Collar, passes through the end hole in the Crank 12 and through the round hole of the Flat Bracket bolted thereon.



The new Miniature Dunlop Tyre used in this model. See announcement on page 155

Various Types of Steering Gear

There are several kinds of steering gears in common use in addition to the worm and bevel types already mentioned (the latter type being represented in Meccano by means of Pinion and Contrate Wheel gear, as in the well-known Meccano model Motor Chassis).

One form of steering mechanism sometimes met with makes use of plain rack-and-pinion gear, wherein a spur pinion engages with a rack that, in turn, is connected to the steering arm by means of a link-rod.

A crude form of steering apparatus used in the early days of motoring was operated by a wire cable attached to the front wheels and passed around a bobbin secured to the steering wheel shaft. On rotation of the steering wheel, the cable was wound on and off the bobbin, thereby imparting the turning movement to the road wheels.