

ON BEHALF OF
FOLEY UNITED
THANK YOU...
FROM RIVER FALLS,
WISCONSIN



CCCS

A photograph of a large, modern building with a corrugated metal roof, likely a golf clubhouse or maintenance building. The building is surrounded by green grass and several trees. In the foreground, there is a parking lot with several empty spaces. To the right of the building, there is a large, illuminated sign for "FOLEY UNITED" mounted on a brick base. The sky is clear and blue.

**“Reel” Science
and
Optimum Cut Technology
GRINDING Session**



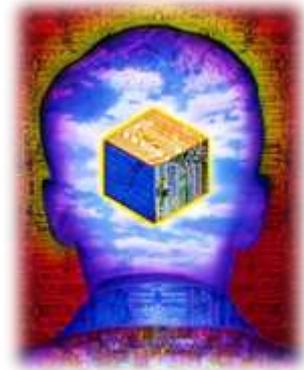
We express special thanks to Iowa State, Jacobsen, John Deere, Toro, and others for material contained in this program.



GRINDING Session

Elevating Skill Levels – Old to NEW...

Superintendents and Technicians are increasing knowledge and skill levels



Today's golf mechanics come from varied backgrounds and typically learn reel maintenance from someone already in place.

While this “maintenance by tradition” holds many positives, it's important that Superintendents have a firm understanding of why certain things are done when it comes to reel maintenance...

RATIONALE

High cost of cutting equipment make goals of minimizing potential for issues more critical than ever.

It's all about you, saving money, being more productive with your time, and making things easier in the workshop.

OBJECTIVES

- You walk out the door with a better understanding of why the manufacturers design the cutting units the way that they do...
- You understand the benefits and options of maximizing your cutting equipment investments...

TOPICS

- 1) Grinding Education 101 – A REEL Standard
 - Why is ‘sharp’ and ‘shape’ important
 - It’s all about “Quality of Cut” & “Performance”
- 2) “Quality of Cut” - What’s Providing It...
 - Traction System Evolution & Reel Technology Basics
 - Reel Manufacturer Optimum Design
- 3) Performance - Staying On Cut...
 - Adjustments – Backlapping – Facing Bedknives
 - Grinding – The Last Step
- 4) “Shop Tools” – Basic Grinding Objectives
 - “Upright” & “Tabletop” Grinder Technologies Today
 - Bedknife Grinding & Goals
- 5) Rotary Blade Sharpening: Impact and Performance
- 6) Grinding Education Conclusion – What Managers Should Know

Grinding Education 101

- 1) to crush, pulverize, or reduce to powder by friction, especially by rubbing between two hard surfaces
- 2) to shape, sharpen, or refine with friction
- 3) to wear down, polish, or sharpen by friction
- 4) to press together with a rotating motion
- 5) to operate or produce by turning a crank

To ***“Grind”*** as it relates to our turf industry can be defined as ***“Sharpening and Shaping”*** through the friction and impact of a rotating stone and a rotating reel.

Do owners have a full understanding of the impact that grinding plays with their investments...



- ❑ Millions spent on a golf course: irrigation, the clubhouse, sod, seed, shaping, etc.
- ❑ \$300-\$750k spent on greens, fairway, and trim units based on quality-of-cut, longevity, and performance. Serious question we're always curious...by show of hands how many are under 300k.....how many over?
- ❑ Stepping back, we soon realize we've spent a tremendous amount of money to make three to five reel type cutting heads cut grass.

So it's quite simple...



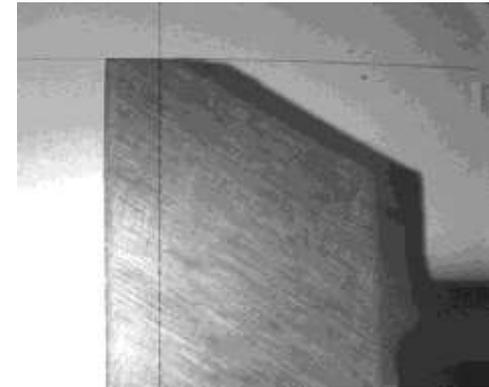
- 1) The original equipment manufacturers put a great deal of effort and dollars into producing a better reel type cutting system than their competitor.
- 2) Assumption: The way the reels are delivered to the field is the way they will function the best.
- 3) Conclusion: There's a standard the manufacturers would point to when it comes to taking care of what's providing the quality-of-cut.

Defining A “Standard”

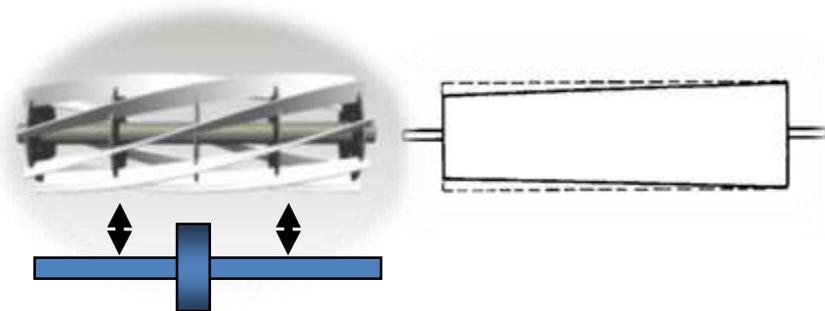
“Sharp” & “Shape”

The OEM Design From All Manufacturers

The original shape and sharp edge that comes from Jacobsen, John Deere, and Toro...it doesn't matter if it's a greens or fairway mower, all blades look like this when new.

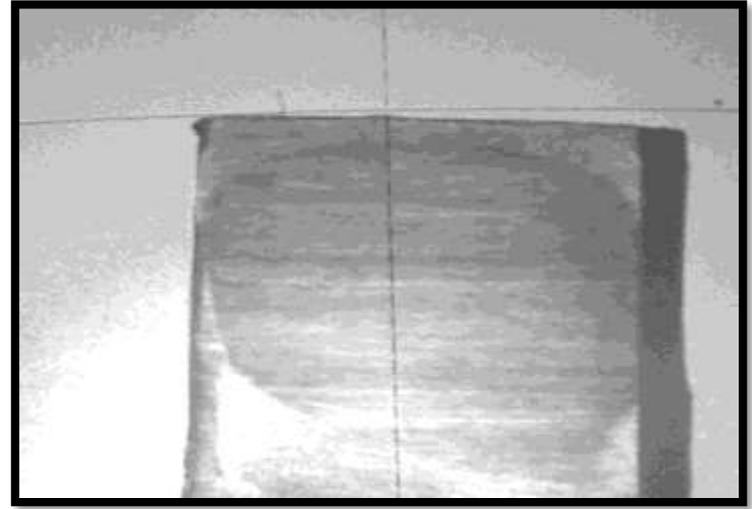
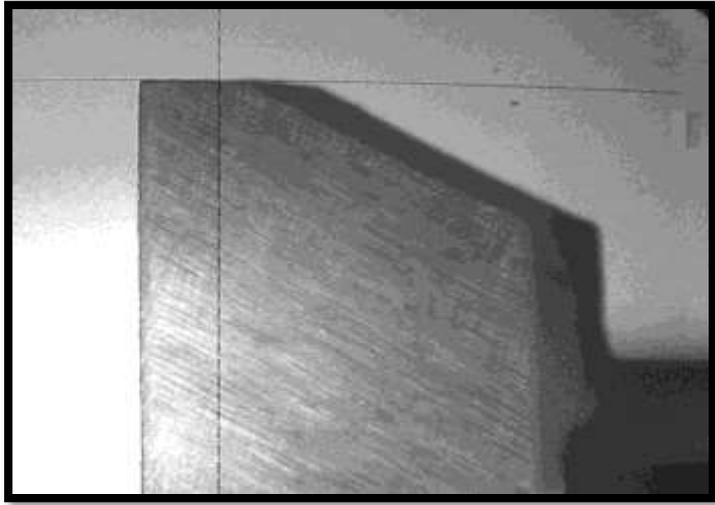


Reels are a perfect cylinder when new, but over time they typically become cone-shaped which can cause aftercut issues...



An identifiable “Standard” from the manufacturers

Is producing a sharp edge the “Standard”?



A quick visual and the
answer is “no”

Fact is, all grinders produce a sharp edge...



Staying on the simplistic side of things,
we do one of two things when
it comes to putting a reel
in a grinder:

Touch-up Spin Grinding
or
Spin & Relieving to Specs

The “REEL” question is what’s the manufacturers take...what would they like to see...why do they recommend what they do?

What maximizes performance and minimizes potential for issues?

Why is “Sharp” & “Shape” important?

Technology has
changed...



Expectations
have been
elevated...



Why is “Sharp” & “Shape” important?

You’re spending a lot of
\$\$\$
to make these cut grass.



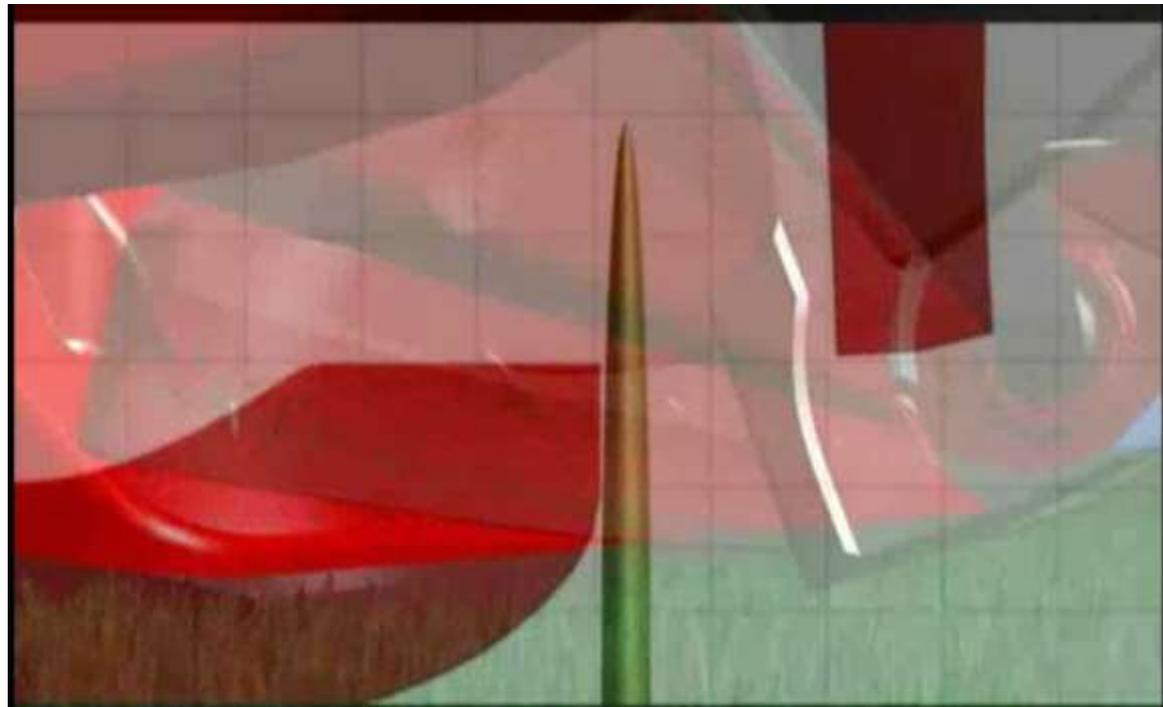
Ultimately, I’m buying “Quality of Cut” & “Performance”

“QUALITY OF CUT”



This type of damage can happen whether the reel is sharp or dull...

...but will always be most prevalent with dull and/or misadjusted reels.



“QUALITY OF CUT”



While you're trying to minimize the frayed tips and torn tissue, something happens along the way...

Natural progression of losing “shape”

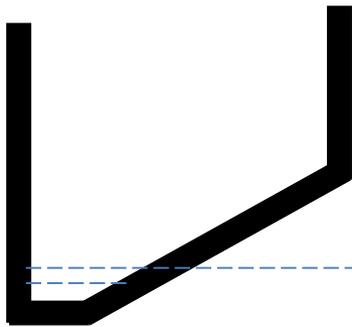


Figure 1: NEW

Sharp edge, relieved, and in a perfect cylinder...

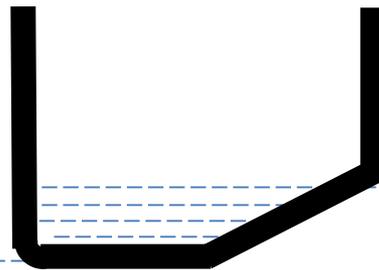


Figure 2: USED & DULL

Adjustment wear over time will require lapping and/or a touchup spin grind...



Figure 3: FLAT & DULL

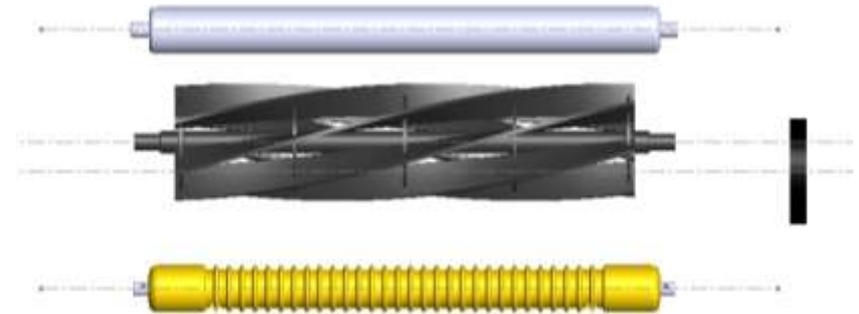
All shape is lost...the sharp edge and relief is gone, and it's likely the reel is no longer a perfect cylinder from end to end...

What happens between Figures 1 & 3?

“PERFORMANCE” & “CUT”

What we do between “NEW” and “FLAT-DULL” may vary, but Superintendents and Technicians want to be on the same page of objectives.

- ❑ Your mission is to have the best quality of cut and best aftercut appearance possible 100% of the time...



- ❑ You want adjustments to be easier and units to stay on cut as long as possible...
- ❑ You want as many options to stay on cut as possible while also minimizing potential for issues...

Superintendents & Technicians

“Quality of Cut” and “Performance” Outcomes

Grinding is the only process capable of returning reels to “LIKE NEW” and maximizing both...

A planned grinding schedule will reduce

- Labor
- Fuel
- Chemicals
- Equipment Repair
- Equipment Replacement

Quality-of-Cut and Performance Outcomes: How did we get here...

...There's some history that's taken us to where we are today.

- 
- **Traction System Changes**
 - **Changes in Reel Technology Basics**
 - **Original Reel Manufacturers Specifications**
(OEM Specs = a “Standard”)

Traction System Technology

Fascinating horsepower requirements in the early days

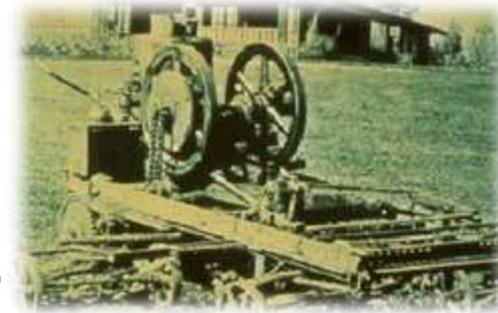


Steam & horses...



...interesting times indeed

Heavy chain driven type systems continued to evolve...



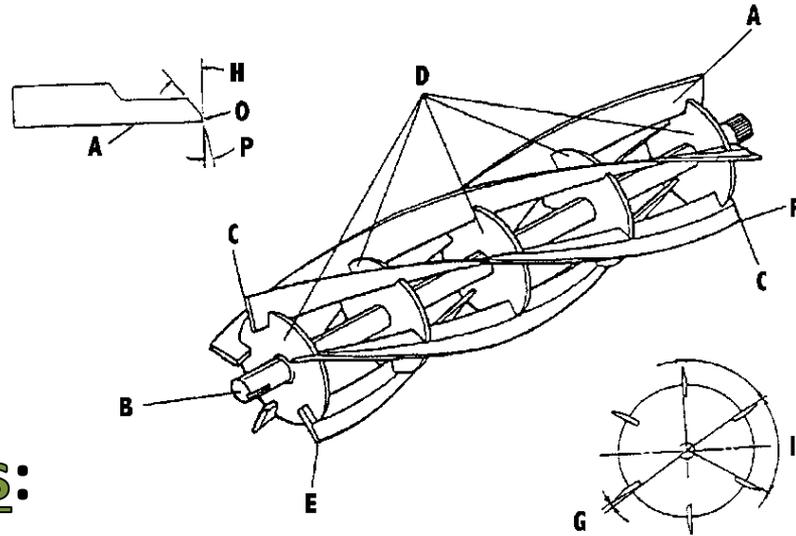
...to tractor ground type drive units, and desires for more productivity.



Traction systems today have changed in significant ways.

While we recognize that traction systems are quite different today...

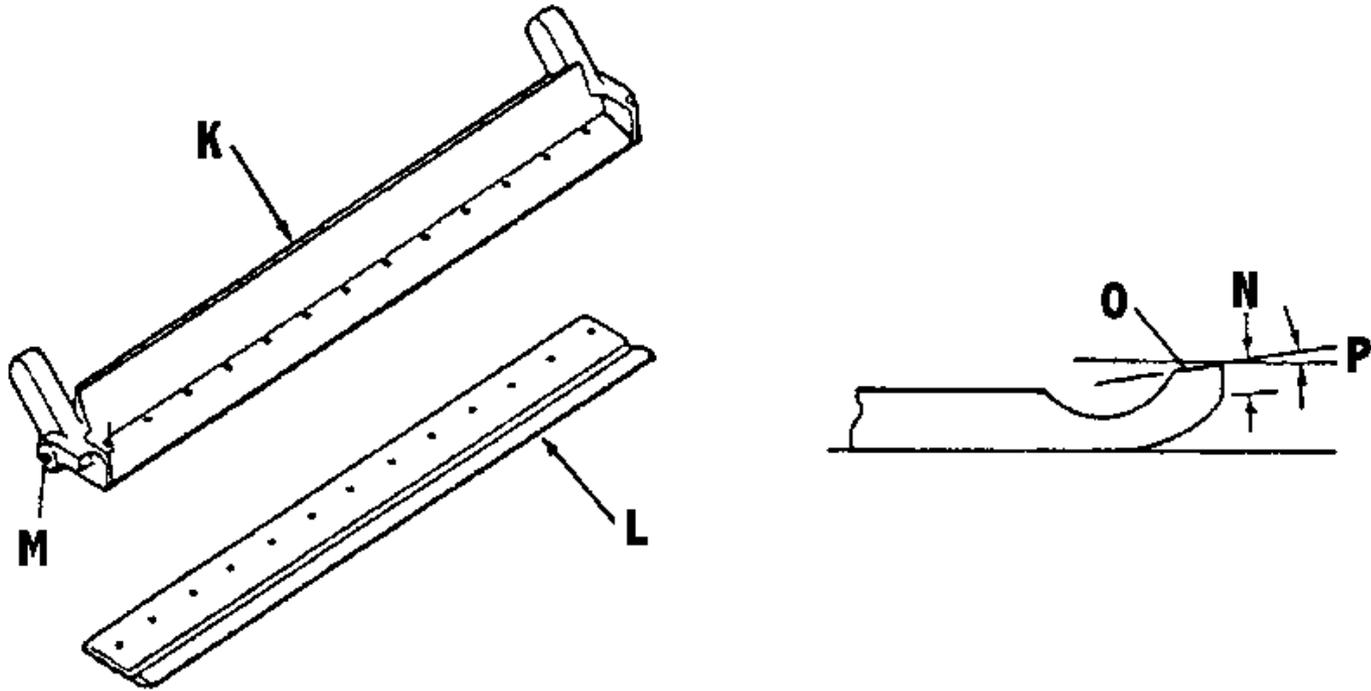
...the basics of the reel design has not changed so much when it comes to sharp, shape, and function.



Reel Blade functions:

- The reel blade rotates across the edge of the bedknife acting similar to a half pair of scissors
- The reel blade gathers the grass and discharges the clippings...

The Bedknife also serves two functions...



Bedknife functions:

- It pushes against the blade of grass and stands it up in a vertical position
- The bedknife edge acts as the second half of a pair of scissors

The reel & bedknife work together to form the Clip Rate or Frequency of Clip (FOC)

Clip rate, or FOC is the distance traveled between each reel blade rotating and gathering the grass into the bedknife. This 'clip rate/FOC' is typically equal (plus/minus 20%) to the height of cut (HOC) and is determined by three things:



- 1) The number of reel blades...**
- 2) RPM of the reel...**
- 3) Forward travel speed of the traction unit...**

NOT TO SCALE



JACOBSEN
A Textron Company



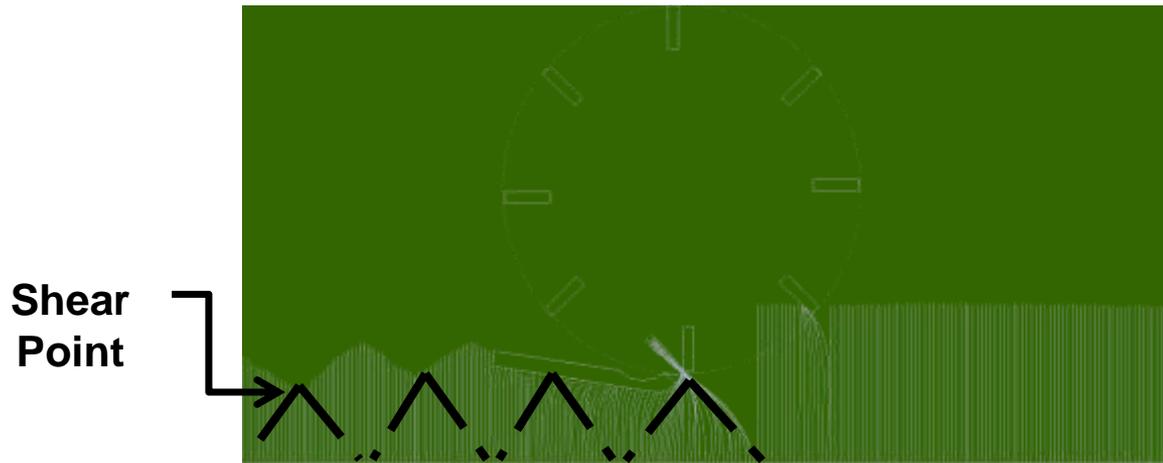
Initial .500 FOC	Change .250 FOC	Change .125 FOC	Change .062 FOC
Blades = 2	Blades = 4	Blades = 4	Blades = 4
RPM = 1000	RPM = 1000	RPM = 2000	RPM = 2000
Speed = 3mph	Speed = 3mph	Speed = 3mph	Speed = 1.5mph

What has changed over time...?

DESIRES & EXPECTATIONS

Clip Rate & Frequency of Clip

Clip forms a triangle as the reel blade gathers the grass into the bedknife as illustrated below.



The end result of this cutting action leaves 20-30% of grass mass that is not cut at the "shear point"

Smoother & Faster Surfaces

Want to bump up the stimp-meter?

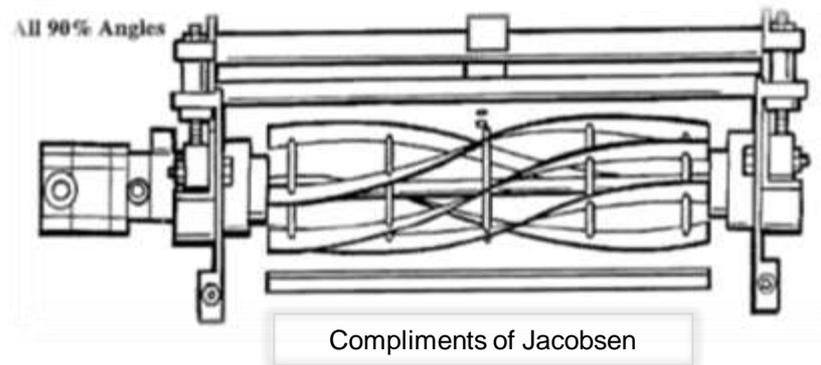
- Cut to a shorter HOC...
- Increase Clip rate...
- Roll to lay the ridge down
- Double-cut to remove some of the 'ridge' left from the initial cut...
- Agronomic practices

Everyone has gone to hydraulics in order to get the needed reel RPM's for various HOC's and clip rates and more recently, increased blade counts...

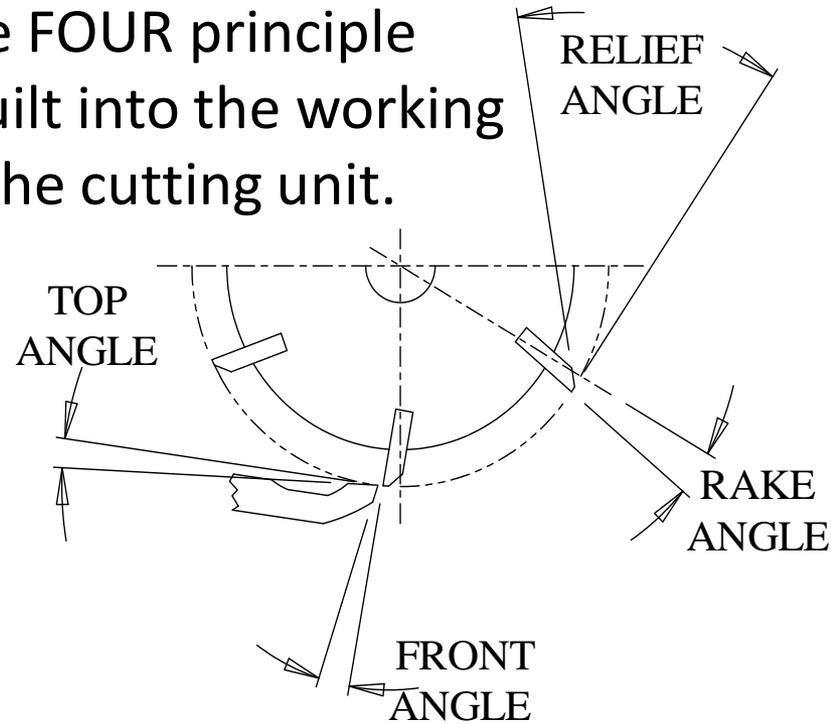
Original Reel Manufacturer Specifications = A “Standard”

(OEM Specs for short!)

Reel Manufacturers “Optimum Design” & Engineered Cutting Unit Performance



There are FOUR principle angles built into the working parts of the cutting unit.



The cutting head design is a “box-like” construction. In other words the frame, rollers, reel, and bedknife are square and parallel.

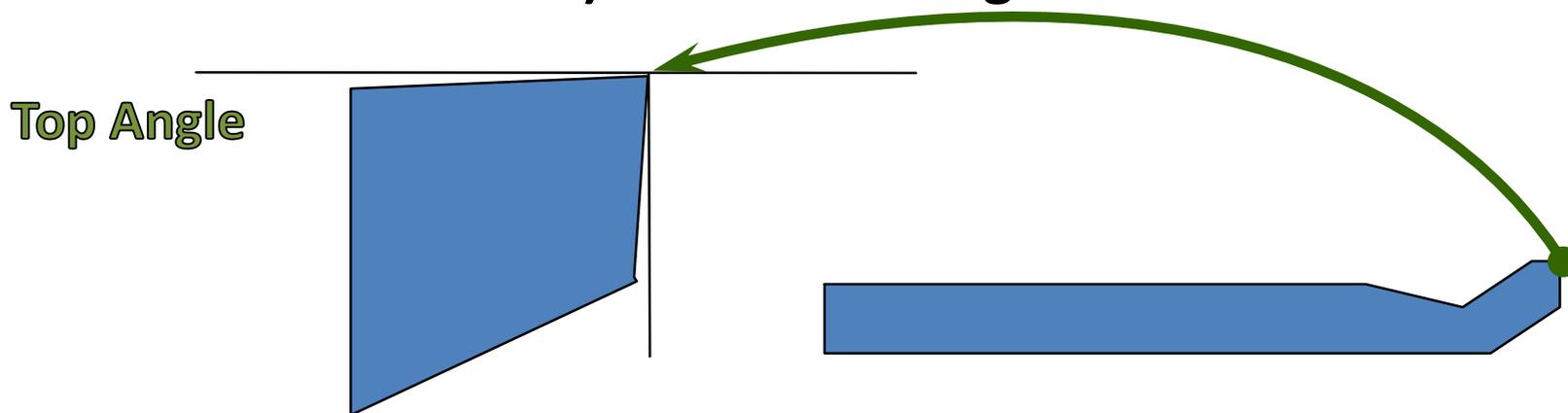
Reel Manufacturer Specifications

Bedknife Angles

The BEDKNIFE is associated with two angles:

1) TOP FACE ANGLE

2) Front Face Angle



- 1) It reduces the amount of surface area that exists as the reel blade sweeps across its cutting edge.
- 2) It allows for the cut grass to be ejected from the cutting unit, optimizing dispersion and minimizing clumping.
- 3) It also supports the cutting edge, optimizing wear rates.

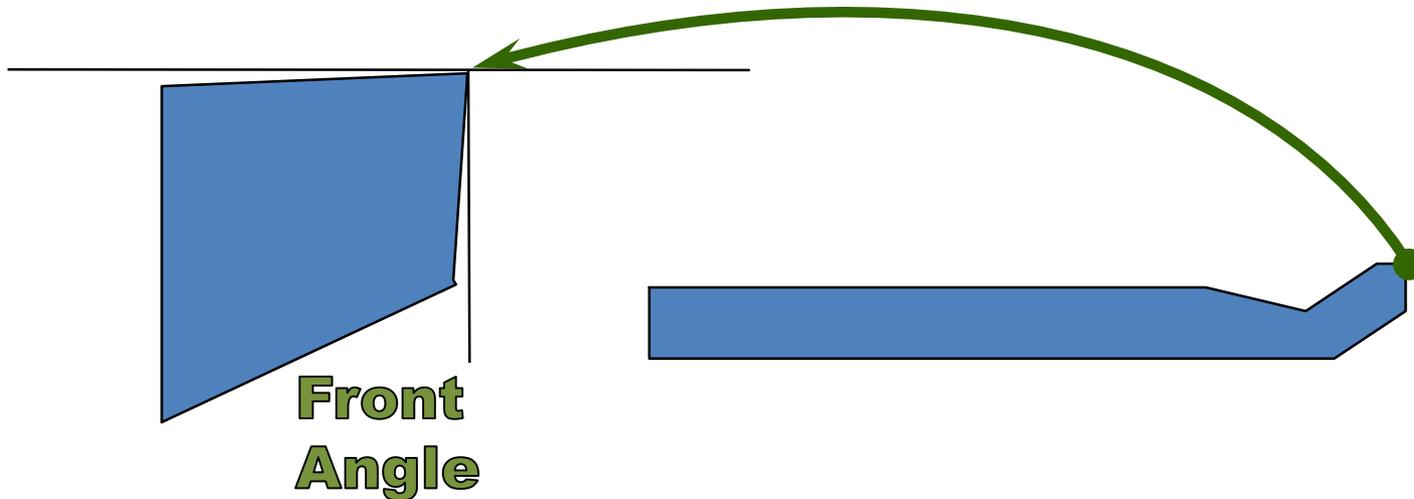
Reel Manufacturer Specifications:

Bedknife Angles

The BEDKNIFE is associated with two angles:

1) Top Face Angle

2) FRONT FACE ANGLE



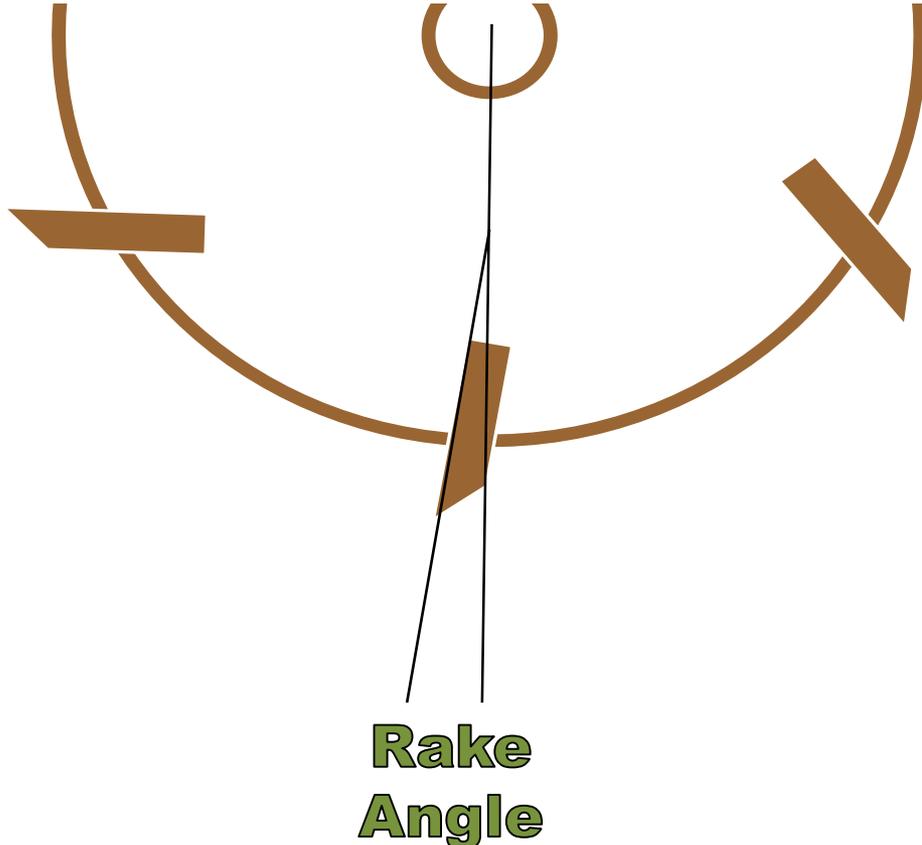
- 1) This angle stands the grass up vertically, rather than pushing the grass over prior to the reel blade making its pass over the cutting edge. This ensures fewer stragglers...
- 2) This angle also ensures that wear rates are at an optimum and that the front edge is less susceptible to damage...

Reel Manufacturers Blade Angles

The REEL BLADE is associated with two angles:

1) **RAKE ANGLE**

2) Relief Angle



The reel *RAKE ANGLE* is created by the slot in the spider which locates the blade on an angle. The angle ensures that the front cutting edge is always forward of the blade body, which in turn cuts, not pushes the grass.

Reel Manufacturers Blade Angles

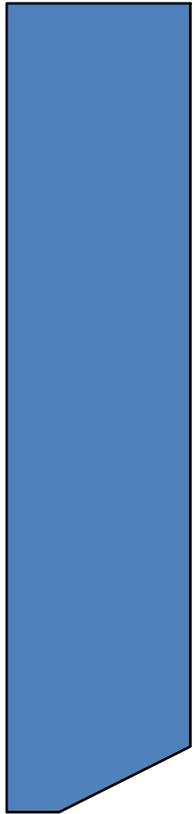
The REEL BLADE is associated with two angles:

1) Rake Angle

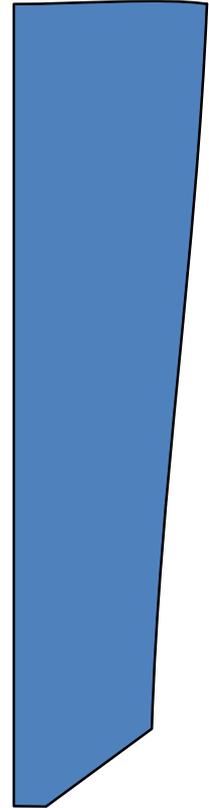
2) RELIEF ANGLE

FAIRWAY/ROUGH mowers have a much thicker blade design and a “**Ground-in**” RELIEF ANGLE is produced at the factory from all of the reel manufacturers.

More recent design of the thicker fairway unit blades includes a milled area with the ground relief to maximize cutting unit performance.



**GROUND
Relief**



**MILLED &
GROUND Relief**

Reel Manufacturer's Blade Angles

GREENS/TEE mowers have a thinner blade and uses a “**Milled-in**” blade design. Reel manufacturers then produce the ground-in **RELIEF ANGLE**, similar to what is done with the fairway units.

With the advancement of “battery and electric motor” technology, a relief grind on greensmowers can play a bigger role in optimizing performance.



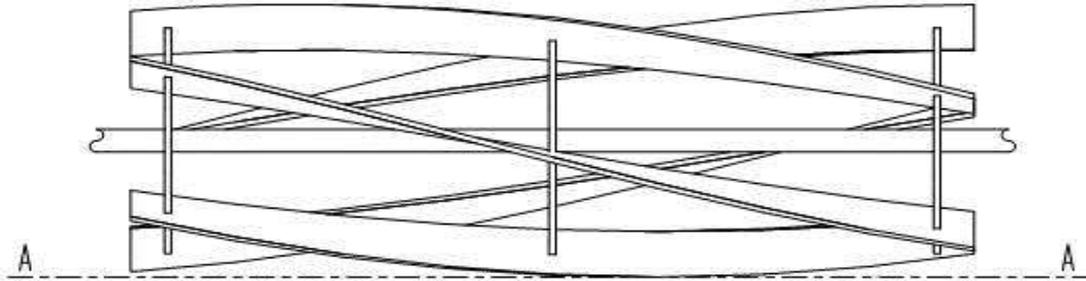
Electronic reel motor systems make relief more important in optimizing energy and extending the charge of the battery systems.

**Milled &
Ground
Relief**

Reel Manufacturer Cutting Unit Configuration

NEW REELS OUT OF THE FACTORY

- ALL of the reel blades are on the same cutting circle
- The reel diameter is equal from end to end



BEDKNIFE IS STRAIGHT AND TRUE



Note: "CYLINDRICAL GRIND" is often confused as a one-dimensional term (all blades on the same cutting circle), but needs to include both facets of 'cylindrical' noted above. Optimum cutting unit performance is achieved when the circularity of "A-A" is straight and parallel with bedknife surface "B-B".

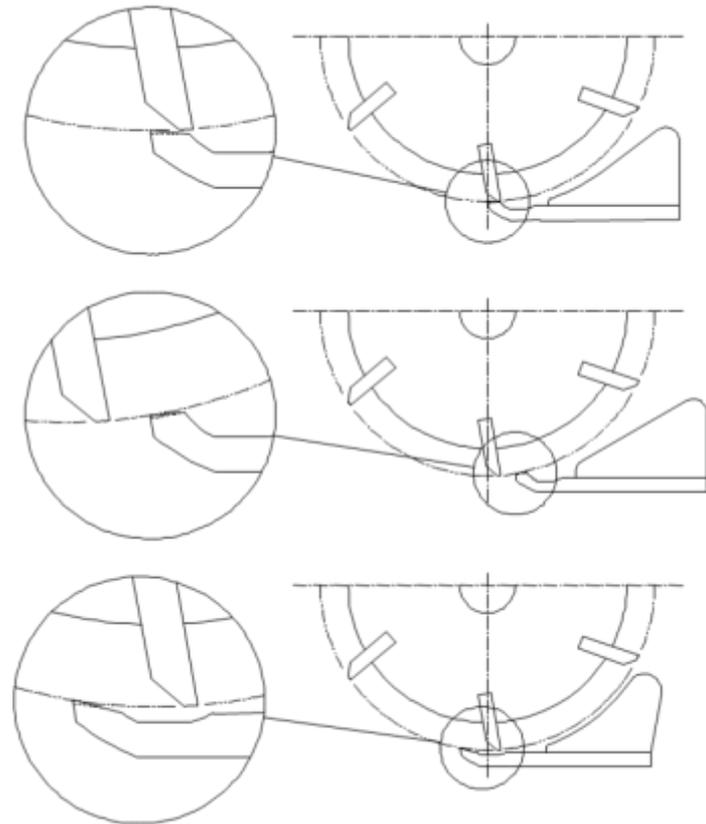
Reel Center-line & Bedknife Relationship

There are three possible positions of the bedknife cutting edge in relation to the center line of the reel.

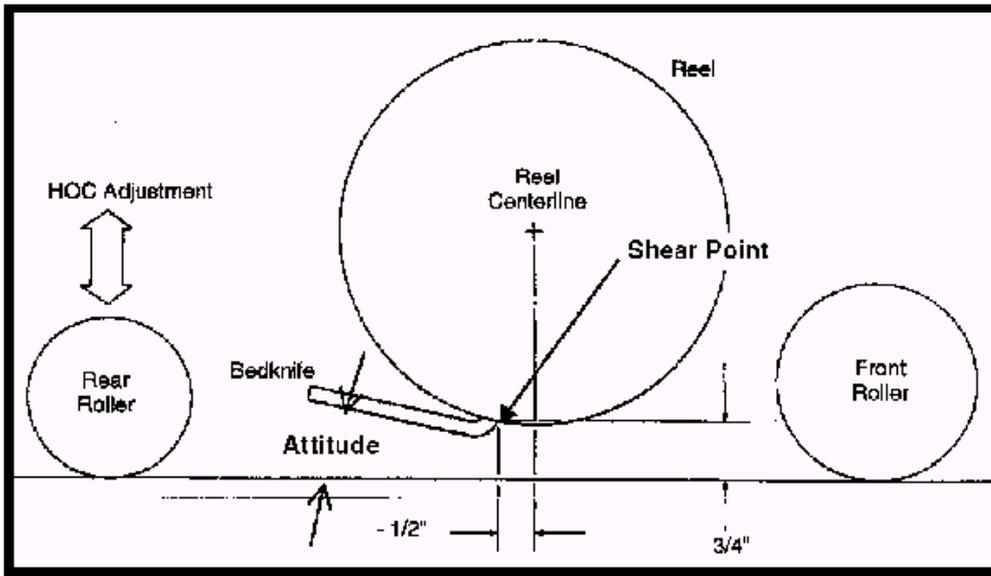
If the bedknife edge is directly under the center point of the reel, typically the reel blades do not gather the grass as efficiently.

When the bedknife edge is moved further back from the center point, the reel blades actually go below the front edge of the bedknife to gather the grass.

This bedknife position will play a key role in the manufactured angles for the knife, as the OEM's try to maximize wear rates and minimize maintenance.

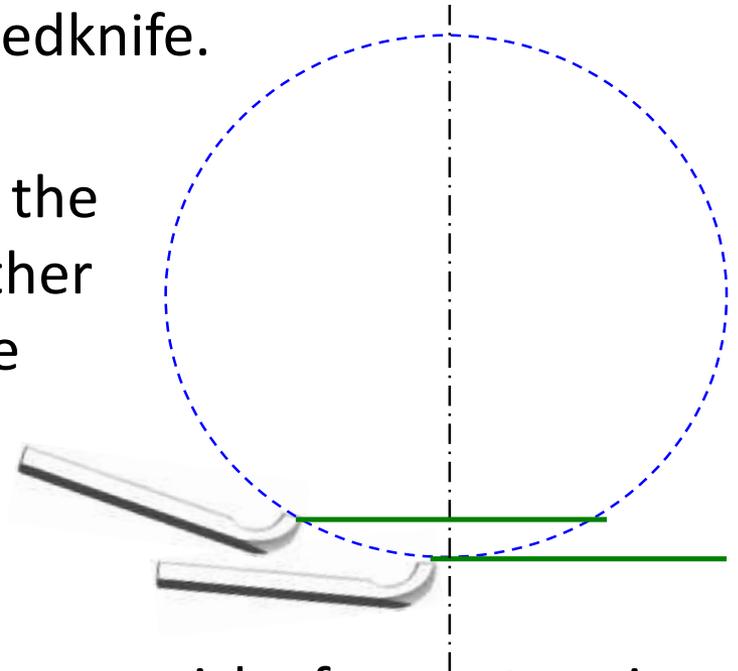


Reel Center-line & Bedknife Relationship



The distance between the shear point and the center line will dictate how aggressively a unit cuts, this is called the “ATTITUDE”, or the resulting angle of the bedknife.

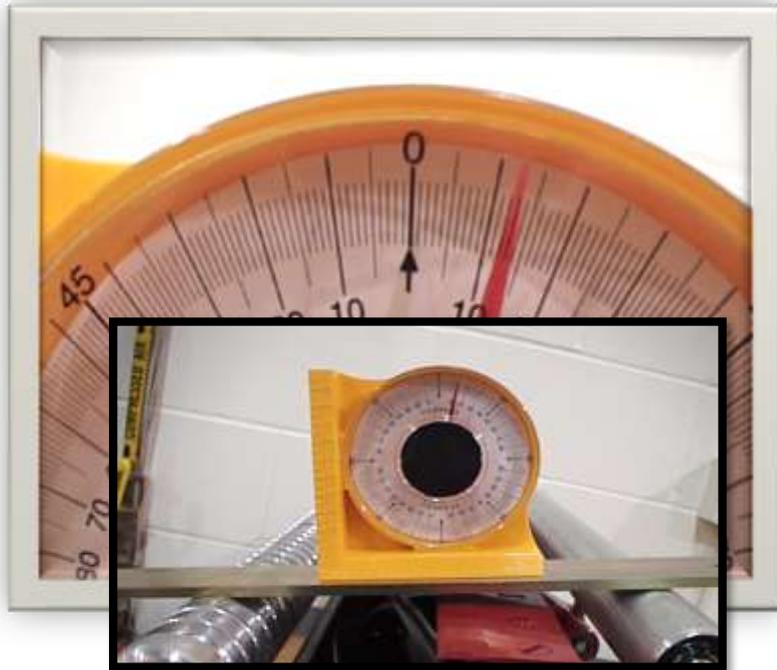
When the shear point moves farther from the reel centerline, the blade path will dip farther below the front edge of the bedknife while gathering the grass, making the cut more “aggressive”.



If the cut becomes too aggressive, there is more risk of over stressing the grass, especially at lower heights of cut.

Bedknife Attitude

You can change the attitude by manipulating the roller position relative to the height of cut. Using a mag base angle gauge, you can determine an angle by simply resting a flat bar on the rollers...



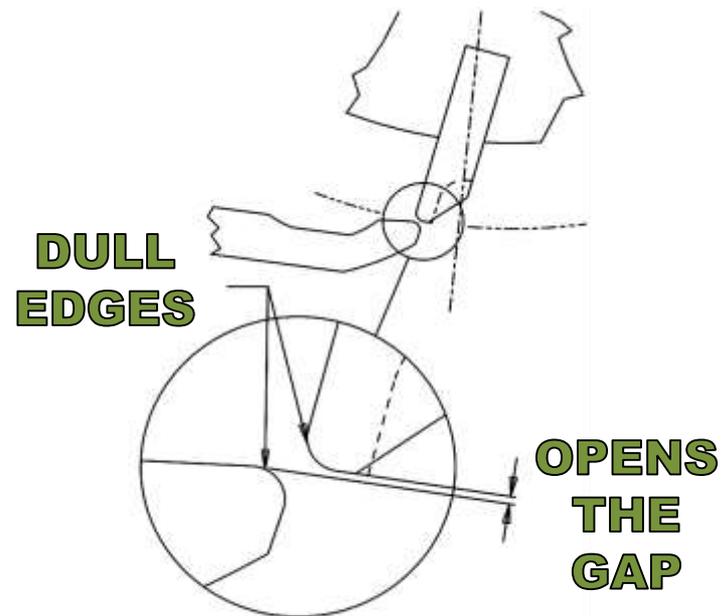
... You can then place the angle gauge on the bedknife/bedbar assembly and the difference between the two angles will provide the attitude angle that is specified by various manufacturers.

The Dulling Process

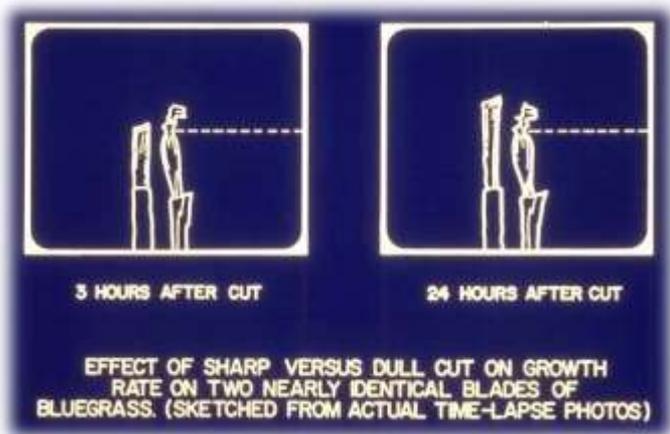
What Happens When We Put The Cutting Units Into Operation?

TOPDRESSING practices have influenced the need to grind more regularly than any maintenance practice in our industry:

- SAND - TOPDRESSING
- Chemicals
- Rust from Moisture
- Dirt
- Foreign Objects
- Grass itself



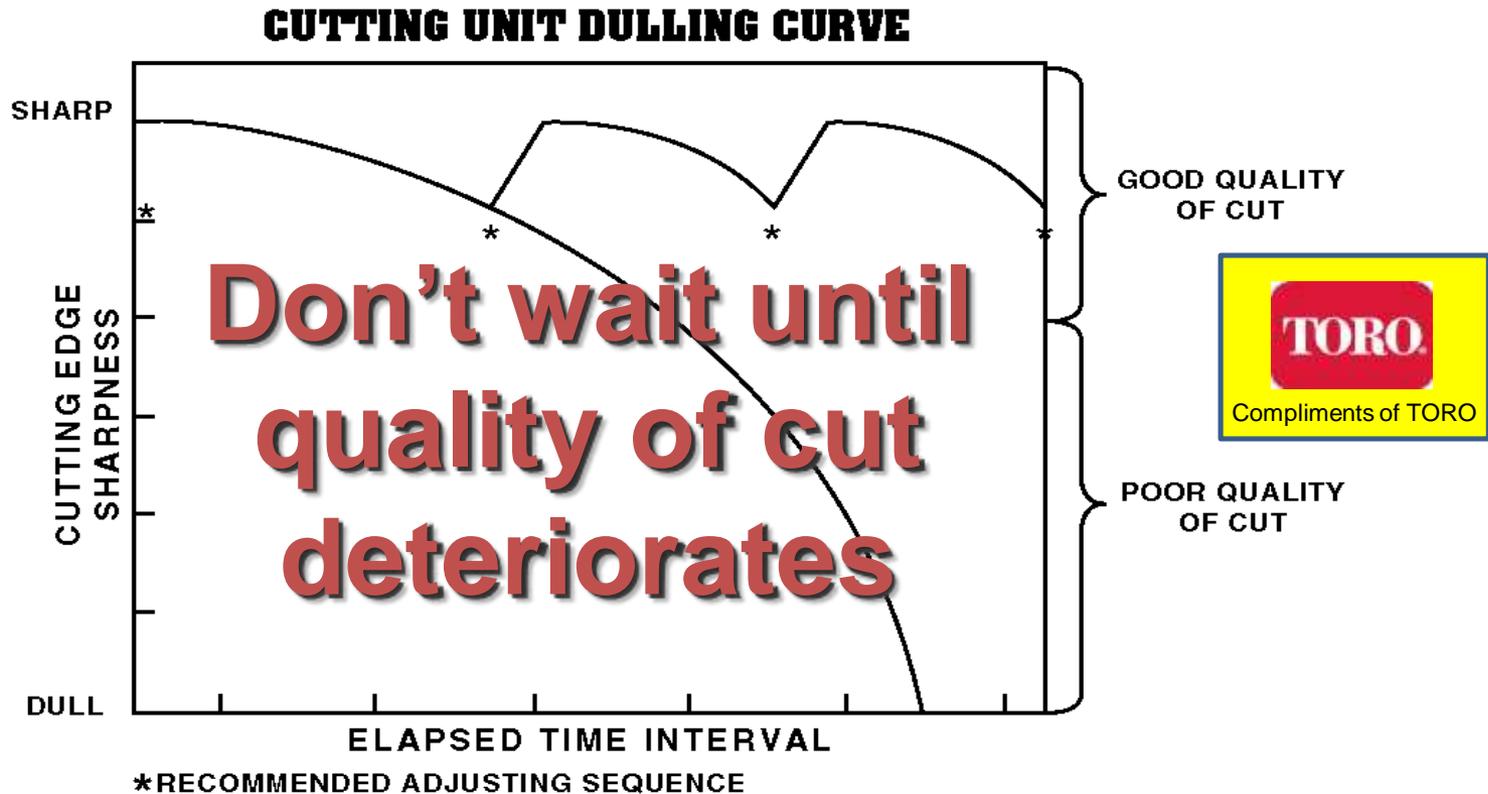
A dull reel not only creates a poor cut, but stunts the growth of the grass...



(Compliments of Toro)

The Dulling Process – Losing Sharp & Shape

What role does the OEM design play in the actions we take to stay on cut?



Note that it only takes 6 to 8 hours for the sharp, crisp edges to begin to round off and dull...

“PERFORMANCE” – Staying on Cut

What happens between Figures 1 & 3?

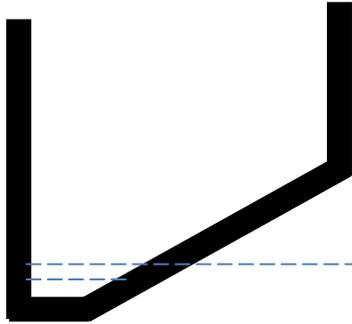


Figure 1: NEW
Sharp edge, relieved,
and in a perfect
cylinder...

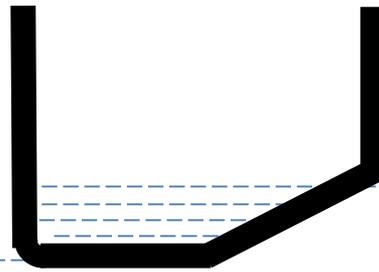


Figure 2: USED & DULL
Adjustment wear
over time will require
lapping and/or a touchup
spin grind...



Figure 3: FLAT & DULL
All shape is lost...the sharp
edge and relief is gone, and
it's likely the reel is no longer
a perfect cylinder from end
to end...

Typically, there are four actions/activities taken between these three stages of use while attempting to stay on cut:

1) Adjust

2) Backlap

3) Face

4) Grind

You take these actions to maximize longevity of cut and grinding is a last resort.

ADJUSTMENT

Before making the adjustments, also remember the basics: Reels will adjust easier, faster, and more positive when the reel and bedknife are sharp and ground at the proper angles. (Excerpt from Textron)

Light contact between the bedknife and reel will help promote a self-sharpening action. (Excerpt from a Toro)

There is a tendency in our industry for people to over-tighten adjustments when the units aren't cutting well. Over adjustment of the reel to bedknife can cause the reel to climb over the bedknife and may produce what is called rifling.

CRITICAL UNDERSTANDING

There are bearing differences and other engineering differences between the manufacturers that lead to their recommendations.

For this reason, testing is specific to the design criteria of a Jacobsen, John Deere, and Toro and rest assured they tell you what works best for highest quality of cut and their application.

ADJUSTMENT

The three Reel Manufacturers promote similar adjustment practices...



Pinch paper – “Light” Contact

0.025mm - 0.075mm (.001”-.003”)

0.025mm - 0.05mm (.001-.002”)



Ever think about how small of an amount
.001” to .003” is over a 21 inch span?

What does this mean to you...

“REEL” Education & the Adjustment Process

What’s the significance of Light Contact as it relates to “QUALITY OF CUT”



	Visual Quality	Mowing Injury	Chlorophyll Content	Ethylene Production
SHARP with “LIGHT” Contact →	8.68	0.83	17.46	0.541
SHARP with “NO” Contact →	8.20	1.85	15.73	0.593
DULL with “LIGHT” Contact →	8.41	1.28	17.12	0.603
DULL with “NO” Contact →	8.07	2.35	16.34	0.669



Figure 1



Figure 2

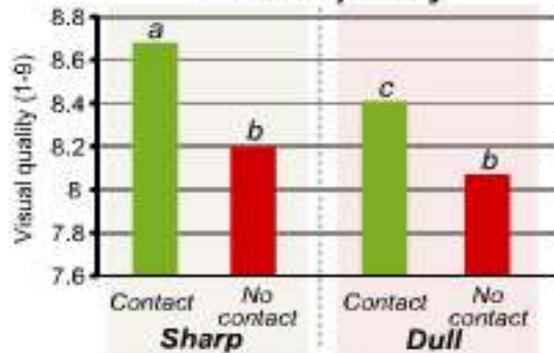


Figure 3

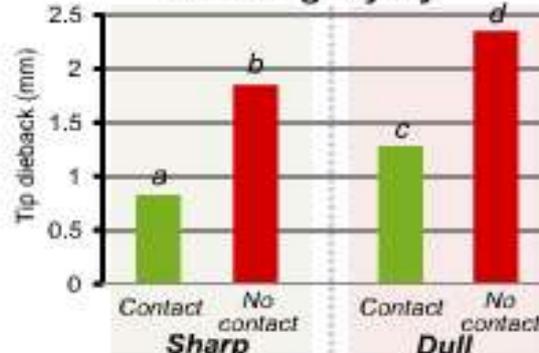


Figure 4

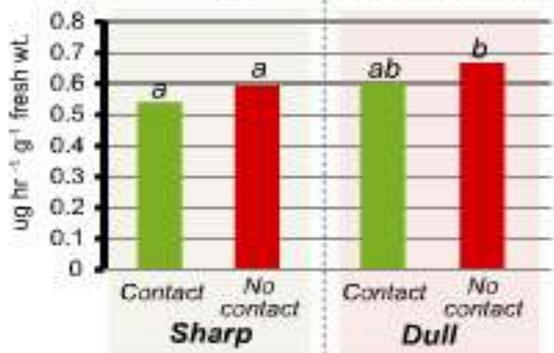
Visual quality



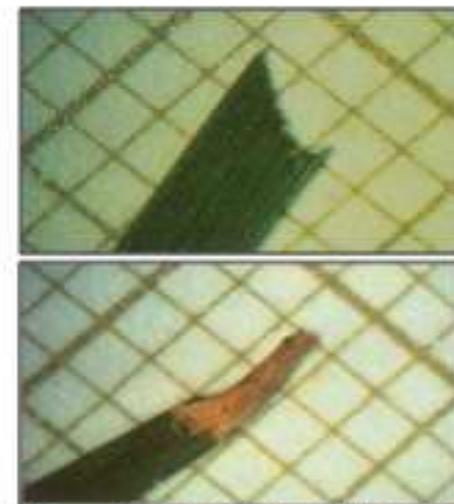
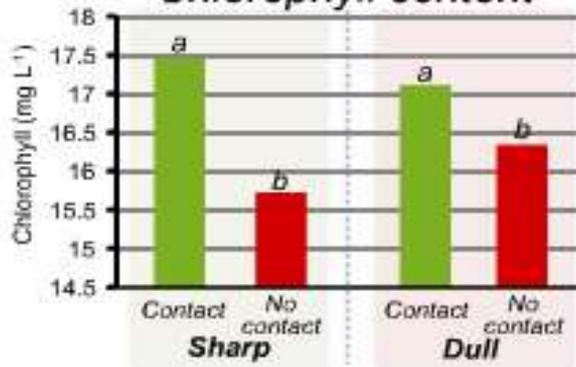
Mowing injury



Ethylene production rate



Chlorophyll content



Top: leaf cut with sharp, light contact
Bottom: dull without contact

Results were published in GCM: Mark Howison & Nick Christians. 2001. Mower setting, PGRs affect turfgrass quality. Golf Course Management. June 2001.

Sharp with contact:

- Caused less injury to leaves
 - Produced higher visual quality rating
 - Resulted in higher chlorophyll concentration
 - Resulted in less ethylene produced
- Light contact was as or more important than sharpness



Light contact was as or more important than sharpness

ADJUSTMENT – Longevity of Cut

IOWA STATE STUDY

(Compliments of Mark Howieson)

- **OBJECTIVES:** To quantify mower sharpness and mowing injury over time and estimate how frequently reel-type mowers should be sharpened to achieve the best possible cut quality.
- **EQUIPMENT:** This study used three 18-inch walking greensmowers, with each mower ground by three different grinder manufacturers:
 1. Single Blade Carbide Milling – Light Contact
 2. Cylindrical – NO Contact
 3. Cylindrical with Relief – Light Contact
- **PARAMETERS:** Each mower was used to cut approximately 25,000 – 40,000 ft² of ‘L-93’ creeping bentgrass every week for 12 weeks at a height of cut of 0.50 inches.
- **METHODOLOGY:** Measurements of mowing injury and photosynthetic yield were made weekly:
 - The length of necrotic and torn leaf tissue was measured under a microscope 24 hours after mowing
 - Photosynthetic yield was measured with a portable chlorophyll fluorometer 6-9 hours after mowing

Iowa State Study (continued - page 2)

Grasses cut with mowers sharpened by carbide milling consistently developed smaller wounds (Figure 1) and contained the greatest chlorophyll concentrations (Figure 3).

Grasses clipped with mowers sharpened by using cylindrical grinding often formed the largest wounds and contained low concentrations of chlorophyll. In addition, photosynthetic yield measurements indicate that cutting grasses with mowers sharpened with the cylindrical grind process is more injurious than clipping grasses with mowers sharpened by carbide milling (Figure 2).

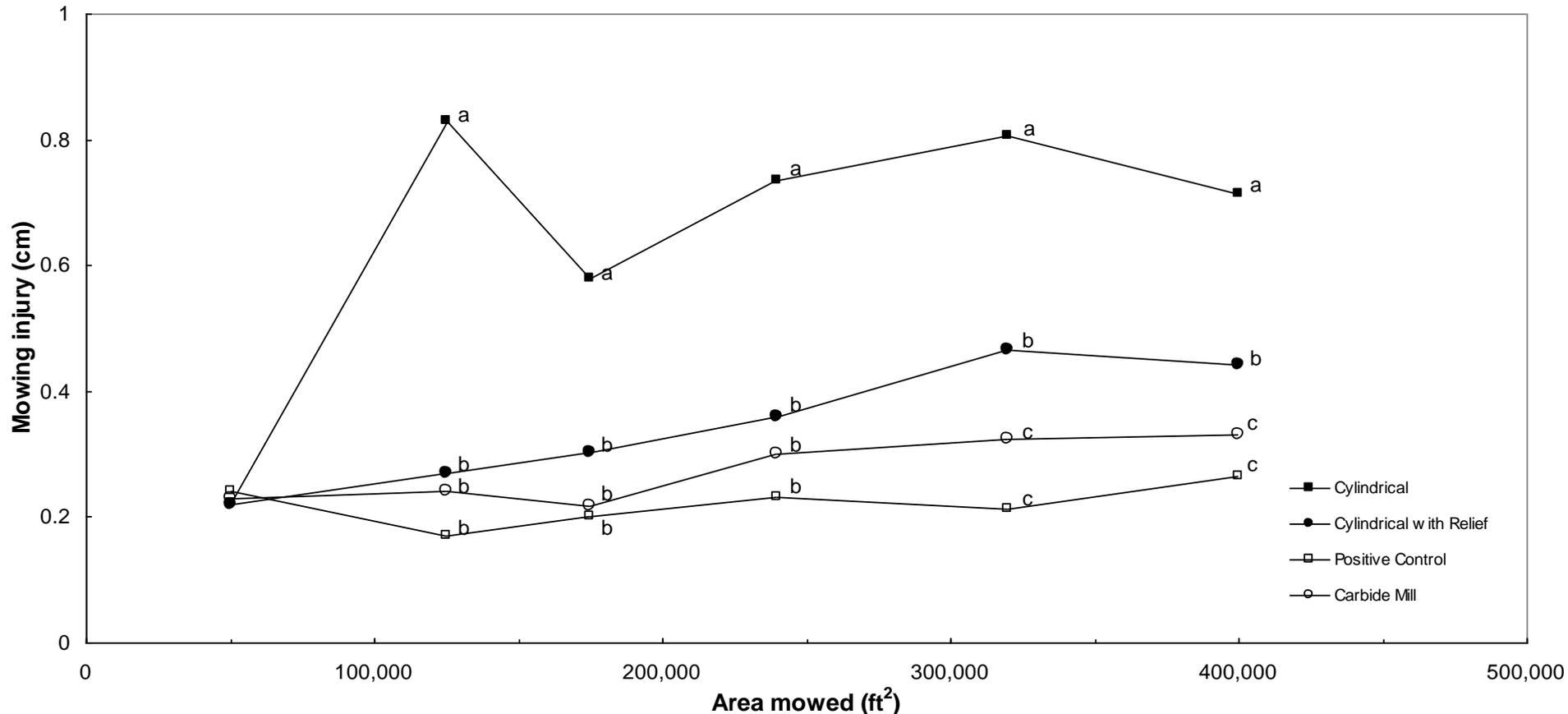


Figure 1: Each data point is the mean of 120 observations. Means labeled with the same letter at each sampling time are not different at $P < 0.05$. Means were separated by using orthogonal contrast.

Iowa State Study (continued - page 3)

Grasses cut with mowers sharpened by using cylindrical with relief grinds compared favorably with grasses cut by mowers sharpened by using carbide milling. No differences in mowing injury were observed between these treatments until over 250,000 ft² of grass had been mowed (Figure 1). Likewise, photosynthetic yield (Figure 2) and chlorophyll concentration (Figure 3) values were similar between these treatments at times during the study.

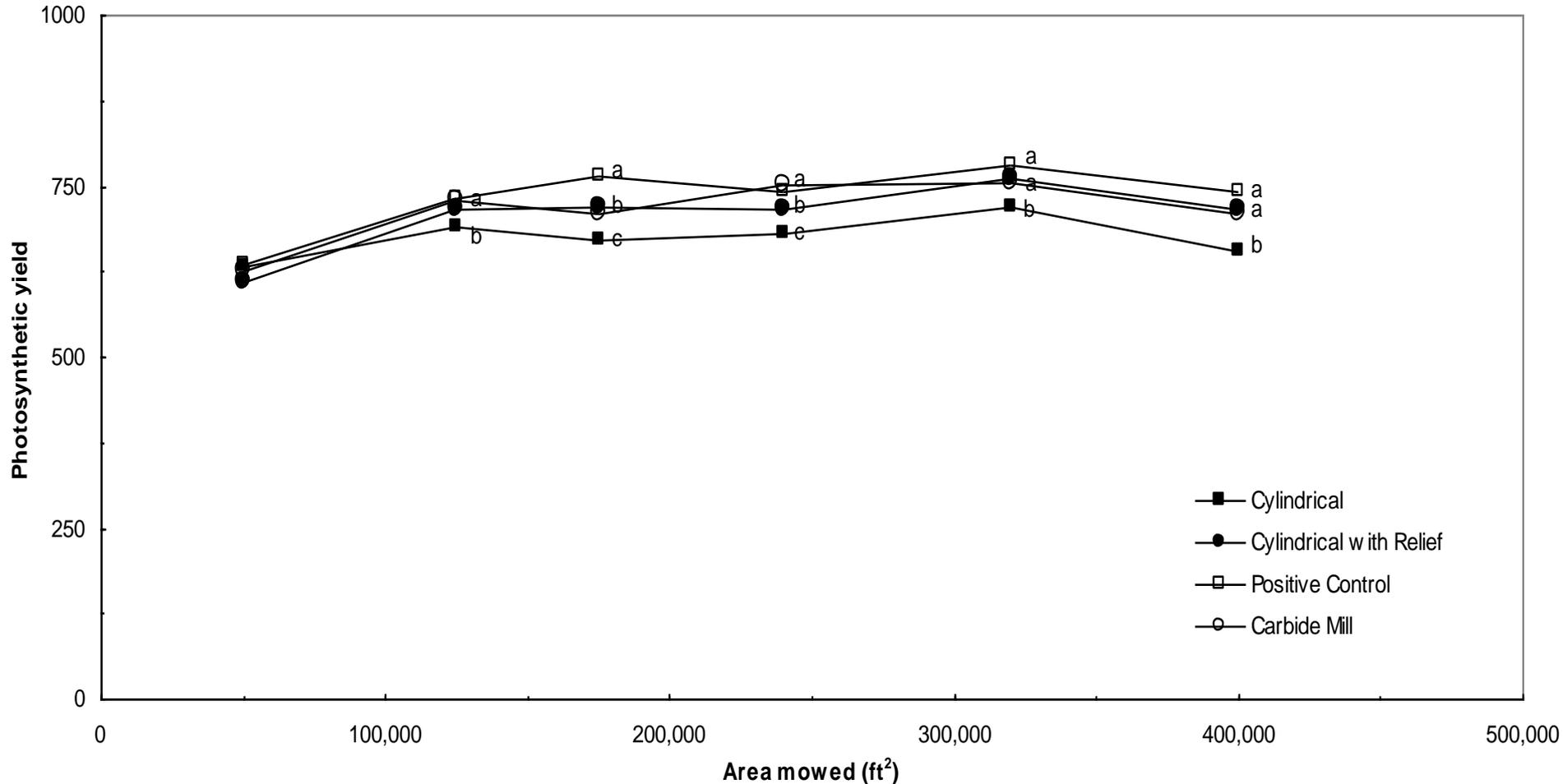


Figure 2: Each data point is the mean of 120 observations. Means labeled with the same letter at each sampling time are not different at $P < 0.05$. Means were separated by using orthogonal contrast.

Iowa State Study (continued - page 4)

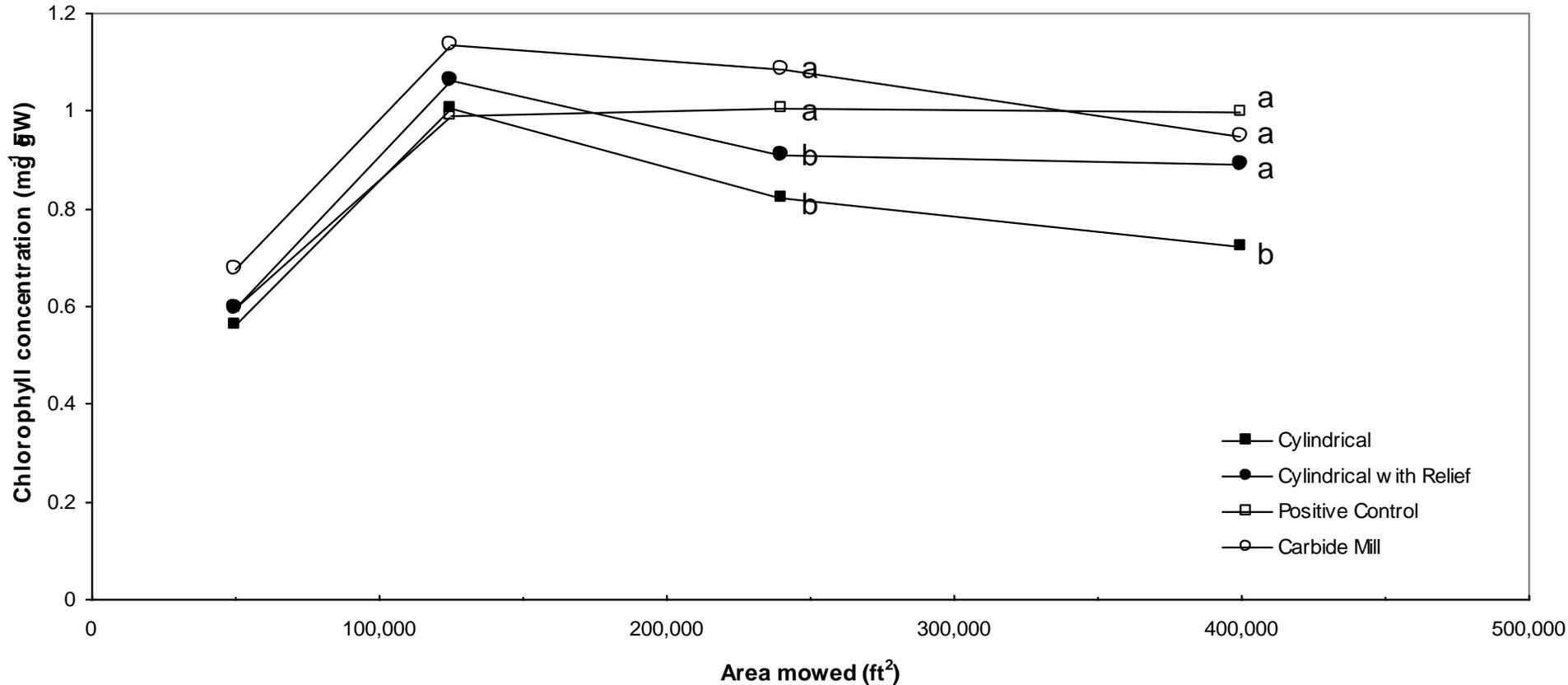
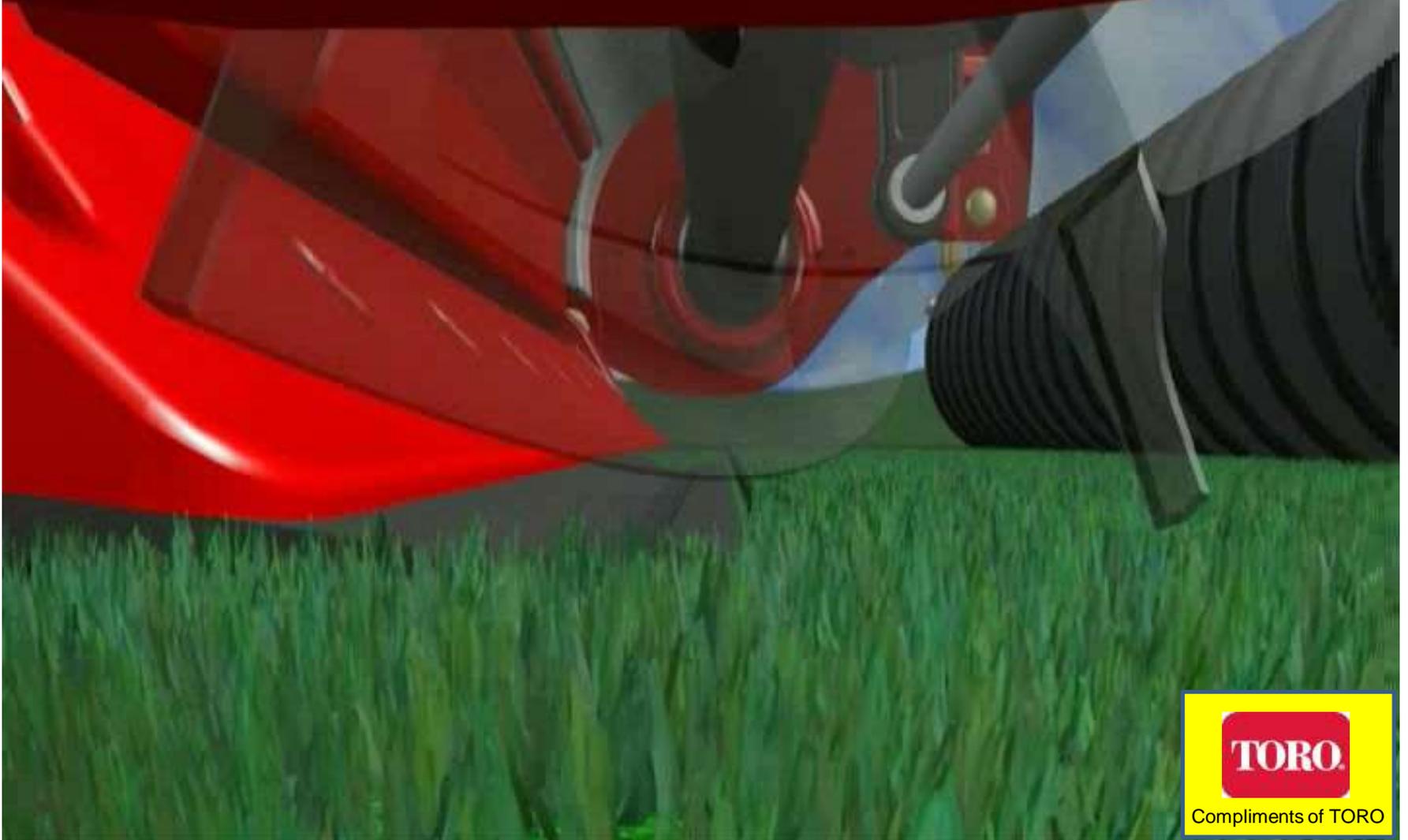


Figure 3: Each data point is the mean of 120 observations. Means labeled with the same letter at each sampling time are not different at $P < 0.05$. Means were separated by using orthogonal contrast.

Conclusion

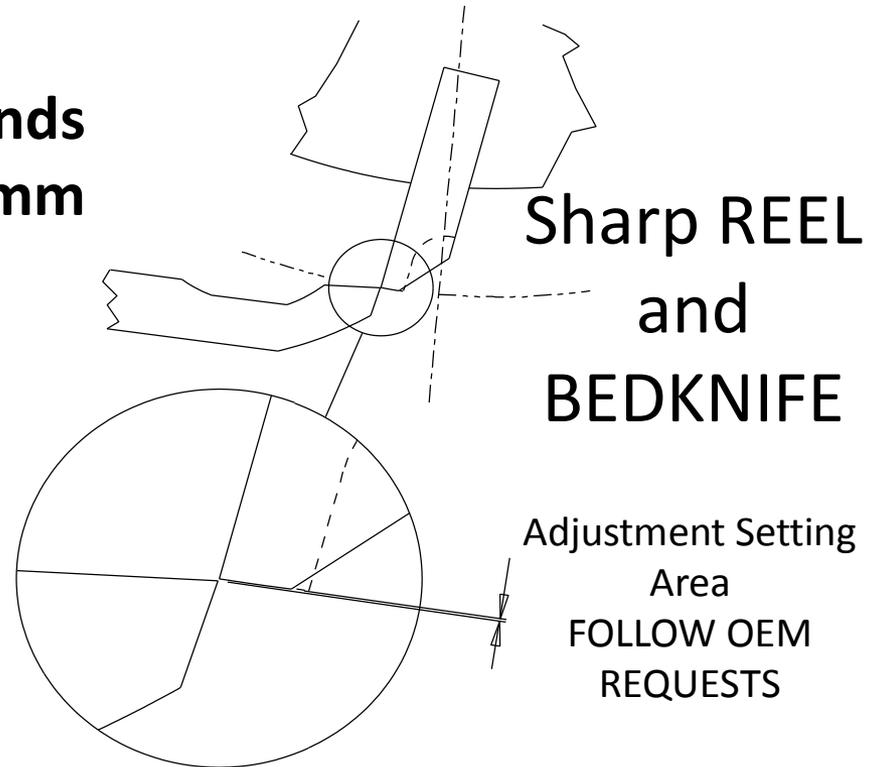
Mowers sharpened with the cylindrical grind process would need to be sharpened more frequently than mowers sharpened using cylindrical with relief grind or carbide milling processes to maintain acceptable quality of cut, perhaps as often as every 100,000 to 150,000 ft². Quality of cut was similar between mowers sharpened by cylindrical with relief grind and carbide milling processes, however, carbide milling-sharpened mowers remained sharper longer as indicated by mowing injury (**Fig. 1**).

**There's specific testing that dictates
why Toro recommends their
preferred settings.**



One shoe does not fit all when it comes to adjustments...

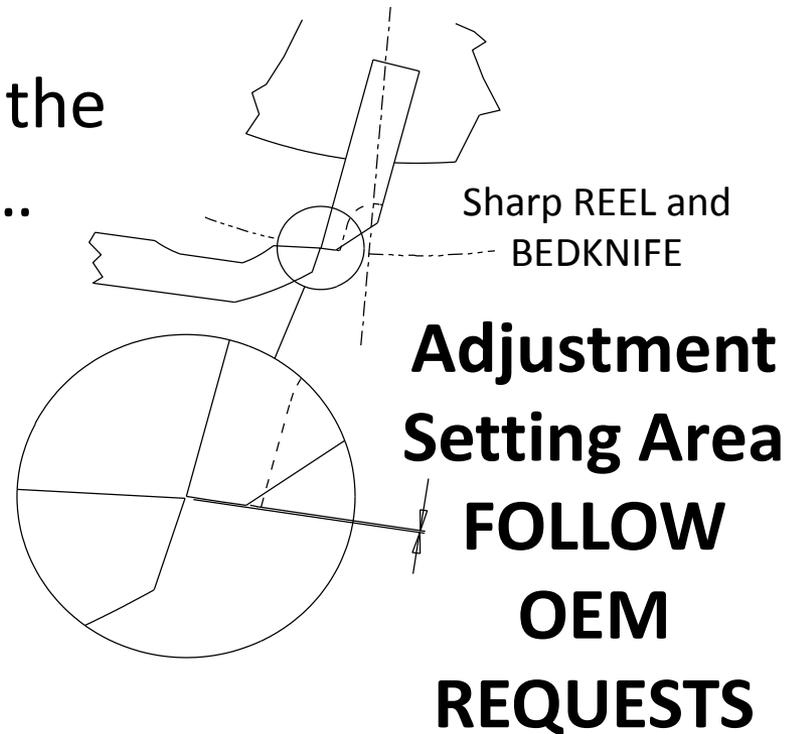
- As we know, Jacobsen recommends a setting of .025mm to .075mm (.001" - .003")
- We also now that John Deere recommends a .025mm to .05mm (.001" - .002") adjustment gap setting



It's important to note that the recommended bench settings with a gap may change when the cutting units are dropped and put on the turf and into operation:

What happens when we put the cutting units on the turf and in operation?

- Reel “start-up surge” ...
- Centrifugal inertia and weight of the reel in the bearing housing area...
- Ground pressure pushing up on the bedknife ever so slightly...
- Cutting in dry conditions...
- Torsion load & reel flex over the extended length of the reel...



DO NOT “OVER-ADJUST” your reels coming out of the shop. If units are not cutting properly with the recommended bench settings...lapping, facing, or grinding may be required.

“REEL” Education & the Adjustment Process

What’s the significance of Contact/Touching
as it relates to “PERFORMANCE”



REQUIRED HORSEPOWER & REEL ROTATION

0.05mm to 0.125mm GAP – Ensuring NO Operational Contact

- **OEM Relief .75 hp per cutting unit**
- **“NO” Relief .87 hp per cutting unit**

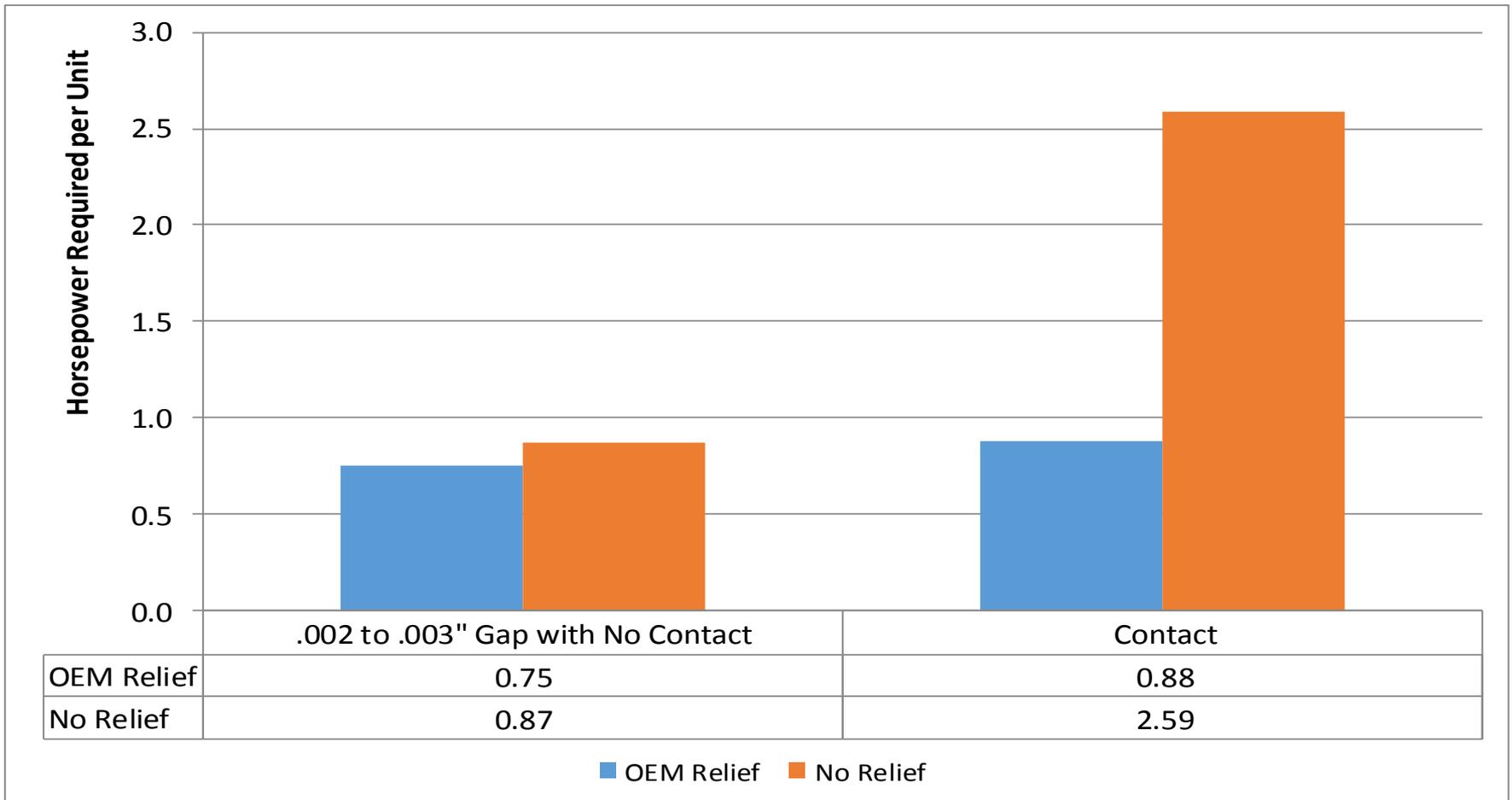
CONTACT/“Touch”

- **OEM Relief .88 hp per cutting unit**
- **“NO” Relief 2.59 hp per cutting unit**

Note that a “relieved” reel making contact puts little strain on the engine and hydraulic systems when “NEW”.

Horsepower Study

As the reel wears flat and loses shape, more stress and strain will be put on the cutting systems.



Horsepower & Your Traction Systems

35hp Engine - 5 gang drive system:
OEM design WITH Relief

.88 HP
x 5 REELS
~4.5 HP
Needed to rotate the reels



35 HP
-4.5 HP
~30.5 HP
Designed to drive the traction system

We know what happens over time...the relief wears away until the blade is flat.

35hp Engine - 5 gang drive system:
FLAT reel WITHOUT Relief



2.59 HP
x 5 REELS
~13 HP

35 HP
-13 HP
~22 HP

The worn reel and traction system still works, it still cuts, and it's designed to be able to function like this... but it's not designed to run like this long-term.

This is why grinding to “Like New” will maximize performance.

SO, When It Comes To Adjustments...

...Follow the original reel manufacturers recommendations, because the design criteria is specific for what each of the manufacturers want you to do.

The reel design standard of “reel-type” cutting equipment performs better when like new:

- Adjustments are easier

- Units stay on cut longer

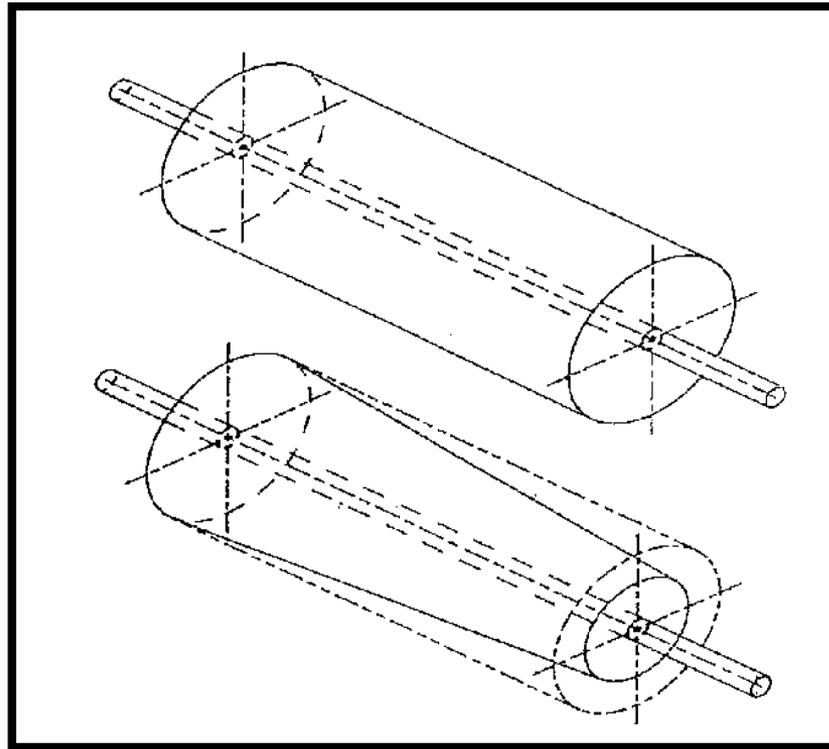
- Less strain on the engine

- Less stress on the hydraulic systems

OPERATIONAL WEAR

Even reels that are properly adjusted can start to lose their cylindrical shapes and become coned or tapered.

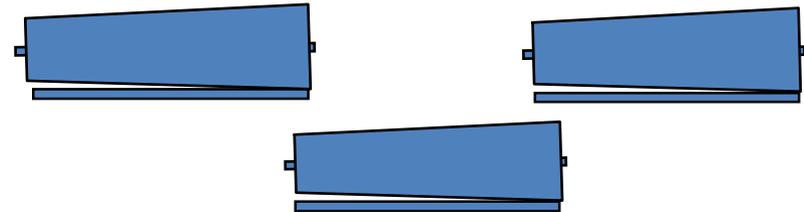
As the "relief" wears away through the season and more surface of the reel blade passes the bedknife, the adjustments may accentuate inaccurate wear patterns.



ADJUSTMENT & OPERATIONAL WEAR

WHAT EFFECT DOES TAPER HAVE ON ADJUSTMENTS?

It used to be that you could take rollers out of parallel and twist the bedknife to compensate for taper.



Taper will not only put undue load on the bearings, but can induce torque on the bedknife and housing assembly...

Study has shown that only .010" of an inch of taper can start to effect your after-cut appearance...

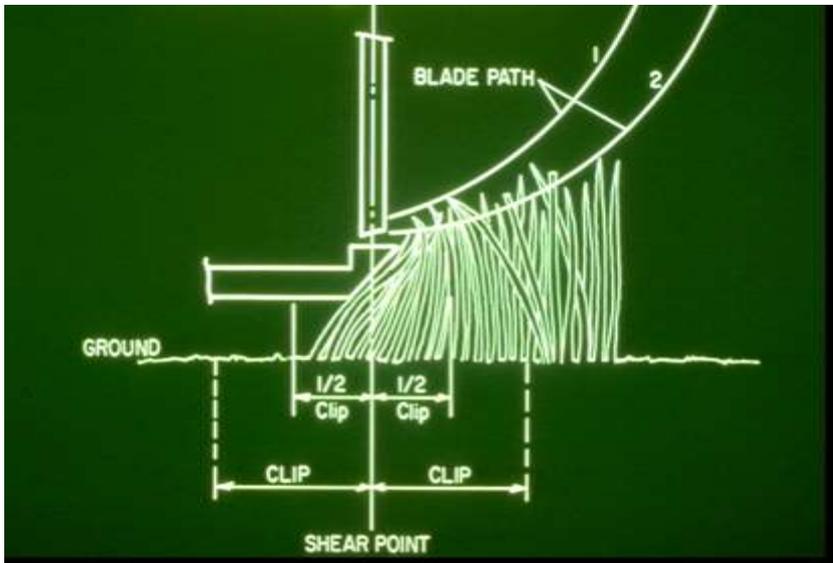


Rocking Motion?

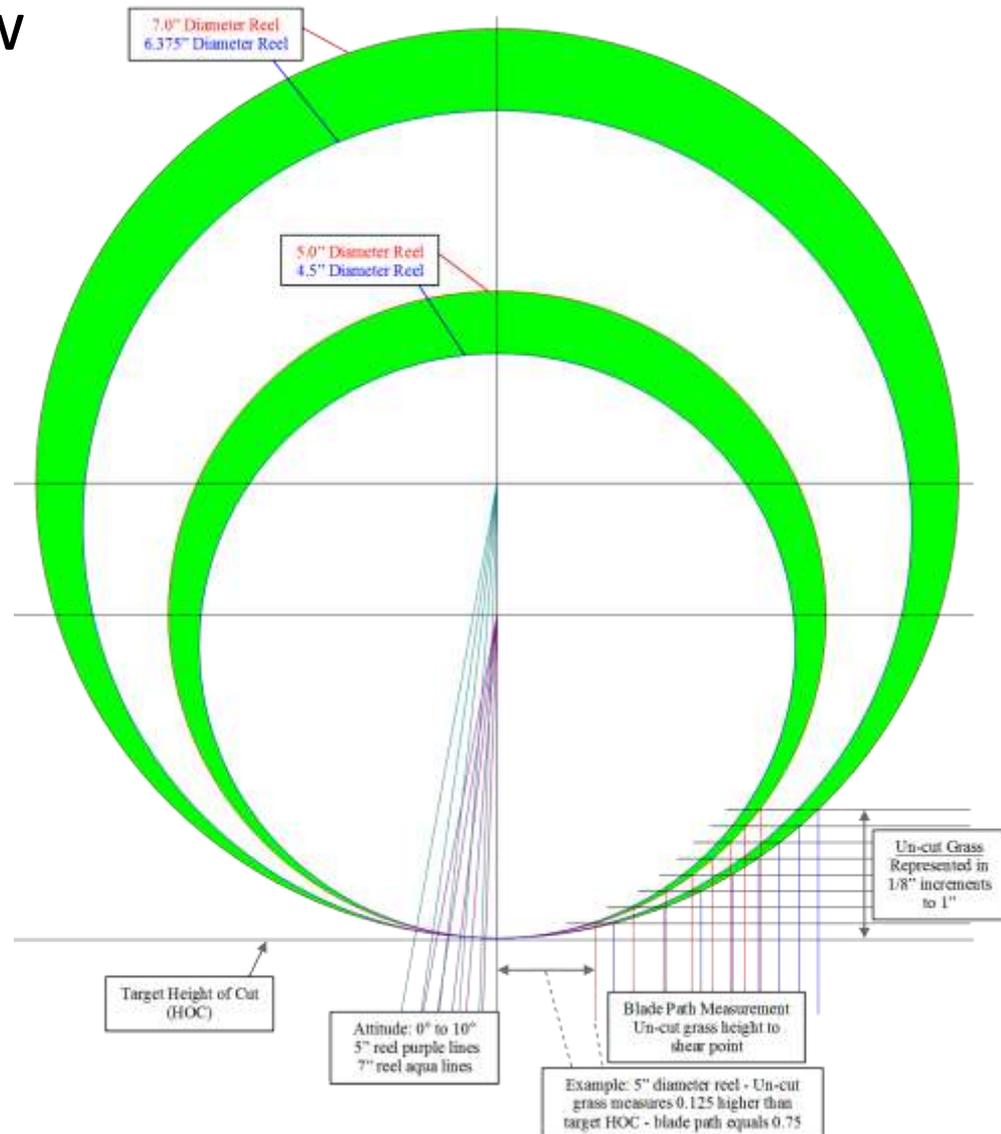
A surface plate is the solution

OPERATIONAL WEAR

Basic reel wear will effect how the reel blades pull grass into the edge of the bedknife, as blade path will be different from new to worn...



Compliments of Jim Nedin



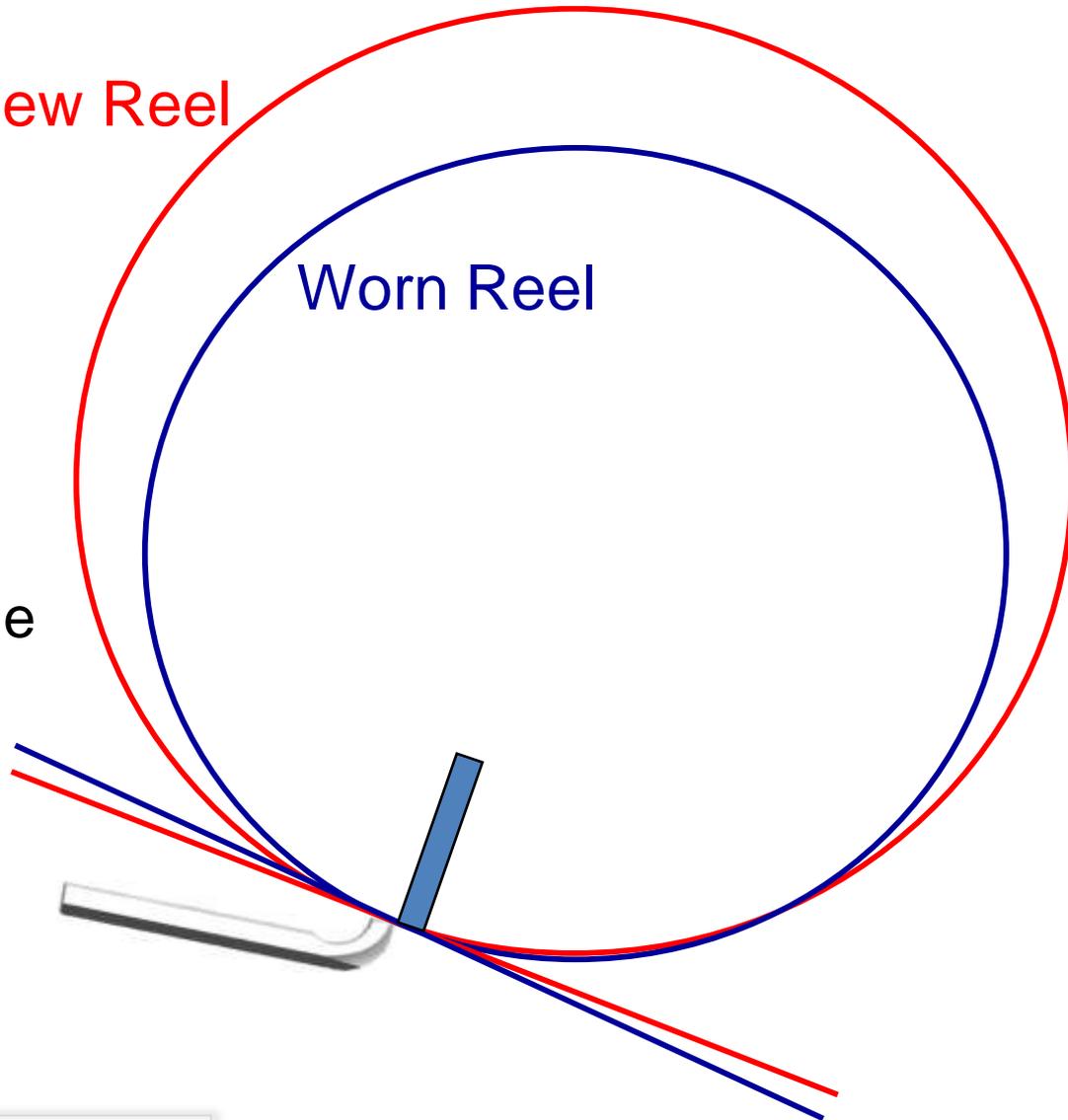
Blade Path

New Reel

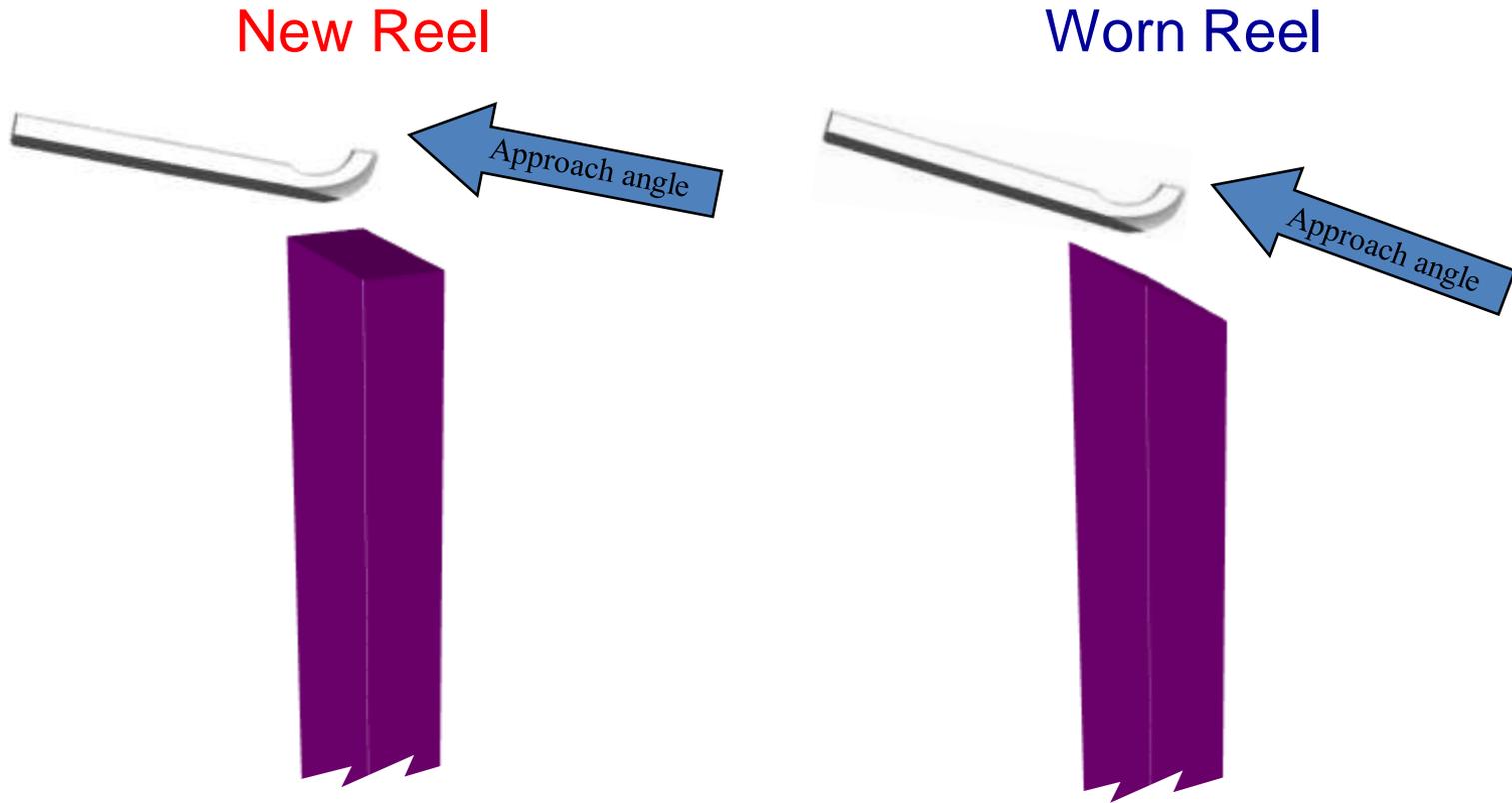
Worn Reel

Worn Reel

- Travels slower
(blade tip speed)
- Bedknife cutting edge moves further behind the reels centerline and attitude is increased

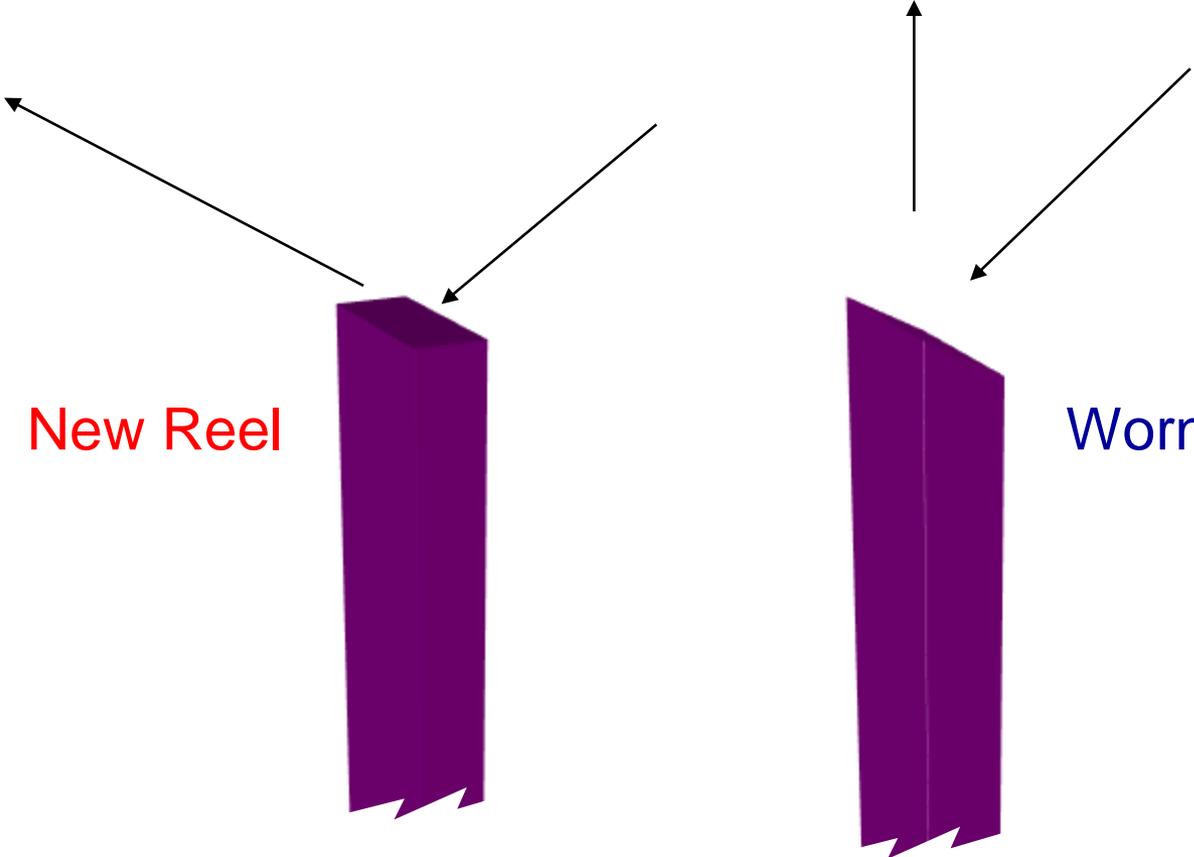


Blade Path



Compliments of Jim Nedin

Blade Path



Compliments of Jim Nedin

BACKLAPPING

One of the most misunderstood
&
miscommunicated maintenance
practices there is...

Lapping is a preventive maintenance process – it is NOT a re-sharpening process. The idea is to maintain a square edge, not to create one.

BACKLAPPING

If it takes more than two to five minutes to lap, one of two things has likely occurred:

- 1) The reel has dulled so badly that the reel and bedknife edges are difficult to correct by this process (it will take too long to lap)...
- 2) The relief has diminished enough on the reel that the lapping process is not effective.

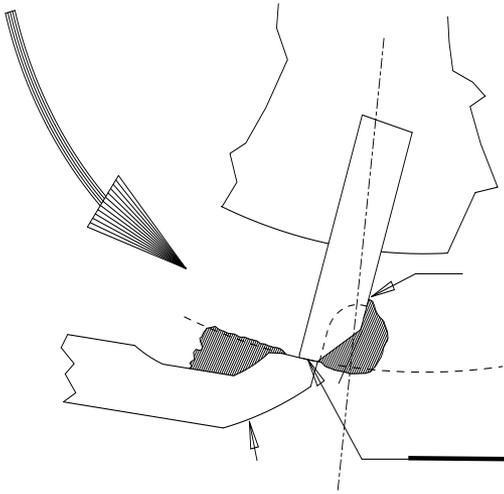
BACKLAPPING

The relief on the reel blades provides an area for the compound to adhere to, transferring more material between the two parts and making the process more effective...

As grit is forced to pass between the reel & bedknife, relief provides less surface and less metal to remove, minimizing time for the procedure...

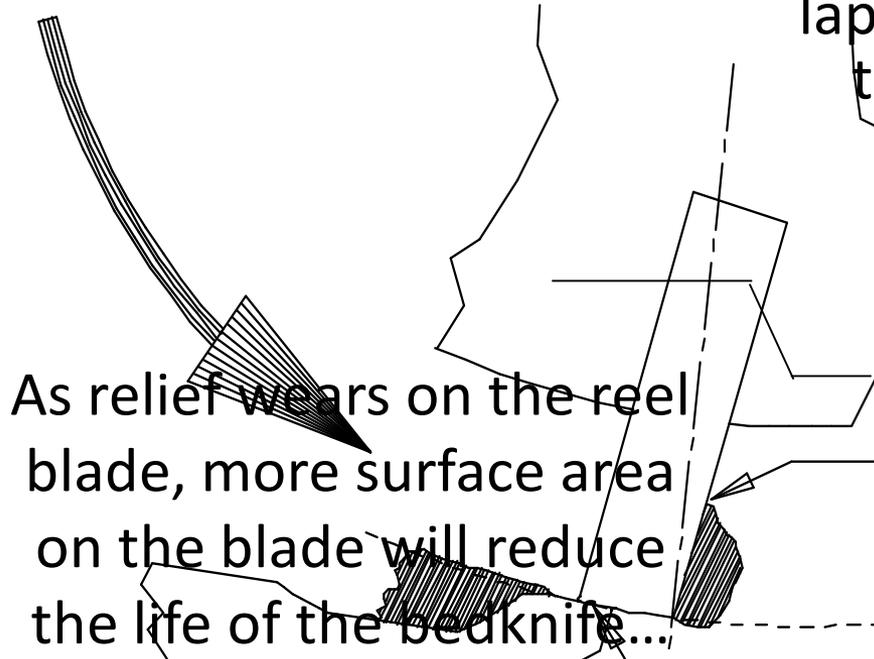
Angles on both the reel and bedknife contributes to a more effective process...

It doesn't require much compound to do the work, and two dips of the brush as seen in the picture to the right should be sufficient. After one pull of the brush as seen, apply from left to right, and the second pull you apply right to left, and simply work the brush back and forth distributing the compound...



BACKLAPPING

When the relief on the blade wears away, lapping compound clings to the back of the reel blade, forcing less material between the two parts...



...Not only is less grit forced between the reel blade and bedknife, there's more metal to remove

Without the Reel Manufacturer's design with relief on the reel blades, backlapping will be a less effective process.

A Preventative Reel Maintenance Process

Backlapping modes on traction units and walkers are there to make the job easier...

Type	Backlap	Grit
8" - 10" Diameter ROUGH MOWER reels used 15-20 hours/week	As Needed	60 or Higher
5" - 7" Diameter FAIRWAY reels used 20-30 hours/week	As Needed	80 or Higher
5" Diameter GREENS & TEE MOWER reels used 15-25 hours/week	As Needed	120 or higher

Simply another tool in the tool bag...

BACKLAPPING CONCLUSION



Lapping can be effective early on, but pay attention to the amount of relief left as you get into the season. A couple of 'touch-up' spin grinds will be more effective after a certain point and/or until you decide to do your preventive maintenance full re-conditioning grind...

Lapping tips to ensure results meet the effort:

- 1) Redistribute the compound over the two to five minute process, as this prevents build-up of compound in certain areas that can possibly cause other issues.
- 2) Use quality lapping compounds that have a high grade grit and a suspending gel that can easily wash off.

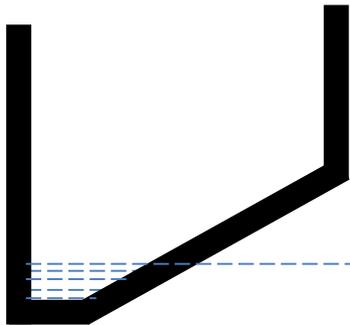
FACING BEDKNIVES

- Facing provides one good edge to pull grass into, but is temporary. Care should be taken if using on certain bedknives that have special hardening coats or carbide inserts.
- Try to be consistent with speed and angle across the width of the bedknife and avoid gouging the frontface.
- Do not grind back too far during the life of a bedknife. Remember the front cutting edge relation to the centerline of the reel and the effect it may have on aggressiveness and attitude at the shear point. This will be especially true when the reel diameter gets smaller.

Facing bedkives has nothing to do with adjustments or grinding practices. It can temporarily improve cut quality for units with “light contact” or “no contact”, and works on relieved or non-relieved reels. It’s key that it be done correctly.

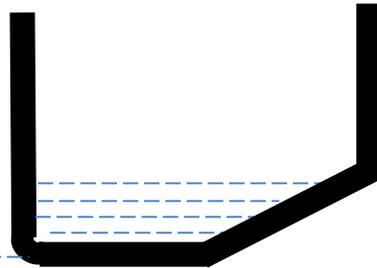
GRINDING – THE LAST RESORT

**ADJUSTMENT, BACKLAPPING, and
FACING** will run their course and
eventually lead to your final action...



NEW

Sharp edge,
relieved, and in a
perfect cylinder...



USED & DULL

Adjustment wear over
time will require lapping
and/or a touchup spin
grind...



FLAT & DULL!

All shape is lost...the sharp
edge and relief is gone, and
it's likely the reel is no longer
a perfect cylinder from end
to end...

Once all the relief is gone, there's only one alternative to re-conditioning the cutting unit to the Reel Manufacturers specifications...the last resort = GRINDING!

REEL GRINDING BASICS

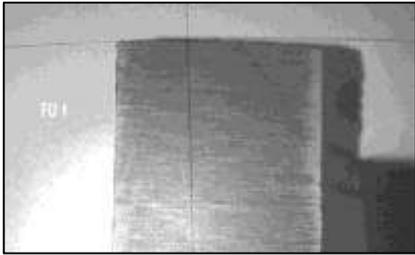
“Making the Most of Your Investments”

Grinding is more than producing a “sharp” edge, it’s a PREVENTIVE MAINTENANCE re-conditioning practice to “RESHAPE” the cutting units to “LIKE NEW”!!!

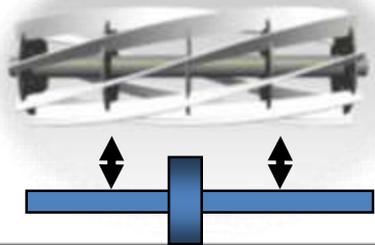
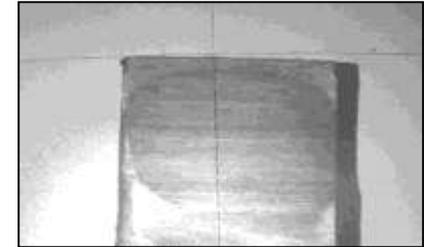
Grinding as a preventive maintenance practice not only keeps units performing at their best, but can ultimately lengthen the life of your investments...

REEL GRINDING BASICS "101"

When you make the effort to grind, there are three objectives to make it "LIKE NEW"...



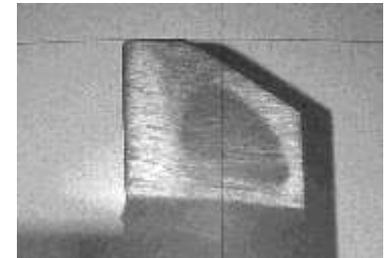
Produce a
SHARP EDGE



**REMOVE
TAPER**



RELIEF GRIND
To the Reel Manufacturer Specifications



While “Grinding 101” notes three basic objectives, we remind you of the simplistic choice when you put a reel on a grinder



“Touch-up” SPIN Grind
Or
“SPIN & RELIEF” Grind

“Spin” or “Spin & Relief”

What Does This Really Mean?

A Touch up spin-only program follows very specific recommendations

Spin-Only

- Adjust to No Contact: This must be done to ensure less load and stress on the engine & hydraulics
- Don't Backlap: Lapping is much less effective when flat & no relief
- Face Bedknife: This gives one good edge to pull grass into

Spin & Relief

- Adjust to No Contact...
- Don't Backlap...
- Face bedknife...

...Adjustments, lapping, and facing are maintenance practices that have nothing to do with your grinding practice...

There are times when each of these grinding practices are important...

Your ultimate goal is to have the best quality of cut and premium performance for as long as possible with the least amount of effort.

An optimal reel maintenance program involves using all “tools in the tool bag” through the progression of losing shape:

- New: Adjust according to the OEM's
- Backlap early on
- Face when needed
- Touch-up spin grind
- Ultimately re-condition to ‘like new’



Regardless of what you choose to do,
today's grinder technology can lower
labor cost in your shop
and there are options that make the
process safer than ever.

- Complete Enclosure Systems
for Dust & Noise
- Automation of In-feeds for Both
“Spin” & “Relief”
- Auto-Indexing Systems for Relief Grinding

When Is It Time To Grind

Compliments of Jacobsen

There are some "general" time frames that can be estimated for grind intervals and they are as follows:

8" - 10" Diameter ROUGH MOWER reels: Should be lapped "as needed"; if estimated use totals 15-20 hours per week, you should grind approximately every 400-500 hours, or once every six to eight months.

5" - 7" Diameter FAIRWAY reels: Should be lapped "as needed"; if estimated use totals 20-30 hours per week, you should grind approximately every 375-425 hours, or once every four to six months.

5" Diameter GREENS & TEE MOWER reels: Should be lapped "as needed"; if estimated use is five to seven times per week, averaging 15-25 hours, you should grind approximately every 200 to 250 hours, or once every three to four months.

The grind intervals noted above are strictly estimates. The need to grind will depend on course conditions, top-dressing practices, adjustments, backlapping or non-backlapping practices, relief grinding practices, but ultimately and finally the judgment of desired cut quality.

REEL PREP – Preventive Maintenance

Prior to grinding a reel, the mowing unit must be prepared. This preparation is very important and should be performed whether using “Upright Style” grinders or “Table-top Style” grinders.

ALWAYS INSPECT:

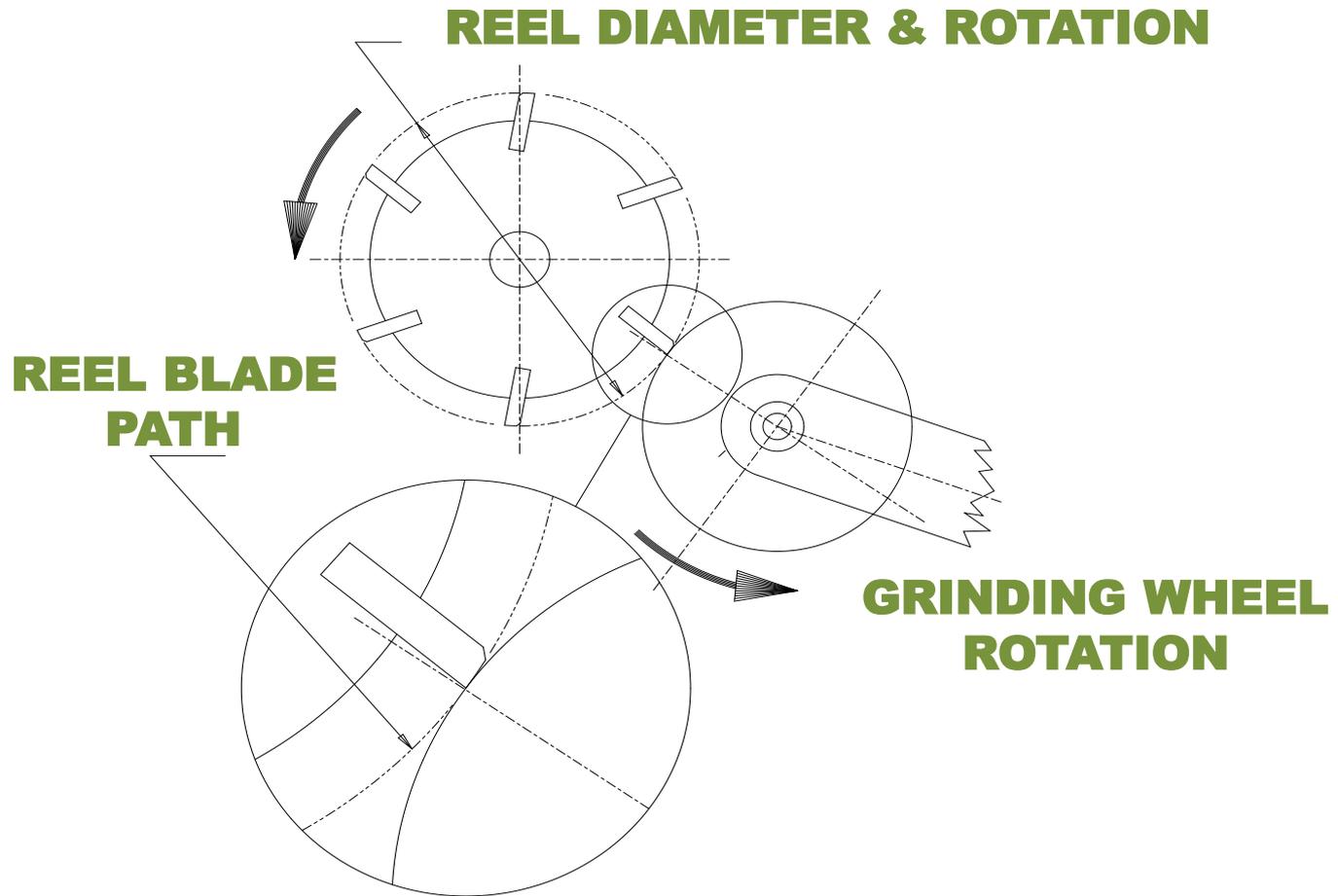
- **REEL BEARINGS** - They must be in good condition and properly adjusted to assure that the reel assembly spins true to the reel axis.
- **ROLLER BEARINGS** - Front and Rear rollers must be checked, because movement of the reel while grinding will have an effect on the quality of the grind. In the field, the condition of the rollers will effect the overall performance of the cutting unit.

ALWAYS DO:

- **THOROUGHLY CLEAN THE REEL** - Remove grass and debris off the blades and bearing areas.
- **VERIFY “FREE” REEL ROTATION** - Verify that the reel spins freely in the frame with no “sticking” spots.
- **INSPECT FOR BENT OR BROKEN BLADES** - When trying to straighten out severely bent blades, avoid having to heat the blades if possible. Be careful that the blades do not crack, and/or pull away from the weld in the spiders.

REEL GRINDING BASICS

As the reel rotates in the 'spin' process, the back of the blade hits the stone first and the opposite directional contact peels metal toward the front edge, creating a burr.



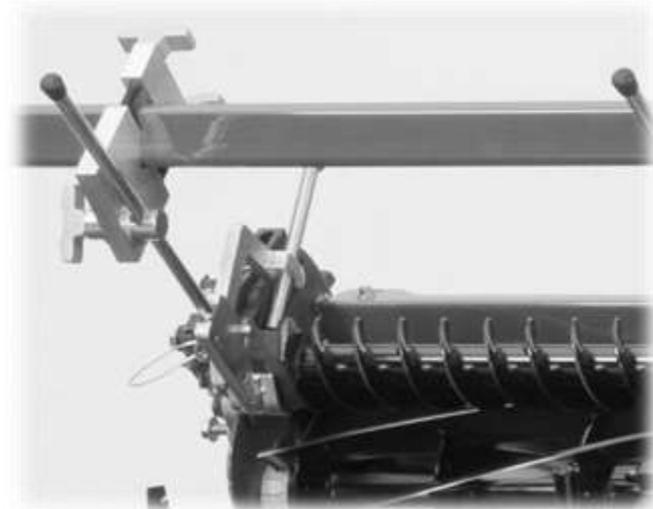
First Things First: Placement of the Reel

“Upright” Spin/Relief Grinders

Reels are placed in the rear of the grinder and sits in an “upright” position with the rear roller resting in some form of a “V” block positioning system.

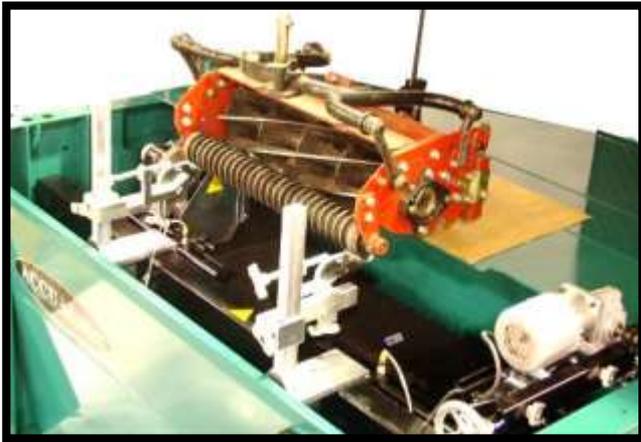
Every reel will have a unique “lean” position in the machine as overhead arms attach to the front roller or somewhere else on the frame of the reel.

Once determining the placement, marking the upper arms for each reel will speed the process of set-up.



“Upright” reel grinders used to be the norm, as “Table-top” units have become more popular...

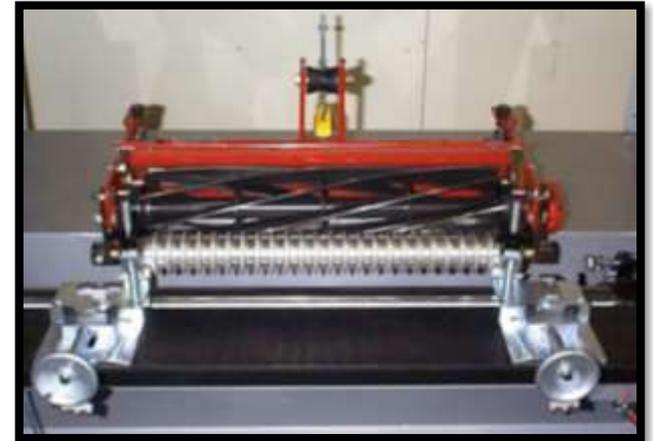
“Table-top” Reel Grinders – a 3 step process...



1) Placement

2) ????

3) Grind

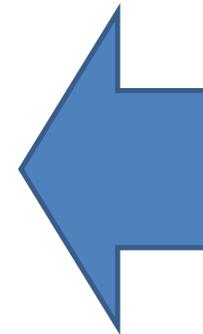
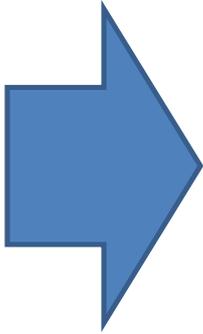


Aside from “PLACEMENT” of the reel in the grinder, there is a “middle step” that must take place before the third step of actually making sparks and “GRINDING”...

“TABLE-TOP” SET-UP

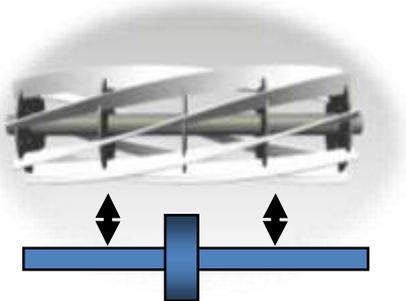
A 3 Step Process

- Place
- Gauge
- Grind

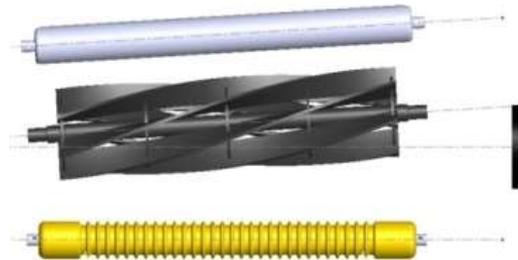


- Place
- “Touch-off”
- Grind

This “MIDDLE STEP” reveals you can either “gauge” or “touch-off”. While neither requires much effort, gauging adds quality control to the spin process...



If the front roller has hit something, the reel will not rest squarely in the machine...



Gauging produces the highest quality spin grind possible

NEW TECHNOLOGY FOR REEL PLACEMENT

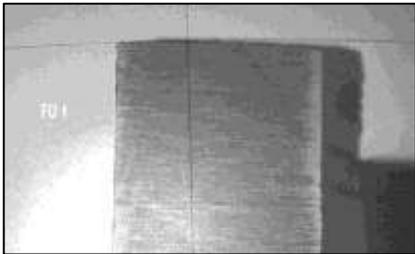
Locates the Reel by the Rear Roller



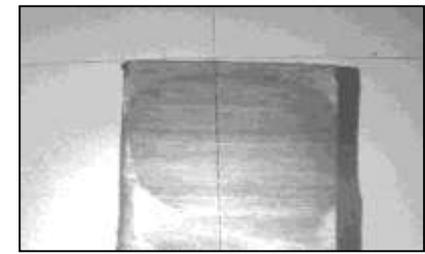
REEL GRINDING BASICS

You “Spin Grind” to produce a sharp edge, but it’s only 1/3 of the process...

OBJECTIVE #1



SHARP EDGE



Spin Grind

“Floor-to-Floor” spin grind times for greens mowers will typically range between 5 to 10 minutes and fairway mowers will range between 5 to 15 minutes.

It simply depends on how dull the reel is and how much taper has developed through use...

EXPECTATIONS: The “SPIN GRINDING” Process and “Back/Impact Grind ” Results

GRINDING HEAD TRAVERSE DESIGNS

Three basic traverse systems in the field were tested for spin grind results and each showed deviation from the front to the back of the blades, commonly known as an “Impact” grind.



PHOTO # 1

Fixed Grinding stone with a carriage traverse system:
The deviation from the front cutting edge to the rear of the reel blade was .0073”.

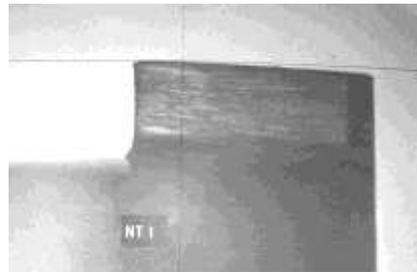


PHOTO # 2

“Live Shaft” stone without spring loaded handwheels:
The deviation from the front cutting edge to the rear of the reel blade was .0067”.

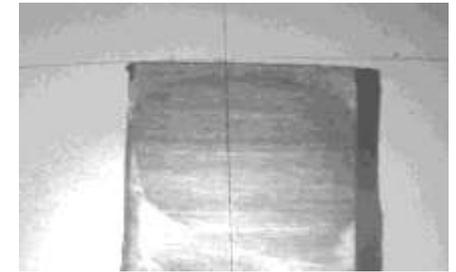


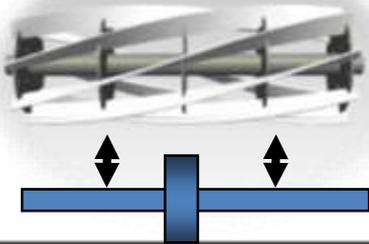
PHOTO # 3

“Live Shaft” stone with spring loaded handwheels:
The deviation from the front cutting edge to the rear of the reel blade was .0085”.

REEL GRINDING BASICS

While everyone spin grinds with similar results, removing taper requires something extra...

OBJECTIVE #2



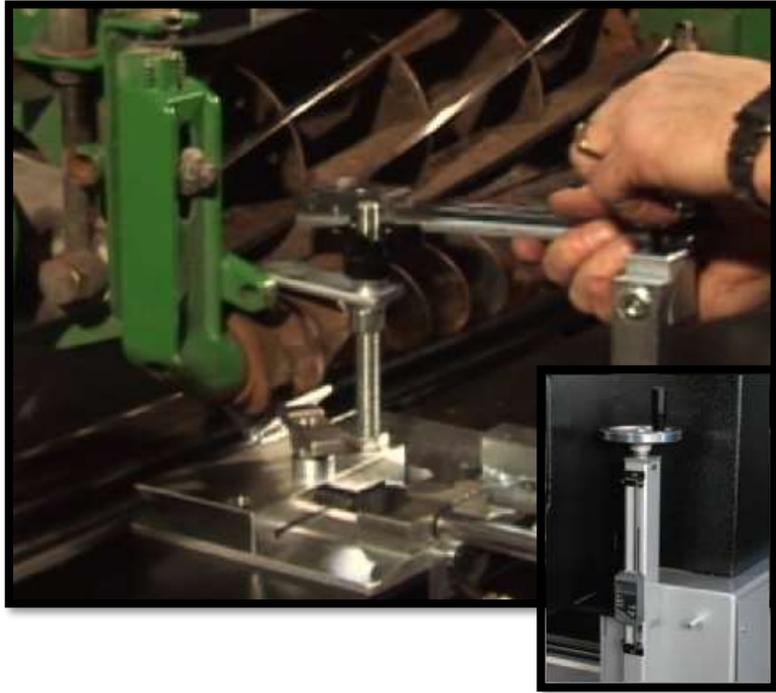
REMOVE TAPER

Cylinder vs Cone



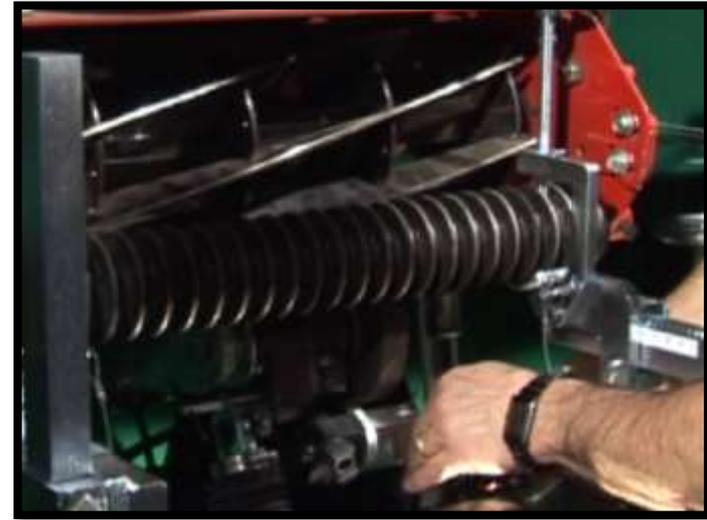
There are different ways
to remove taper.

GRINDER TO REEL ALIGNMENT



A live shaft table-top style unit can use a digital gauge that mounts on a tooling bar. This aligns the reel to be parallel to the grinding shaft, then measures taper on the tip of the blade. Taper is then compensated for and removed by following a chart using digital gauge in-feed scales on the live shaft in-feed handwheels.

There are units that align from the front and the bottom of the reel...

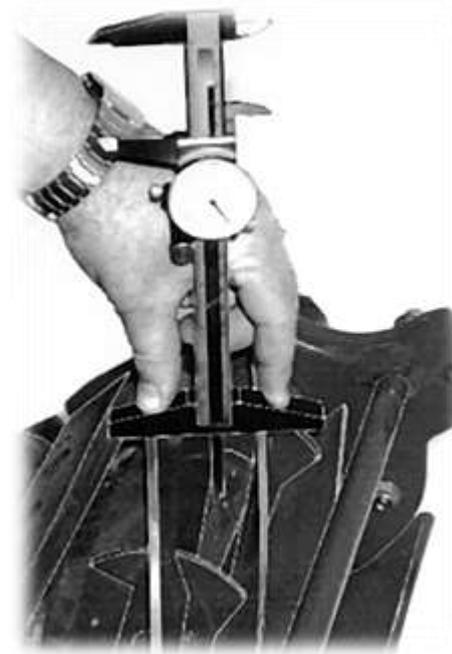


Grinders that have no alignment capability built into the machine can use alternative methods to remove taper or cone-shape:

Pi-Tape measurement...



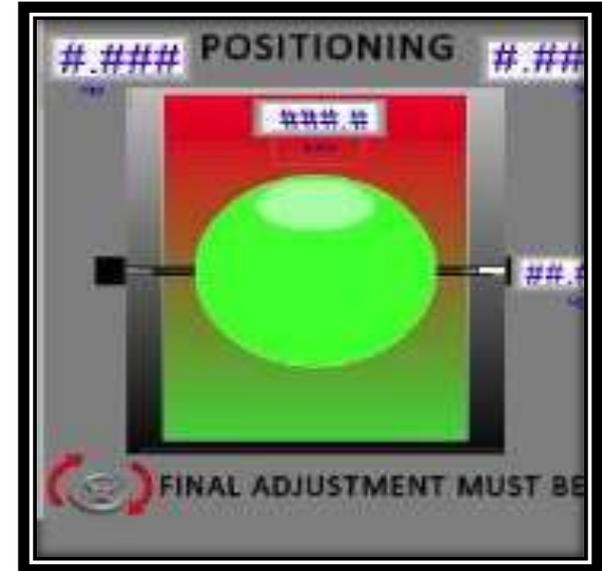
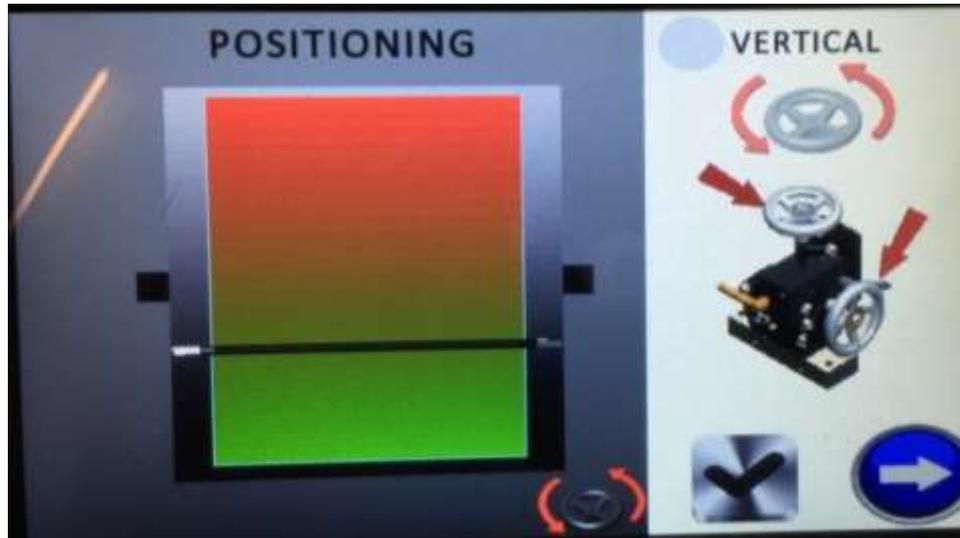
Taper Measurement Tool..



These methods may require multiple checks and readings during the spin grind process, but are good tools to produce the Reel Manufacturers cylindrical specification:

NEW TECHNOLOGY FOR REEL ALIGNMENT

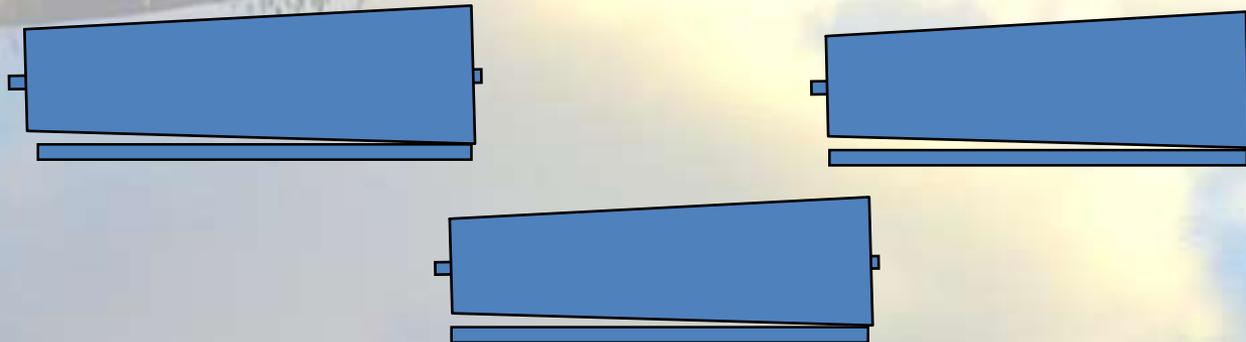
Computer Graphic & LED Systems



There are new gauging systems that are visual, and tells the operator which way to turn the handle for proper alignment.

SPIN GRINDING – Taper Removal

Two-Thirds of the Reel Manufacturers
GRINDING OBJECTIVES can be
accomplished through the 'spin' grind
process...producing a sharp edge and
removing taper.



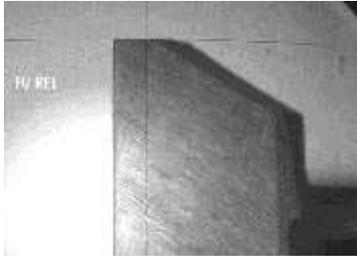
Toro Reel & Bedknife Specification sheet

Product Group	Reel Cylinder						Bedknife	
	Diameter	Service Limit	Blade Choices	Relief Angle	Land Width	Maximum Taper	Top Angle	Front Angle
GR 105, 500	3.5"	3.2"	9	30° ± 10°	040" ± 010"	010" (.2mm)	0°	30° ± 4°
GR 800 & 1000 Flex 18 & 21	5"	4.5"	5, 8, 11	30° ± 10°	040" ± 010"	010" (.2mm)	3°	13° ± 2°
GR 3000 Std reels	5"	4.5"	5, 8, 12	30° ± 10°	030" ± 010"	010" (.2mm)	3°	13° ± 2°
GR 3000 HD reels	5"	4.5"	5, 8, 12	43° ± 10°	060" ± 010"	010" (.2mm)	3° ± 2°	13° ± 2°
RM108	7"	6.6"	5 & 6	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	30° ± 5°
RM 223D RM 5100 - 5400	5"	4.5"	5 & 8	30° ± 10°	040" ± 010"	010" (.2mm)	5° ± 2°	5° ± 2°
RM 5210 & 5410	5"	4.5"	5, 8, 11	25° ± 5°	040" ± 010"	010" (.2mm)	5° ± 2°	5° ± 2°
RM 216 RM 2000 series RM3100 Grounds Pro	7"	6.6"	5, 8	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	30° ± 5°
RM 5500 RM6500 & 6700	7"	6.6"	5, 7, 11	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	5° ± 2°
RM5510 & 5610	7"	6.6"	5, 8, 11	25° ± 5°	040" ± 010"	010" (.2mm)	5° ± 2°	5° ± 2°
RM 335 & 450 RM 3500 RM 4000 series	8"	7.2"	5, 7, 11	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	30° ± 5°
Turf Pro	7"	6.6"	5, 7	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	15° ± 2°
Spartan & RM 11	7"	6.6"	11	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	30° ± 5°
Spartan & RM 5 & 7	8"	7.2"	5, 7	30° ± 10°	060" ± 010"	010" (.2mm)	5° ± 2°	30° ± 5°

REEL GRINDING BASICS

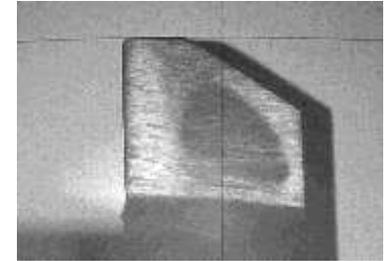
The relief systems used today follows a process, as the same steps are followed every time...

OBJECTIVE #3



RELIEF GRIND

Final step to OEM Spec



“Auto-index” relief features that are built into the spin/relief grinders allow for a safer process as hands are removed from the work area.

Relief grinding is done one blade at a time and was once a very labor intensive process. The reel blade is trapped between the stone and a fixed relief finger and the angle is dictated by the position of the fixed finger relative to the stone...



“Spin Grinding” And The Final Reel Manufacturing Relief Process

PHOTO # 3

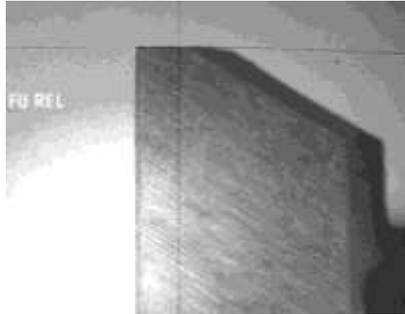


Photo # 3 above is an aftermarket grind. The reel was spun ground to a sharp edge and the secondary relief was reground in. This shape is the final objective when taking the time to grind.

PHOTO # 4

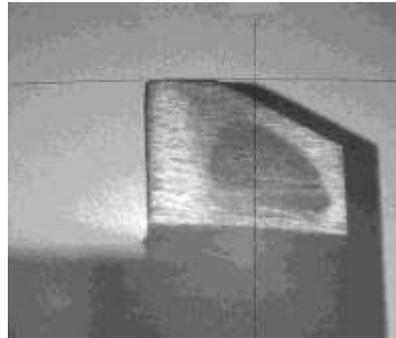


Photo # 4 above is a NEW OEM DESIGNED blade as it looks from the manufacturer. The Reel Manufacturers design the reel to reduce friction and stress on the hydraulic, engine and drive systems, and to reduce the grind frequency through the course of a season.

“RELIEF” GRINDING CHANGES

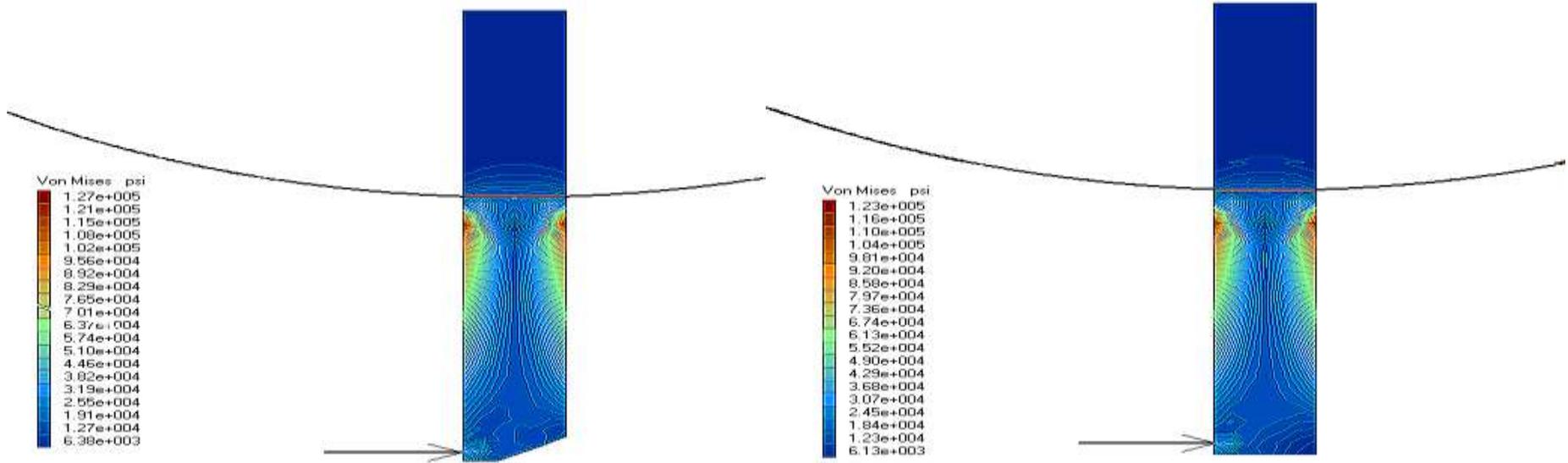


FIGURE 1: Relieved Reel Blade

FIGURE 2: Flat Ground Reel Blade

Solid debris passing between the reel blade and bedknife reveals that the stress area effected does not reach the rear two thirds of the blade.

As blades have gotten harder, the land areas have become less...

Older blade design was approximately a 1/3 land area, because the softer metals required more mass to minimize damage to the tips of the blades...

Sharp Edge Principle Benefits & Values

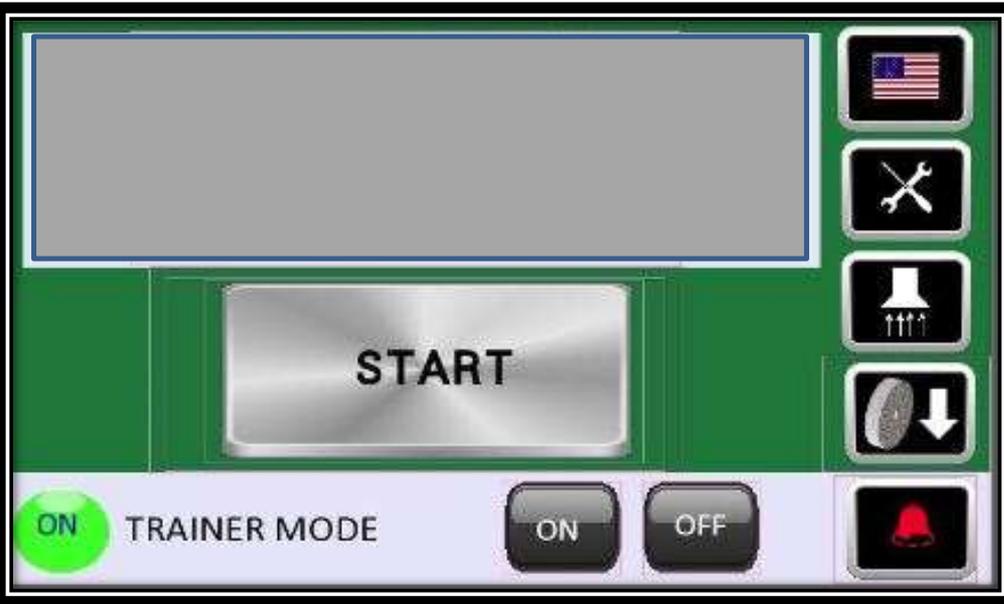
1. Actual points of the “cutting action” that provide the optimal cut 100% of the time
2. Minimize damage and die-back at the grass tip which effects the aftercut appearance
3. Minimize adjustment pressure needed to make the units cut
4. Maximize water and chemical usage, ultimate result = less potential for disease

Shape's Principle Benefits & Values

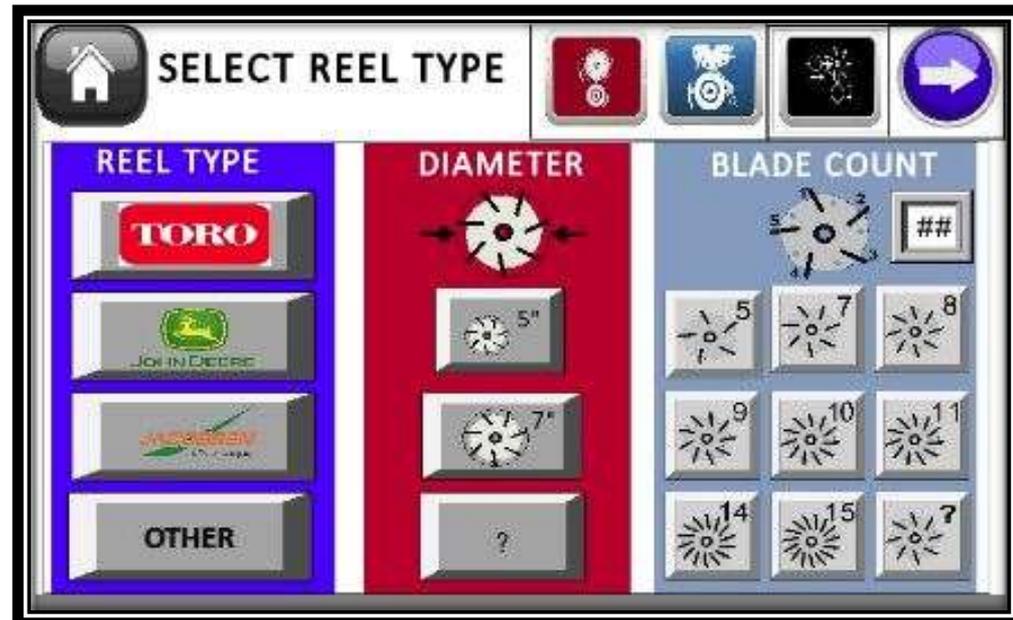
1. Units stay on cut longer
2. Adjustments are easier over a longer period of time
3. Less stress on the engine as horsepower is minimized to rotate the reels
4. Minimize hydraulic oil temperatures with less strain on the system and maximizing the performance of the pumps
5. Minimize twisting and distortion of the bedknives

AUTOMATED TECHNOLOGY – Lowering Labor Costs

There are now tutorial systems to walk new technicians through the operation of both the spin and relief grind processes.



Automated in-feed cycles in today's world lowers labor cost in the shop as operators are free to do other tasks while the machine does the work.



BEDKNIFE GRINDING

Every time you grind the reel, you should also grind the bedknife. If you do not, the reel to bedknife clearance may vary from one end of the reel to the other, and thus could affect the “quality of cut”.

TWO BEDKNIFE GRINDING OPTIONS

- 1) Regrinding a used bedknife.
- 2) Replacing the bedknife and grinding the “new” bedknife.

GRINDING A NEW BEDKNIFE

Replace the bedknife when it is worn to the point where it can no longer be reground with a correct relief on the top surface.

- Inspect the bedbar for flatness and distortion by using a high quality straight edge.
- Install the new bedknife per mowing unit manufacturer's recommendation. This should be done by applying an anti-seize lubricant to the screw threads, and installing the bedbar screws with a torque wrench. Tighten the screws from the center holes out to prevent the bedknife from loading up due to torque on the bedbar.



KEY ELEMENTS OF AN EFFECTIVE QUALITY BEDKNIFE GRIND

- Control heat buildup so it never exceeds a comfortable touch. If your grinder does not have a flood coolant system, take a bucket of water and a rag (sponge, etc.), and rub the wet rag across the bedknife with each pass to keep it cool.
- Always pass off the ends of the bedknife for a uniform grind.
- Never remove an excessive amount of material creating excessive heat with one in-feed of the grinding wheel. You may get what is called a surface burn. This will typically clean up with a lighter pass, as the key here is to not reduce the temper of the metal of the bedknife.
- Sparking out is a relative term – look for consistent sparks, and be sure that the entire length of the bedknife surface is ground at the front edge. Once this occurs, the grinding process

Grinding Bedknives and Establishing the Reel Manufacturers Angles to be Ground



All angles specified by the Reel Manufacturer is in relation to the bottom surface of the bedknife. Mounting has been made much easier by use of magnetic surfaces .



Most bedknife grinders on the market today allow the operator to pre-set the angles for the front and top faces of the bedknife.

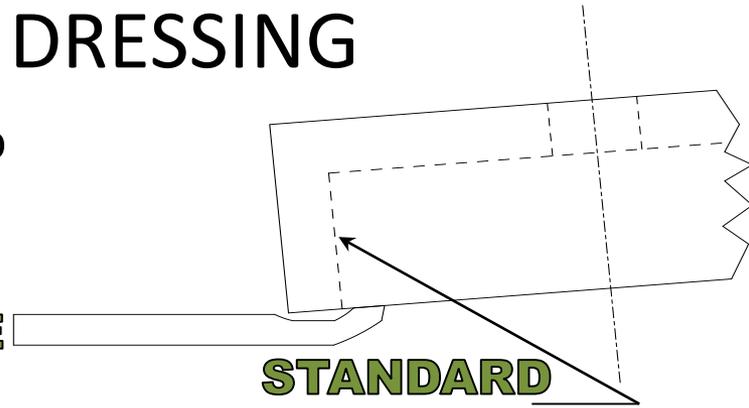


GRINDING WHEELS & DRESSING

This picture shows the position of a standard cup grinding wheel when in use. Note that the full surface of the bedknife is covered by the face of the grinding wheel. There may be some cases where this is not possible and it will be important to dress the grinding stone to ensure an even surface.

BEDKNIFE

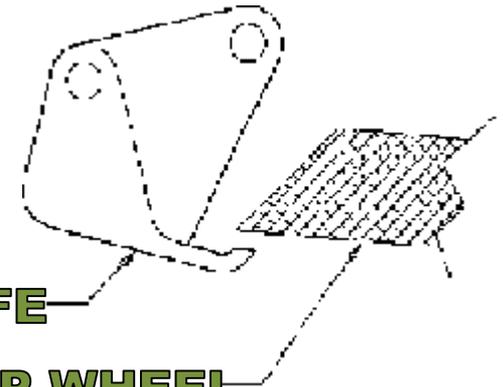
**STANDARD
CUP WHEEL**



This picture shows that on some bedknives, a special flared cup wheel may be necessary to avoid hitting the “ears”, or casting portion of the bedbar.

BEDKNIFE

FLARED CUP WHEEL



With new hardened inserts on some bedknives, there are special grinding wheels for this purpose (see grinding wheels next page).

GRINDING WHEELS & DRESSING



Standard Cup Wheel: This is a “vitrified” ceramic based stone that is designed for low impact grinding and is formulated of Silicone Carbide with a ceramic binder. These wheel need to be dressed using a diamond dresser. Dressing the wheel removes imbedded material from the face of the wheel, exposes new sharp cutting edges on the grit, and relieves the ceramic from between the grit stones making it grind more aggressively.



Flared Cup Wheel: This wheel is the same composition as the standard cup wheel, but is flared to provide more clearance with obstructions that may exist on certain bedbar shoes. This wheel is also dressed with a diamond dresser. All vitrified wheels need to be checked for cracks before mounting by a practice called “ringing”.



Borazon Cup Wheel: This is an aluminum cup wheel that has a borazon coating imbedded on the rim area. Borazon is a super abrasive compound. The “dressing” process is different than what is used on ceramic wheels. This stone comes with a hand held dressing brick that is formulated to clean the surface without removing borazon material. This will keep the wheel free cutting without loading up.

GRINDING WHEELS & DRESSING



This picture shows a diamond dresser in a 'parked' position...



This picture shows the diamond dresser released and in a stroke position to face the stone...

A grinding wheel which is “loaded” will cause excessive heat build up and can cause an irregular grind. There may be different dressing designs, but it’s key to not “over-dress”.

ROTARY BLADE GRINDING

PRIOR TO GRINDING

CLEAN THE BLADE: A rotary mower blade which has buildup of dirt and dried grass clippings will be difficult to properly sharpen and/or balance.

To clean your blade follow these steps:

1. Put on safety glasses
2. Scrape off the heavy grass buildup with a flat scraper that will be effective.
3. Use a wire wheel on a bench grinder or a wire brush by hand to finish cleaning.

INSPECT THE BLADE: If the blade is bent, twisted, or cracked, it must be replaced.

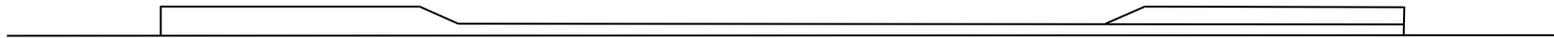
A blade can be checked for cracks by performing a ring test. If you put the blade on a small horizontal steel pin and then tap it with a hammer it should ring. If it is cracked, generally it will not ring and should be replaced.

Do not attempt to straighten or repair a bent, cracked or twisted blade. The use of such a blade could present a serious safety risk.

CHECKING FOR ROTARY BLADE DAMAGE



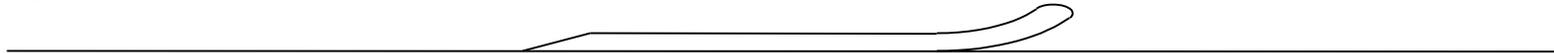
Warped Blade: This should be replaced as it can cause vibration and significant premature damage to the spindle assembly.



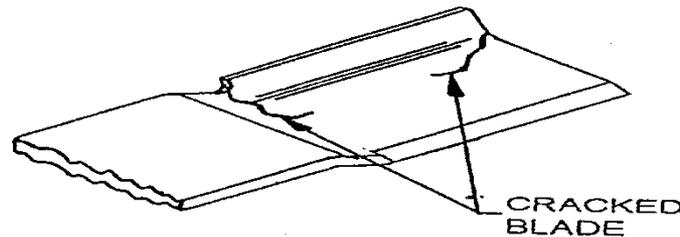
Straight Blade: This is the correct condition.



Twisted Blade: View the end of the blade and make sure that there is no twist. This can cause damage to the spindle assembly and will negatively effect the dispersion of the grass clippings.



The end view inspection of the blade reveals that the blade is not damaged/twisted and “lifting capacity” of the blade will be correct.



Beware of cracks that are in the blade

Manual Rotary Blade Grinding

GRINDING: With the motor off, match the cutting edge whenever possible. On most rotary blade grinders this can be accomplished by either raising or lowering the stone in relation to the base that the blade rests on, or if there is a stationary stone with an adjustable blade guide.



The cutting edge angle should be approximately 30 (thirty) degrees. If it is not, adjust the blade guide and/or the depth control until the desired bevel is achieved.

NEVER overheat the blade during grinding. You can quench the blade in water to keep it cool.

ALWAYS balance the blade. You can do this as you are grinding for less correction at the end.

Grind the same area of the blade as the manufacturer had ground when new.

Automated Rotary Blade Grinding

Use of rotary mowers in roughs has become more popular, as roller designs on the decks provide a striping look that rotaries could not provide in the past.

Grinding is recommended every 10-12 hours of use and there is new technology that makes the task easier, safer, and more efficient.



There are dual and single head designs that grinds both ends of the blade simultaneously or one side at a time.



Enclosure systems to control dust and noise are now available in the field



Automated Rotary Blade Grinding



The picture on the left illustrates the ground area and a very distinct blend radius that is built into the blade. This “blend” radius minimizes stress points in the blade as it’s ground through its life.



The blend is created by a tilting radius bar...



This picture shows the relief radius bar engaged...

ROTARY BLADE GRINDING



You can avoid producing a hook grind or a step grind by grinding the blend radius into the blade...



This illustrates a blade that has been ground beyond its useful life.

HOLE CUTTER SHARPENING

Cutting a hole with a dull cutter will tear the root system. Torn roots will cause brown rings or halo effects on the greens. The way to avoid and/or correct this problem is to keep the hole cutter blade sharp so it is cutting and not tearing.



There are typically three general types of cutters:

- 3 Scallop Cup
- 4 Scallop Cup
- Straight Bottom Cup Cutter

Three primary methods to keep the cutter blade sharp:

1. Hand Filing: Often not done on a regular basis.
2. Blade Replacement: A good method, but expensive
3. Cup cutter sharpeners or hand grinders: Cup cutter sharpeners can sharpen the various types in the field... and hand grinders are used as well.



Full Circle Education of Grinding Impact

Grinders are “shop tools” ...

Two things we know about this acquisition:

- This is the only investment owners make that'll be used to recondition what does all the work...
- This is a very long-term 12 to 15 year purchase...

What Owners, Board Members, and People in Charge of the Purse Strings Should Know

Poor cut quality can weaken the root structure of the grass and make the grass more susceptible to disease.

This can make chemical use less effective, and can effect water absorption rates to levels where you wind up spending more money for both.

With all the top-dressing being done today, making it easier to grind and doing so with today's better technology can reduce the labor cost in your shop.

Grinding can be one of the most important preventive maintenance practices the technicians can do.

What Owners, Board Members, and People in Charge of the Purse Strings Should Know

Having a handle on owning between \$300-\$500k of cutting equipment requires an understanding of what's actually doing the cutting and providing the "quality of cut"...

If they're educated, they'll typically provide the funds needed for "shop tool" that will make your job easier and more efficient.

Grinders are a minimal expense when looked at in the big scheme of what you're trying to achieve...

Planning Your Grinding and Preventive Reel Maintenance Program

Grinding is the only process capable of returning reels to “LIKE NEW” and maximizing the performance of the cutting unit ...

Cutting unit performance and quality of cut is what it's all about and having options to stay on cut provides more tools in the tool bag...

While ‘time’ and ‘speed’ is part of the criteria with grinding objectives, “Quality” of the finished grind should be priority number one...

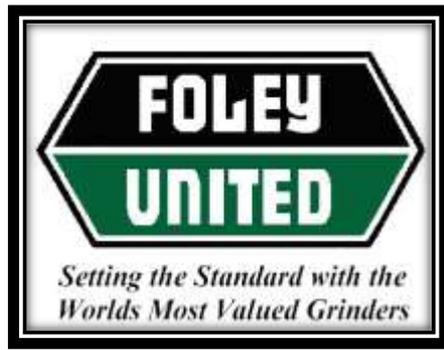
GRINDING SEMINAR CONCLUSION

Elevating Skill Levels – Old to NEW...

**Increasing
Knowledge and
Skill Levels**



Your understanding the role that grinding plays in performance and quality of cut objectives brings knowledge to the table, and hopefully puts you and the technician on the same page.



Supporting
the
BIG THREE



**Questions..., Thoughts,
Comments, etc...?**