Tractor Stability

Learning Goals

- Explain the role that center of gravity plays in tractor overturns
- List reasons the center of gravity moves within a stability baseline
- Understand how to be protected during a tractor overturn

Related Task Sheets

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

Introduction

No other machine is associated more with farming hazards than the tractor. Estimates indicate that tractor overturns are responsible for the majority of fatal injuries on farms. Tractors are used for many different tasks and can be versatile machines. However, 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.

Keep the center of gravity inside the stability baseline.

How Tractors Overturn

The center of gravity (CG) 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.

Figure 4.12.a. Expected position of a tractor's center of gravity. Credit: Jeff Mathison

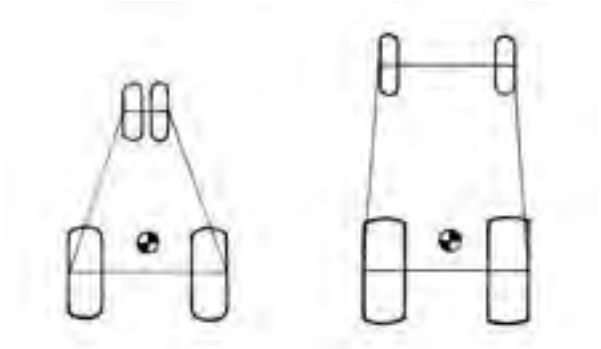

Figure 4.12.b. The tractor's center of gravity is inside the stability baseline. Illustration by Jeff Mathison

Figure 4.12.b 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's 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.

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, Speed, and Slope 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.

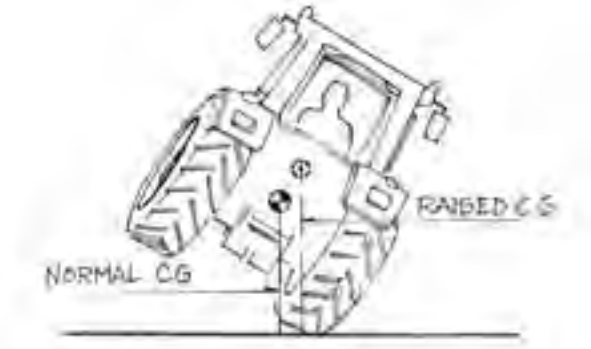

Figure 4.12.c. When a tractor is on a slope, the distance between the tractor's CG and stability baseline is reduced. Illustration by Jeff Mathison

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.

Figure 4.12.d. A raised CG makes it easier for a tractor to turn over sideways. Illustration by Jeff Mathison

Centripetal force (CF) is the center-seeking force exerted on objects moving in a circular rotation. During a turn, CF is that force trying to keep the tractor from rolling over on its side whenever the tractor is turning. However, inertia of the tractor generated from the center of gravity is acting tangentially to the center of rotation. This pushes the tractor away from the center in a straight line.

These forces are additive. This means that if the inertia force is greater than the centripetal force, the tractor will continue in a straight line and experience a side overturn. The width of the wheel base, the center-of-gravity height, the turning radius, and the tractor's travel speed are the variables impacting a tractor side overturn.

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, overcorrection of steering can result in 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 speed may be needed to push the tractor over.

The tractor's transmission applies results in a rotating 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 torque will force the chassis of the tractor to rotate around 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.

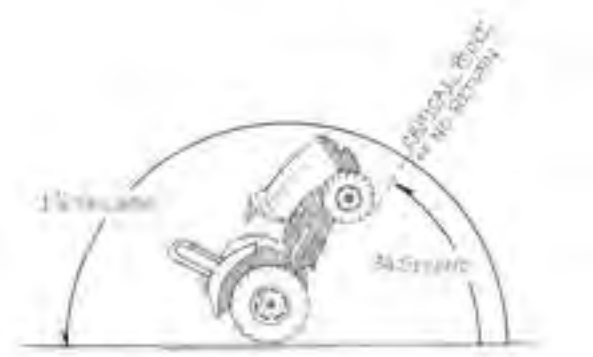

Figure 4.12.e. The point of no return is reached in ¾ of a second. Illustration by Jeff Mathison

The CG of a tractor is found closer to the rear axle than the front axle. A tractor may only have to rear back 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 are stuck in a mud hole, or tires are 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.

Figure 4.12.f. When a tractor is pointed up a slope, the CG is closer to the rear stability baseline. Illustration by Jeff Mathison

When a two-wheel-drive tractor is pulling a load, the rear tires push against the ground. At the same time, the load attached to the tractor is pulling back and down 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 compromised. 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 4.12i show important information about safe hitching points.

Figure 4.12.g. Only hitch to the drawbar. Credit: Jeff Mathison

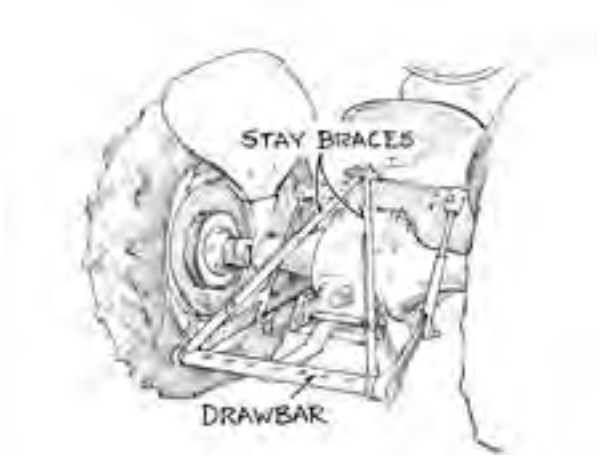

Figure 4.12.h. Never hitch to the top link of a three-point hitch. Credit: Jeff Mathison

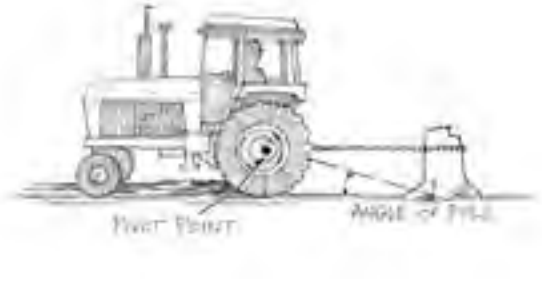

Figure 4.12.i. The angle of pull should be kept to a minimum. Illustration by Jeff Mathison

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 overturns, but it 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, assuming that cab doors and windows are not removed.

To prevent tractors from overturning in the first place, follow the safety recommendations 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.

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 who you know has survived a tractor rollover to speak to the class about the experience.

Figure 4.12.j. 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. Credit: Association of Equipment Managers

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 surviving the rollover?

References

Farm and Ranch Safety Management. John Deere Publishing, 2009.

Safety Management for Landscapers, Grounds-Care Businesses, and Golf Courses. John Deere Publishing, 2001.

Murphy, D. J., J. Myers, E. A. McKenzie, R. Cavaletto, J. May, and J. Sorensen. "Tractors and Rollover Protection in the United States." *Journal of Agromedicine* 15, no. 3 (July 2010): 249–63. doi: 10.1080/1059924X.2010.484309.