Introduction

No other machine is more identified with the hazards of farming as the tractor. Nearly 50% of tractor fatalities come from tractor overturns. Tractors are used for many different tasks. Because the tractor is a versatile machine, operators sometimes stretch the use of the tractor beyond what the machine can safely do. For example, an operator may turn a corner too quickly for the tractor to stay upright. The use of a rollover protective structure (ROPS) and a seat belt can save your life if a tractor overturns while you are driving. This task sheet explains the four major reasons and forces that allow tractors to overturn, gives rules for how to prevent tractors from overturning, and discusses the use of tractor ROPS with a seat belt.

How Tractors Overturn

Center of gravity (CG). A center of gravity is the point where all parts of a physical object balance one another. When you balance a pencil on your finger, you have found the pencil’s CG. This is the part of the pencil that is resting on your finger. On a two-wheel drive tractor, CG is about 10 inches above and 12 inches in front of the rear axle. Figure 4.12.a shows the normal position of a tractor’s CG. Look at Figure 4.12.b. This shows that the CG is inside a tractor’s stability baseline. Drawing a line to connect all the wheels of the tractor as the wheels set on level ground forms a tractor stability baseline. The line connecting the rear tire ground contact points is the rear stability baseline. The lines connecting the rear and front tire on the same side are the right and left side stability baselines. Front stability baselines exist but have limited use in tractor overturn discussions.

There are two very important points to remember about tractor CG and stability baselines:

- The tractor will not overturn if the CG stays inside the stability baseline.
- The CG moves around inside the baseline area as you operate the tractor.

As you can see in figure 4.12.b, a wide front-end tractor provides more space for the CG to move around without going outside the stability baseline.

Learning Goals

- To explain the role that center of gravity plays in tractor overturns
- To list reasons the center of gravity moves within a stability baseline
- To explain how to be protected during a tractor overturn

Related Task Sheets:

- Agricultural Tractors 4.1
- Tractor Hazards 4.2
- Moving and Steering the Tractor 4.10
- Using the Tractor Safely 4.13
- Operating the Tractor on Public Roads 4.14
Reasons the CG Moves Around

There are five main reasons why a tractor’s CG moves outside the stability baseline.

1. The tractor is operated on a steep slope.
2. The tractor’s CG is raised higher from its natural location 10 inches above the rear axle.
3. The tractor is going too fast for the sharpness of the turn.
4. Power is applied to the tractor’s rear wheels too quickly.
5. The tractor is trying to pull a load that is not hitched to the drawbar.

How Center of Gravity and Centrifugal Force Result in an Overturn

When a tractor is on a slope, the distance between the tractor’s CG and stability baseline is reduced. Figure 4.12.c shows how this occurs. On steep slopes, the tractor is already close to an overturn. A small bump on the high side, or a groundhog hole on the low side, may be all that is needed for the tractor to overturn.

A front-end loader or other attachment mounted on a tractor can raise the tractor’s CG. When the bucket is raised high, the balance point for the whole tractor is also raised. Figure 4.12.d shows how a raised CG makes it easier for a tractor to turn over sideways.

Centrifugal force (CF) is the outward force nature exerts on objects moving in a circular fashion. During tractor overturns, CF is that force trying to roll the tractor over whenever the tractor is turning. Centrifugal force increases both as the turning angle of the tractor becomes sharper (decreases), and as the speed of the tractor increases during a turn. For every degree the tractor is turned tighter, there is an equal amount of increased CF.

The relationship between CF and tractor speed, however, is different. Centrifugal force varies in proportion to the square of the tractor’s speed. For example, doubling tractor speed from 3 mph to 6 mph increases the strength of CF four times \((2^2 = 2 \times 2 = 4)\). Tripling tractor speed from 3 mph to 9 mph increases CF nine times \((3^2 = 3 \times 3 = 9)\).

Centrifugal force is what usually pushes a tractor over when the tractor is driven too fast during a turn or during road travel. During road travel, rough roads may result in the tractor’s front tires bouncing and landing in a turned position. If the tractor starts to veer off the road, over correction of steering can result in side overturns. Centrifugal force is often a factor in tractor side overturns. When the distance between the tractor’s CG and side stability baseline is already reduced from being on a hillside, only a little CF may be needed to push the tractor over.

Engaging the clutch of a tractor results in a twisting force, called torque, to the rear axle. Under normal circumstances, the rear axle (and tires) should rotate and the tractor will move ahead. If this occurs, the rear axle is said to be rotating about the tractor chassis. If the rear axle cannot rotate, then the tractor chassis rotates about the axle. This reverse action results in the front end of the tractor lifting off the ground until the tractor’s CG passes the rear stability baseline. At this point, the tractor will continue rearward from its own weight until the tractor crashes into the ground or other obstacle. See Figure 4.12.e.
The CG of a tractor is found closer to the rear axle than the front axle. A tractor may only have to rear to about 75 degrees from a level surface before its CG passes the rear stability baseline and the tractor continues flipping over. This position is commonly called the “point of no return.” As Figure 4.12.e shows, this point can be reached more quickly than an operator can recognize the problem.

Common examples of this type of tractor overturn are: the rear tires are frozen to the ground; tires stuck in a mud hole; or tires blocked from rotating by the operator. Rear overturns can also happen on a slope if an operator applies too much power too quickly to the rear axle. When a tractor is pointed up a slope, there is less rise needed to reach the point of no return because the CG has already moved closer to the stability baseline. Figure 4.12.f shows how this occurs.

When a two-wheel drive tractor is pulling a load, the rear tires push against the forward movement of the tractor. The load is described as pulling down because the load is resting on the earth’s surface. This backward and downward pull results in the rear tires becoming a pivot point, with the load acting as a force trying to tip the tractor rearward. An “angle of pull” is created between the ground’s surface and the point of attachment on the tractor.

A tractor, including the drawbar, is designed to safely counteract the rearward tipping action of pulled loads. When loads are attached to a tractor at any point other than the drawbar, the safety design of the tractor for pulling loads is defeated.

The heavier the load and the higher the “angle of pull,” the more leverage the load has to tip the tractor rearward. Figures 4.12.g, 4.12.h, and 4.12.i. show important information about safe hitching points.

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Protect Yourself in a Tractor Overturn

The rollover protective structure (ROPS) and seat belt, when worn, are the two most important safety devices to protect operators from death during tractor overturns. Remember the ROPS does not prevent tractor over turns, but can prevent the operator from being crushed during an overturn. The operator must stay within the protective frame of the ROPS (Zone of Protection) in order for the ROPS to work as designed. This means the operator must wear the seat belt. Not wearing the seat belt may defeat the primary purpose of the ROPS.

A ROPS often limits the degree of rollover, which may reduce the probability of injury to the operator. A ROPS with an enclosed cab further reduces the likelihood of serious injury because the sides and windows of the cab protect the operator. This assumes that cab doors and windows are not removed.

To prevent tractors from overturning in the first place, follow the safety recommendations that are illustrated in Task Sheet 4.13.

Note: ROPS are available in folding and telescoping versions for special applications, such as orchards and vineyards and low-clearance buildings. Some ROPS may be a protective frame only and not an enclosed cab.

Figure 4.12.j. A rollover protective structure (ROPS) and a seat belt can protect you in the event of an overturn. If you are in the cab of a ROPS-equipped tractor, fasten the seat belt. Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.

Safety Activities

1. Use a toy scale model or a full-size tractor to illustrate the five main reasons tractors overturn.
2. Invite a farmer whom you know who has survived a tractor rollover to speak to the class about the experience.
3. Conduct a survey of area farm people to find out instances of tractor overturns in the last five years. How many overturns resulted in a fatality? How many survived an overturn? Did a ROPS play a role in their

References

1. Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses, John Deere Publishing, 2001. Illustrations reproduced by permission. All rights reserved.
2. www.cdc.gov/Type agriculture tractor overturn hazards in search box/Click on 1 0.67 Tractor Overturn Hazards, August 2002.

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