TORQUE REACTION AND TRACTOR SAFETY

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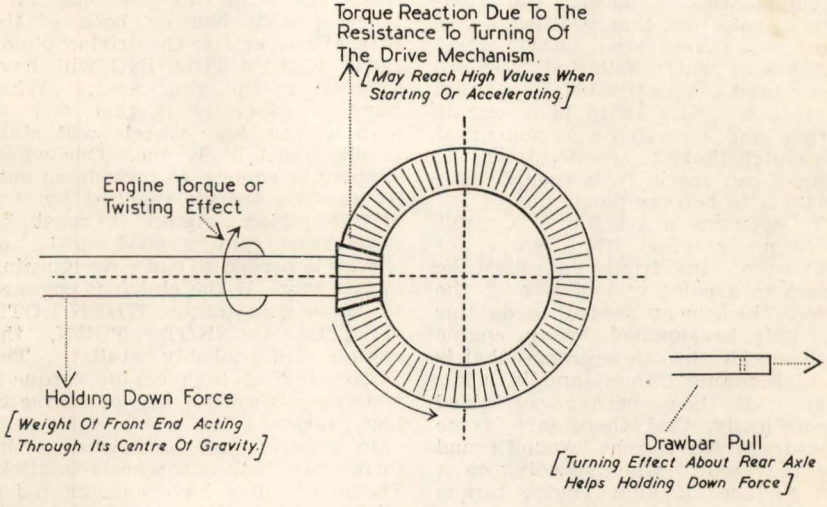
Bulletin No. 240 of this series introduced the subject of drawbar pull and followed with some remarks on safe operation of tractors. It was pointed out in Bulletin No. 240 that overturning backwards is most unlikely to occur as the result of a pull from a standard drawbar due to the automatic reduction of the turning effect should rearing occur. Those remarks on overturning backwards, however, did not cover all the possibilities. This Bulletin completes those remarks by introducing torque reaction and ends with some observations on the operation of crawler tractors.

Torque reaction is a force which acts inside the tractor. It arises from the application of engine torque against the inertia and other resisting forces of the drive mechanism. Torque is an engineering term and is a measure of the effect produced by a twisting force. Engine torque is a measure of the capacity of the pistons to twist the crankshaft. Inertia is a property possessed by all bodies. It is a property which tends to keep still bodies at rest and to keep those that are moving, in uniform motion. For example, when a car is at rest, it takes a greater effort to start it moving than is necessary to keep it moving, once it has started. This is partly due to inertia. A low gear and high engine speed when starting, then a change to a higher gear and lower engine speed, is a common every-day example of the extra effort that must be provided to overcome the inertia,



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friction and rolling resistance of a car.

Torque reaction is most easily understood by considering the driving pinion and the crown wheel, or ring gear, inside the differential housing. (Other common types of drive produce the same result, however). When starting a tractor, or when accelerating, there is a tendency for the driving pinion to climb upwards because the ring gear resists being turned. This resistance is due to the inertia of the ring gear and the other drive mechanism to circular motion, the inertia of the tractor as a mass to forward motion, plus its rolling resistance, and, of course, friction of the moving parts. This upward reaction to the application of engine torque tends to cause the rear axle housing to twist in the opposite direction to the drive wheels, and if the reaction is sufficient—it increases in value if engine torque is applied suddenly—it may result in the rearing of the front end of the tractor. It should be noted here that wheel weights, or rubber tyres filled with liquid, would add considerably to the inertia effect due to their extra weight which makes it more difficult to start them moving. Mention of this is not meant to be an argument against adding weight to the rear wheels. The additional weight is very necessary in some circumstances. It is only the intention to point out that additional care must be taken when either wheel weights or water ballasted tyres are being used. Also it must be realised that it is ONLY with high engine torque and a sudden engagement of the clutch that the reaction to engine torque can reach high enough proportions to become dangerous.

To overturn a tractor as a result of torque reaction the centre of gravity of the front end must be raised to a point vertically over the axle. The energy needed to do this can only be supplied by an engine with a wide throttle opening—that is at high engine torque—and in a low gear. It has been ascertained theoretically, that there are some tractors which can be "wound round the rear axle," when standing on a flat surface, if high engine torque were applied suddenly.

Counteracting the rearing of the front end by means of the driving pinion, is the weight of the front end of the tractor acting through its centre of gravity. It must be pointed out that the turning effect of the force holding down the front end of the tractor has a great advantage over the turning effect of the lifting force exerted by the tendency of the driving pinion to climb upwards. It is readily seen that the distance from the centre of gravity of the front end to the rear axle (the point where pivoting is going to take place) is much further than the distance from the ring gear teeth to the rear axle. The advantage clearly lies with the holding down force. The front end also has inertia which must be overcome.

Should the front end rear, the higher it rises the more dangerous does the position become. This is due to the line of action of the holding down force (the weight of the front end acting through its centre of gravity) approaching the rear axle, or pivot, as the front end is lifted. As it gets nearer, so its turning effect is reduced, while the turning effect of the lifting force remains the same. As a result of this, the tractor would tend to rear relatively slowly at first and then speed up as the front end rises higher, and its inertia has been overcome.

Apart from the sudden application of engine torque and the reaction resulting from the inertia and other resistances of the moving parts, there is another set of conditions which can be even more dangerous. When the driving pinion turns, either the ring gear must turn, together with one or both of the rear wheels, or else the driving pinion IF IT KEEPS TURNING will have to ride up the ring gear. What happens generally is that one or both of the rear wheels will start to slip—most likely one. One wheel slipping is enough to provide an outlet for the energy supplied by the driving pinion. Again it must be emphasised that a good deal of energy is needed to cause overturning in this way. If the clutch is engaged at low engine torque, WHEN BOTH WHEELS CANNOT TURN, the engine will probably stall. The danger lies at high engine torque—wide open throttle—and of course in low gear.

In general, two conditions on the farm cause both rear wheels to stick. The driver may have encountered a sticky patch and in the effort to get out, the rear wheels may have dug in sufficiently to prevent them from turning. A similar condition could arise if the rear wheels got stuck in crossing a ditch. The second condition could arise from the common but dangerous practice of jamming a length of wood, or similar object,

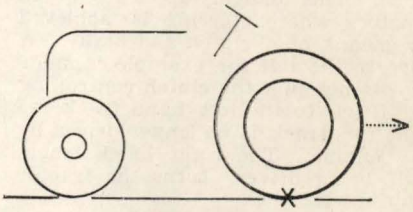
underneath the front of the rear wheels to prevent them slipping. Under such, or similar conditions, engage the clutch carefully, better still, back out if possible, or else fetch another tractor. When facing up a slope the conditions outlined would be more dangerous, depending of course on the angle of the slope. The front end would then already be in a slightly raised position.

In general, crawler tractors are safer on hillsides than wheeled tractors. This is due to their low centre of gravity, to the extra weight of the larger engine and the track mechanism, and to the low setting of the drawbar. The drawbar is placed low so as not to transfer too much weight to the rear of the track. The weight should be evenly distributed over the length of the track in contact with the ground, under high drawbar loading.

The remarks on torque reaction in wheeled tractors apply also to crawler tractors. But with the crawler tractors, which are so much heavier in front than wheeled tractors, the effect of this reaction should not be so dangerous. However, when going up a steep slope WITH NO LOAD AT THE DRAWBAR, a sudden opening of the throttle of a very powerful engine might cause the tractor to overturn backwards. The reaction in this case is due to the inertia of the moving parts and the tractor mass moving at uniform motion which has to be overcome before the whole will move at a higher speed. A sudden increase in slope might cause the operator to open the throttle suddenly. The reaction resulting from the sudden increase in engine torque might be sufficient to cause overturning. For similar reasons never apply high engine torque suddenly to a tractor that is at rest facing up a steep slope.

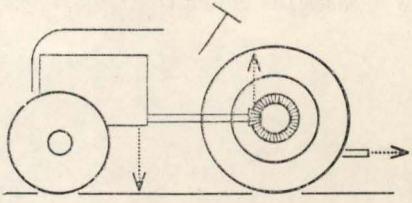
A load at the drawbar helps to keep the forward end down AGAINST TORQUE REACTION if the drawbar is behind and below the rear axle. A moment's reflection will show that the turning effect of the pull at the drawbar about the rear axle is in the same direction as the holding down force, that is, the weight of the forward end. Hitching above the rear axle, or level with it, would be dangerous. The result would be to increase the turning effect of the forces about the rear axle tending to turn the tractor over backwards. Bulletin No. 240 dealt with the external effect of drawbar pull on the tractor as a whole. The external effect tends to cause pivoting about the point of contact of the rear wheels and the ground. The foregoing deals with the internal turning effect of drawbar pull ABOUT THE REAR AXLE.

In general, to guard against the possible effects of torque reaction, never engage the clutch suddenly at wide throttle settings. (The clutch should never be engaged suddenly under any circumstances). If the rear wheels are stuck, for any reason, NEVER try to move forwards by opening the throttle and engaging the clutch suddenly. Under such circumstances, try to back out, or fetch another tractor. When there is a load AT A STANDARD DRAWBAR, torque reaction is unlikely to produce serious effects.



A load at the drawbar has a turning effect about the point of contact of the rear wheels and the ground (Bulletin No. 240).

There is an automatic reduction in the turning moment should rearing occur IF THE HITCH POINT (DRAWBAR) IS BEHIND AND BELOW THE REAR AXLE.



A load at the drawbar, IF THE DRAWBAR IS BELOW THE REAR AXLE, opposes the effect of torque reaction about the rear axle.

Torque reaction must be guarded against when a tractor has no load or is coupled to a load at a point level with or above the rear axle.

The tendency of a crawler tractor to overturn sideways over an axis represented by the outside edge of a track depends largely on the height of its centre of gravity, and upon the width between the tracks. The greater the width and the lower the centre of gravity the more difficult would it be to turn the tractor over

sideways. If the tracks themselves are wide, a large surface area is provided to carry the weight of the machine. This large surface with its relatively light weight per unit area may cause the crawler to slip sideways down a slope. A narrower track, however, would tend to dig in, because a smaller surface area is carrying the same weight. If a crawler tractor, while sliding down a slope, catches an obstruction on the edge of the lower track, the momentum may well be enough to turn it over, if the slope is very steep.

Another, sometimes unsuspected, danger arises when the driver of a crawler tractor, which is moving down a slope, tries to turn it on the slope. This danger applies only to tractors where steering is achieved by means of a clutch and brake. A turn to the left for example is made by disengaging the clutch controlling the drive to the left hand track, so that this track is no longer driven by the engine. The right hand track, still being driven, turns the tractor to the left.

When going down a slope, however, with an idling engine acting as a brake for the tractor, the tracks driving the engine against the compression in the cylinders, the position is different. In these circumstances disengaging a track clutch to make a turn has the opposite effect from that which is produced when driving on the flat. Suppose a driver going down hill wishes to turn to the left. He releases the clutch controlling the left hand track. This track is now free to turn under the down-hill momentum of the tractor and it gathers speed, while the other track, not being disengaged, is still braked by the engine. The result is the tractor swings to the right—in a direction opposite to that intended by the driver. If the intended left hand turn was being made to avoid a gully or some other obstruction, the result of this unexpected turn in the wrong direction could easily be disastrous. Obviously, to make the desired turn under the circumstances outlined, the brakes would have to be used as well, or else the opposite clutch would be disengaged.

The trained engineer will realise that the problem of tractor stability is a good deal more complex than would appear from the foregoing analysis. The problem is a dynamic one and not a static one. Momentum, the reaction of an engine to the delivery of its own torque, and the reaction to the impact of the wheels on a rough surface are but to mention some of the factors that would have to be taken into account for a complete analysis. Some of these factors will depend on particular conditions at a particular moment.

All that has been attempted in this Bulletin and in Bulletin No. 240 has been the sounding of a warning by picking out the three major forces concerned with tractor stability, centrifugal force, drawbar pull and torque reaction. It is hoped that the dangers of over-simplification have been avoided.

Copies of this Bulletin may be obtained from the Secretary, Canterbury Chamber of Commerce, P.O. Box 187, Christchurch.

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