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SPORTSTERPEDIA

Gear Dog Damage: Inspection and Causes

Sportster 4 speed transmissions are similar to the later 5 speeds in many ways.
But there are a lot of distinct differences between them of how the parts work together to transmit power to the rear wheel.
The gear teeth in either are always in constant mesh but do not transmit power to the final drive sprocket without the assistance of the gear dogs.

Overview of the Gears

Gear Names:

- Gear names come from what teeth are carrying power in what (transmission GEAR selected). [1)]
  An understanding of power flow in each gear is essential in order to build and inspect trans parts.
- From the Factory Parts Catalog, “clutch gear” is the technical term for ms4 and “drive gear” is the technical term for cs4; [2)]
  These gears and their proper names are an important part of the power flow.

MS = Mainshaft, CS = Countershaft

	Shaft Group	4 Speed Transmission Gear Names Left to Right				
Clutch Basket	Mainshaft	Clutch Gear	MS 2nd	MS 3rd	MS Low	Transmission Sprocket
	Countershaft	Drive Gear	CS 2nd	CS 3rd	CS Low	

Gear Movements per transmission GEAR selected:
Studying the power flow drawings below;

1. Notice that shifting from neutral to first, you are only moving the countershaft third gear, the one that is splined to the shaft. You are moving it to the right, so its engagement dogs will engage the countershaft first gear. [3)]
2. Then shifting from first to second, you are still only moving that countershaft third gear, this time

to the left, so its dogs engage the countershaft second gear.

3. Shifting into third, you once again move that countershaft third gear, moving it back to its center position where its dogs are disengaged from the countershaft first and second gears. It is effectively in its “neutral” position, with its dogs disengaged from any other gear. To engage third gear, the mainshaft second gear must now move from it's own neutral position, moving to the right to engage it's dogs with the mainshaft third gear. This is the only shift that moves the splined gears on both shafts, the mainshaft second and the countershaft third. So, yes, it does go into neutral while this is happening. It's the only gear change that passes through a neutral state along the way.
4. The third to fourth shift moves the mainshaft second gear to the left, engaging it's dogs in the mainshaft fourth gear, locking the mainshaft to drive it “straight through”, with no countershaft involvement in the power flow.

About the power flow drawings below: The drawings below show the power flow (how power is transmitted) thru the transmission when in different transmission 'GEARS'.

About Splined and Sleeved Gears:
There are '+' signs above/below each gear in Purple, RED or BLACK. Such as, the clutch gear has a PURPLE '+', M2 has a Red '+' and C2 has a BLACK '+'.
The BLACK '+' gears are SLEEVED over bearings on the shaft on which they are located. This means they can turn separately from the shaft unless otherwise engaged.
The RED '+' gears are SPLINED to the shaft on which they are located. This means they always turn whenever that shaft turns.
The SPLINED gears (M2 and C3) are sliding gears, movable on the shaft so they can engage neighboring SLEEVED gears, using 'DOGS' (like fingers) to intermesh between those gears.
SPLINED gears (ML, CD) are not sliding gears, but rather fixed in place.
By the various positions of the sliding gears (M2 and C3), the transmission can be placed into various GEARS (including IDLE).

Notice that every SPLINED gear has a usable SLEEVED gear on the opposite shaft, except for CG and CD. These SLEEVED gears will spin with the SPLINED gears, even when no power is being transmitted thru them.
Since they are SLEEVED, they cannot flow power unless engaged by DOGS.

The Clutch is always directly connected to the Clutch Gear. When the clutch is engaged, it drives the Clutch Gear (not necessarily the Mainshaft).
The Clutch Gear (CG) IS NOT SPLINED to the Mainshaft. The mainshaft slides into a bearing on the end of the clutch gear.
So the Clutch Gear can turn without turning the Mainshaft unless the mainshaft is connected to the clutch gear by way of gear dogs.

Anytime the Clutch Gear is turning, the Countershaft is also turning.
The Countershaft Drive gear (CD), although at a fixed position, is splined to it's shaft and CG and CD gear teeth are always meshed together.

At the other end of the power flow, the mainshaft always drives the final chain 'Drive Sprocket'.
When the Clutch is engaged in 1st-3rd GEAR, power flows out the transmission to the Drive Sprocket from the clutch gear, thru the countershaft, then mainshaft.

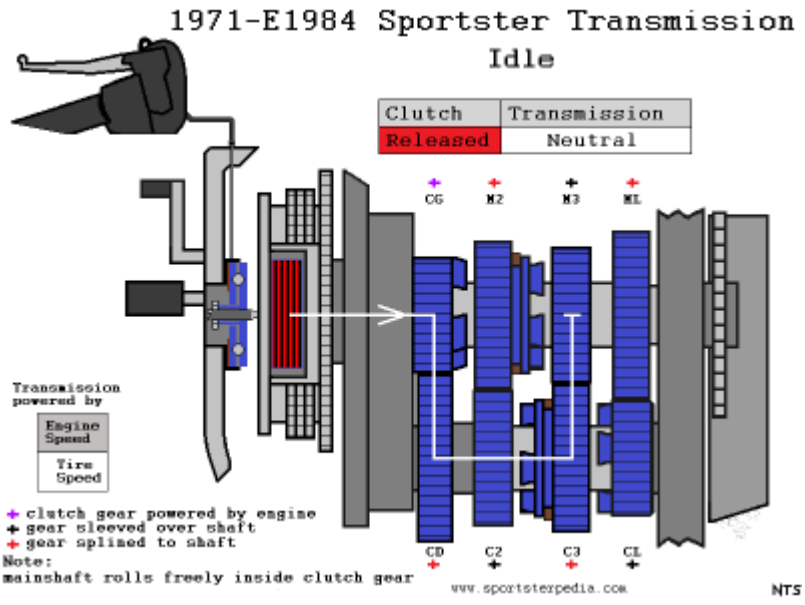
The various sliding gear positions control which gears are involved in the Power Flow per transmission GEAR selected.
When the clutch is engaged in 4th GEAR, power flows out of the transmission straight thru the mainshaft by connecting MS2 to the clutch gear.
The countershaft and it's gears are still turning with the clutch gear but no countershaft gears are used to make the mainshaft turn.

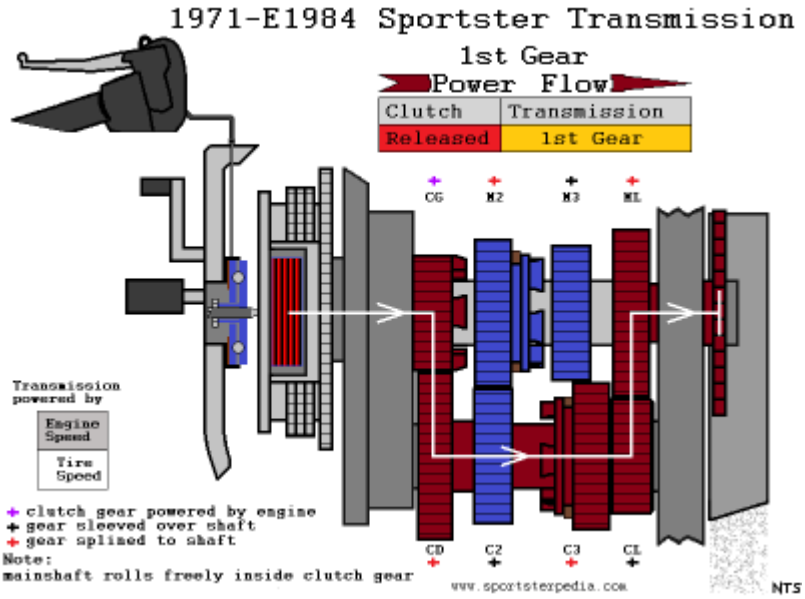
Notice that the 1st to 3th GEAR drawings show 5 gears are involved in transmitting power from the clutch to the Drive Sprocket.
In each of these GEARS, power is transmitted thru the countershaft using CG to drive CD to drive the mainshaft (and thus the Drive Sprocket).
Power flows to the Countershaft solely by way of teeth mesh between the Clutch Gear and the Countershaft Drive Gear.
(no dogs involved to power the countershaft).
Once the SPLINED gear with DOGS engages to a neighboring SLEEVED gear, that SLEEVED gear is now locked to and turns with the shaft.

When the transmission 4th GEAR is selected;
The Mainshaft SPLINED M2 gear is moved so it's DOGS engage the Clutch Gear, thereby flowing power from the clutch straight to the Drive Sprocket.
In this instance is when the transmission is considered to be in 1:1 ratio. The clutch gear and mainshaft turn at the same speed.
However, this is not a 1:1 ratio with engine speed.

A chart for neutral is included below since, technically, power flows from the affected SPLINED gears to their corresponding SLEEVED gears when the clutch is engaged, although power ends there.
The gears involved in that situation are 'idling', with no way of locking themselves to the mainshaft to flow power elsewhere.

Click on any chart to enlarge: [4)]




1971-E1984 Sportster Transmission
1st Gear
Power Flow
Clutch
Transmission
Released
1st Gear
CG
M2
M3
ML
CD
C2
C3
CL
Transmission powered by
Engine Speed
Tire Speed
+ clutch gear powered by engine
+ gear sleeved over shaft
+ gear splined to shaft
Note:
mainshaft rolls freely inside clutch gear
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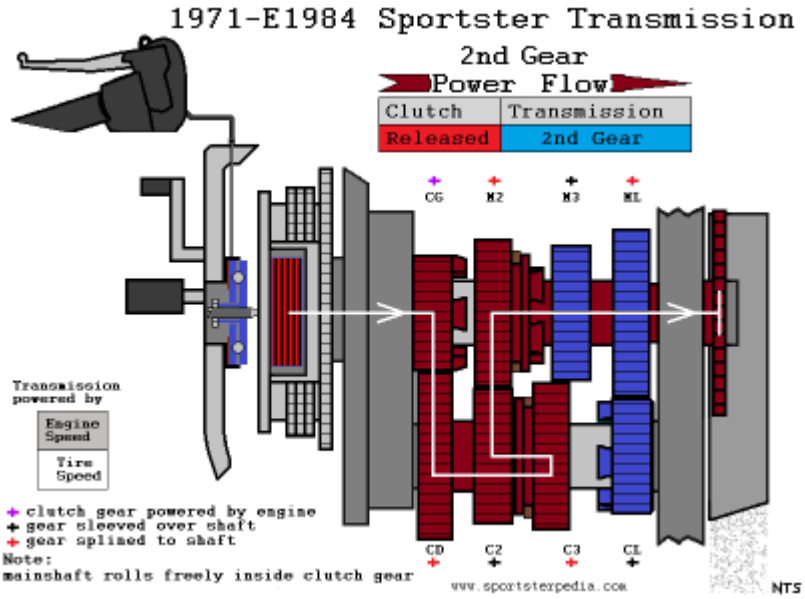
NTS


1971-E1984 Sportster Transmission
2nd Gear
Power Flow
Clutch
Transmission
Released
2nd Gear
CG
M2
M3
ML
CD
C2
C3
CL
Transmission powered by
Engine Speed
Tire Speed
+ clutch gear powered by engine
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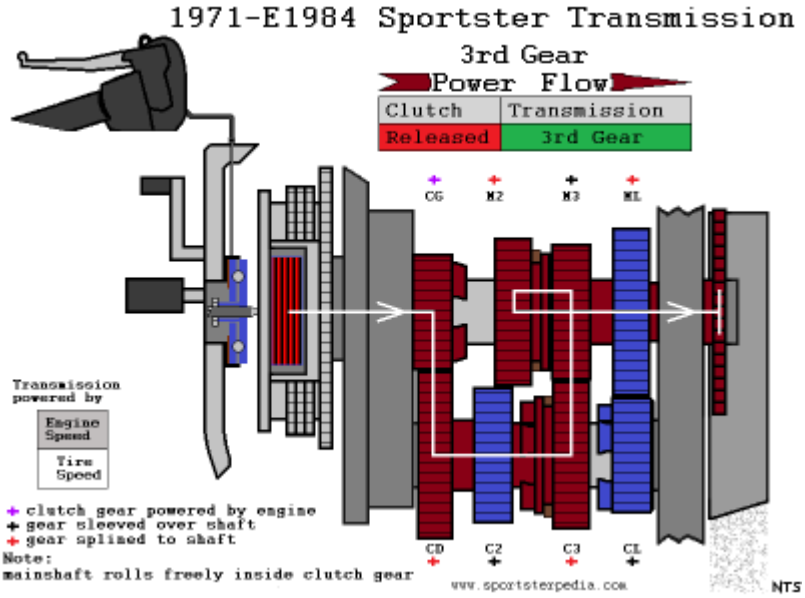
1971-E1984 Sportster Transmission
3rd Gear
Power Flow
Clutch
Transmission
Released
3rd Gear
CG
M2
M3
ML
CD
C2
C3
CL
Transmission powered by
Engine Speed
Tire Speed
+ clutch gear powered by engine
+ gear sleeved over shaft
+ gear splined to shaft
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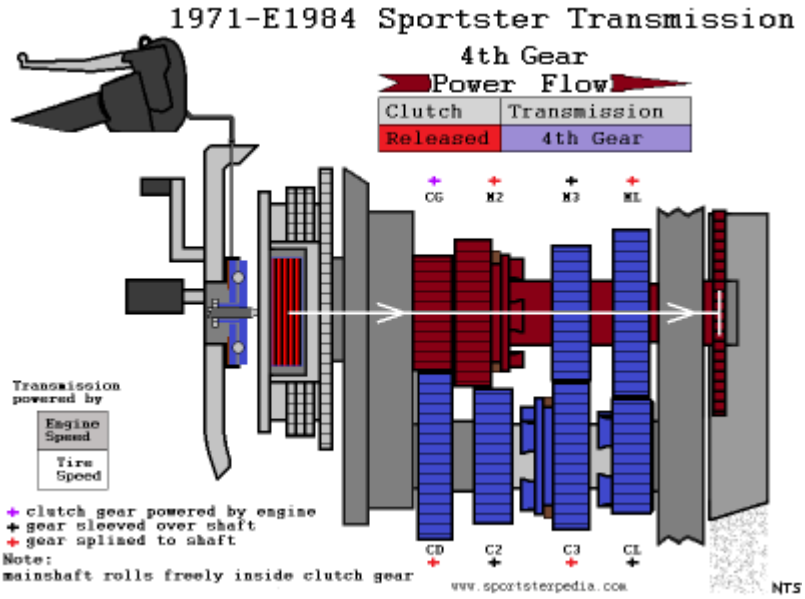


The animated image below shows how the gears are positioned and then moved to attach to their mating gears throughout the gear range.
This may be helpful in determining which gears affect others when accessing the parts.
All shifts in the animation are considered “good shifts” with the dogs sliding into gear as should be.
Bad shifts make the gear dogs hit sides before the sliding gear enters the stationary gear's “dog land”. The spinning gear eventually finds an opening to mate but slaps corners while mating, and damages them.

It's also important to note the source of power changes during a ride.
When you are on the throttle, the motor is driving the transmission, then the rear tire.
When you let off the throttle, the rear tire is trying to drive the transmission (or countershaft) at the same time.
So there is a push/pull going on inside the transmission and the stronger power prevails.
During this time is when the dogs are apt to have lower clamp force on their opposing dogs/slots and a slight separation is possible.

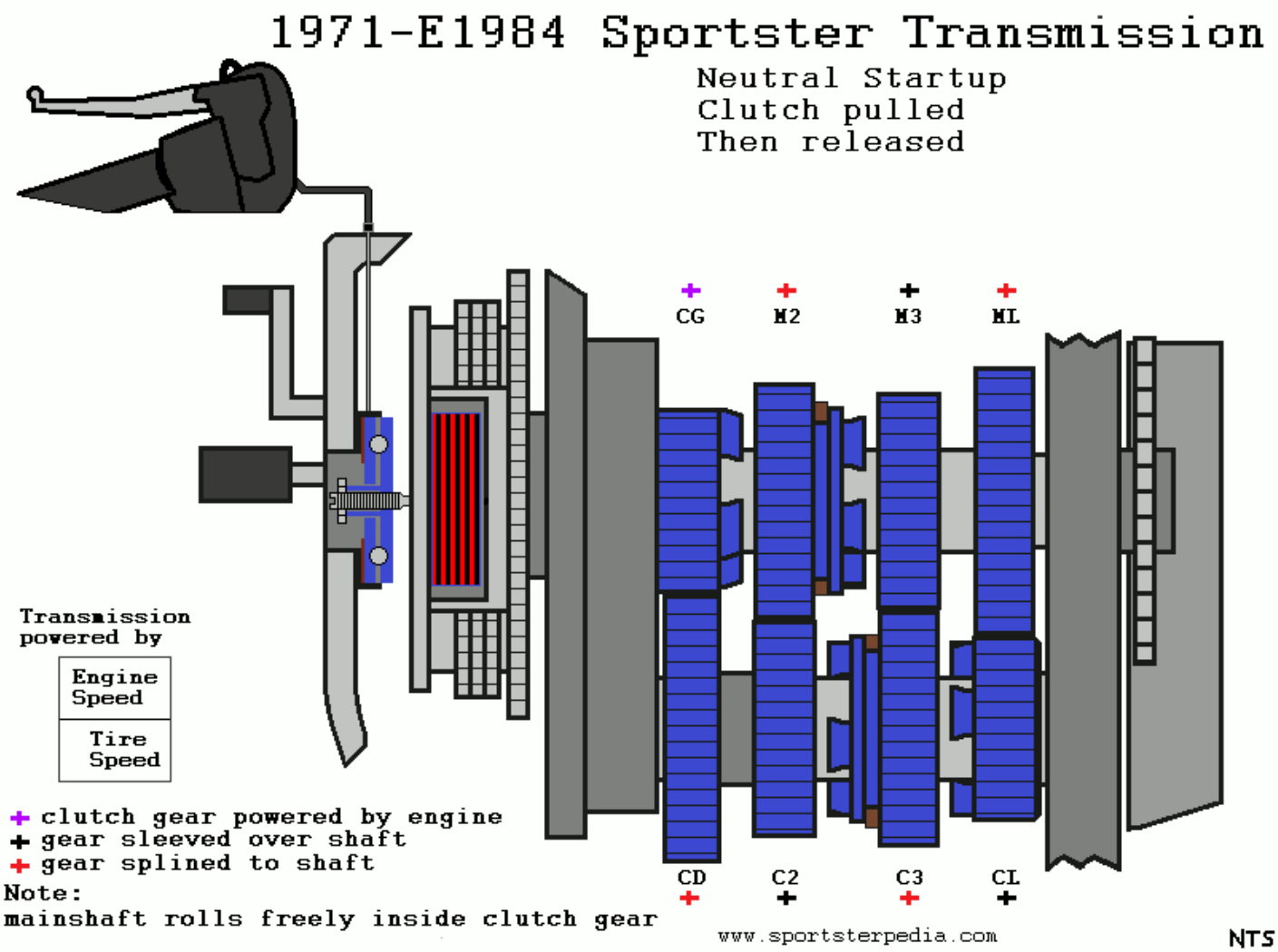
- From the animation; while shifting from 2nd to 3rd as an example (following this closely);
  - First, the shift fork forces C3 to slide to the right, away from / out of mesh thus releasing it's grip on C2. Even with the clutch pulled, the rear tire is still driving both the mainshaft and countershaft due to gear teeth and dog mesh configurations. M2 (splined) is driving the countershaft due to it's teeth mesh with C2 (sleeved) and the connection of C2 and C3 (splined) dogs. Therefore full rear tire load on the countershaft is between the connection of C2 and C3 gears. As C3 moves away from C2, full tire load is on the sliding surfaces and both gears are moving the same speed. At the point of dog disengagement, full tire load is on the dog corners and their mating slot surfaces only. The dogs are undercut (back cut) to help keep them from spreading apart on higher loads and the back cut induces drag between the mating surfaces when they pull apart. Due to the undercut dogs, C3 has to move forward slightly during the move to pull out of mesh with C2.
- As C3 (splined) is pulled away from C2, tire load is lifted from the countershaft and the

countershaft turns now simply by centrifugal force. (That centrifugal force also includes the clutch hub [5]. When you disengage the clutch, you have disengaged the rotating mass of engine from the gear box. BUT, you haven't disengaged the rotating mass of the clutch hub and steel clutch plates as they are solidly keyed to the 4 input gears). C3's teeth are meshed with M3 (sleeved) teeth, and the mainshaft isn't controlling these two gear's speed or the countershaft speed now. The CS shift fork returns C3 to it's centered position then the MS shift fork moves M2 towards M3.

- M2 (still being driven by tire speed) approaches the inside of M3's slot “dog land” and has to move forward a bit to connect dog to slot mating. Depending on current speeds and exact dog/slot positions during this, M3 gear may tap the back side of M2 dogs and slow down or M2 dogs slap surface to M3 slots and speed up M3. If both M2 and M3 were being driven by both tire and motor speed, dog engagement would be rougher when these dogs come together. The gear being engaged has to conciede to the gear engaging to obtain a smooth shift.

The above is just one example of dog mesh situations where one non-driven gear has to concede to the driven gear in order to mesh without damaging the dogs.

About the animation:
The 3 main goals for the animation are gear action, power flow and clutch action.
Gear action is the same for 1957-1990 Sportsters although their were clutch changes and left/right side shifting changes, as well as many other parts changes involved. The shifter shaft, pawl carrier, and shift forks are left out for clarity. From this angle, they wouldn't be seen much anyway. The mainshaft and countershaft is shown from the rear to view how the gears operate. The rest of the imaging is shown from the top view. The gear teeth are for posterity and don't reflect model speed. The dogs are in proper ratio per this model scale, but you can't split a pixel into decimals. So actual ratio will be a little different but comparable to model ratio (as in this gear spins faster than that one). Also it's important to note that when mated, the gears do not actually mate flush together as they are depicted in the animation.

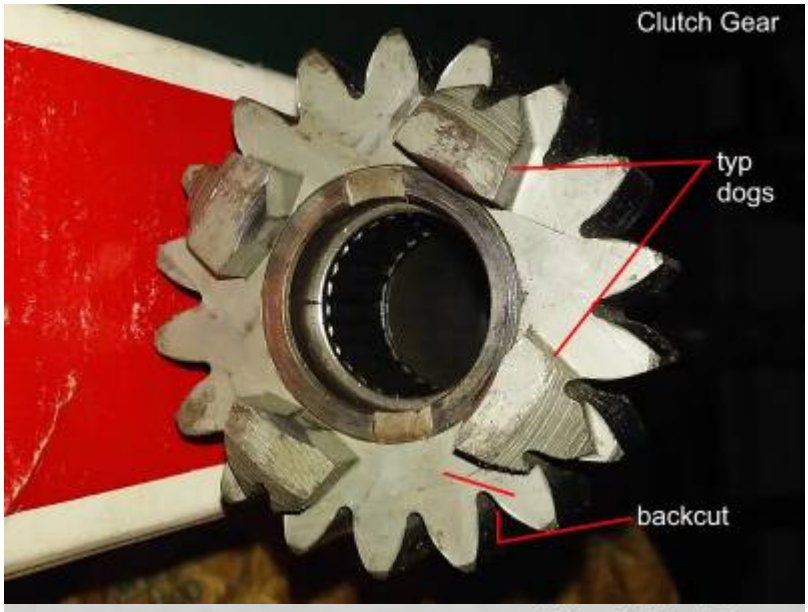


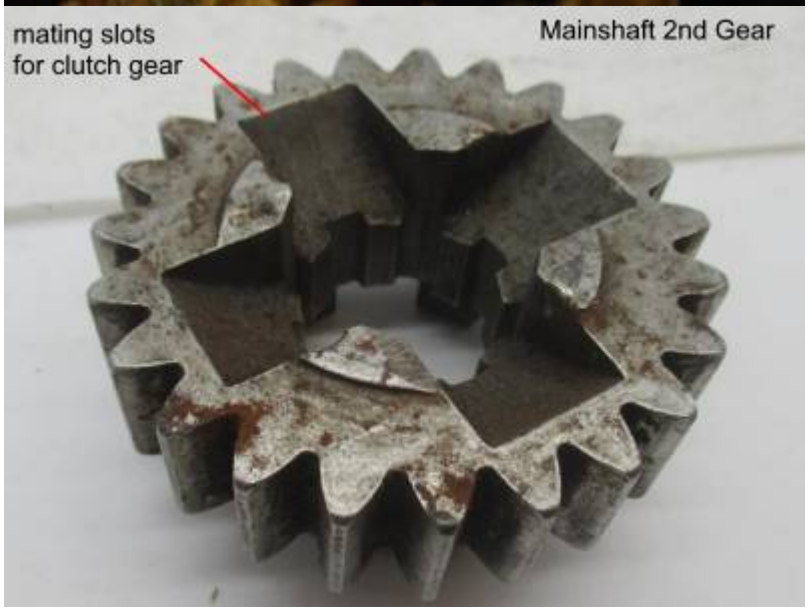
6)

Gear Dogs and Slots

The transmission gears are engaged by way of gears with dogs (male engagement) and gears with slots (female engagement).
The sliding gears are splined to their respective shafts and turn according to “current” shaft speed.
Gear dogs slide into their mating gear's slots to mesh.
The dogs are undercut starting from the outer corner toward their root. This undercut is designed to keep the dogs from slipping out of gear under heavy load.
The slotted gears are also machined to match their mating dogs to achieve full clamp load between the two.

With a 90 degree angle instead, the sliding gear dogs **could** simply spin straight out of mesh (pop out) with high centrifugal force.
With the undercut, they can't simply pull out. The sliding gear would have to first separate from dog mesh and then pull out.
The outside edge of the dogs are straight cut without a chamfer.





Worn Dogs (hopping out of gear)

The gear dogs can wear just about anywhere around them for several different reasons.
The most common thing that happens is when the corners get rounded off instead of being flat on the edges. [7)]
A gear may hop out of dog/slot mesh.
It feels like the transmission jumped into neutral for a second and then jumped back in gear.
It's usually a momentary hop-out. In other words, it hops out and then right back in. [8)]
So the bike hesitates during acceleration and then jerks back forward again.

This is the common cause of hop-out.
The fact the corners are rounded isn't as much of an issue as the REASON they got rounded and the EFFECTED CONDITION of them being rounded.

The corners began as a machined specific angle.
The sides are machined so they are a perfect match to and lay flat against their mating slot.
As use (and abuse) happens, the corners get banged into their respective mating gears which mangles (and changes) the side profile of the dog(s).
Now, instead of equal pressure across the side of the dog, the only part of the dog that is mating is the crunched portions.
So the surface tension is shortened and the undercut isn't fully touching which limits the dog's ability to stay in place on load.
So the gear hops (or backs) out of dog mesh.
Meanwhile, the fork is still trying to hold the gear in mesh and forces the gear back “home” and the cycle continues.

The geometry of the drive dogs that normally keep the bike in gear are degraded to such a point that now they are forcing the bike out of gear. [9)]
The bike will run normally until this “the tipping point”, where (the affected gear) will no longer stay engaged under any power.
To the rider, it seems like a switch has been thrown. Taking a close look at the dogs, the power sides are angled in a fashion that makes them 'screw together' under force. [10)]
When this happens the fork holds the gears from bottoming.
When the dogs get peened from use this 'screw together' turns into 'screws apart'. Now the fork is loaded in the opposite direction.
When the 'screw apart' force becomes great it overpowers the fork material.
Once your dogs are this worn, it don't matter what the fork material is. Any material will fail.

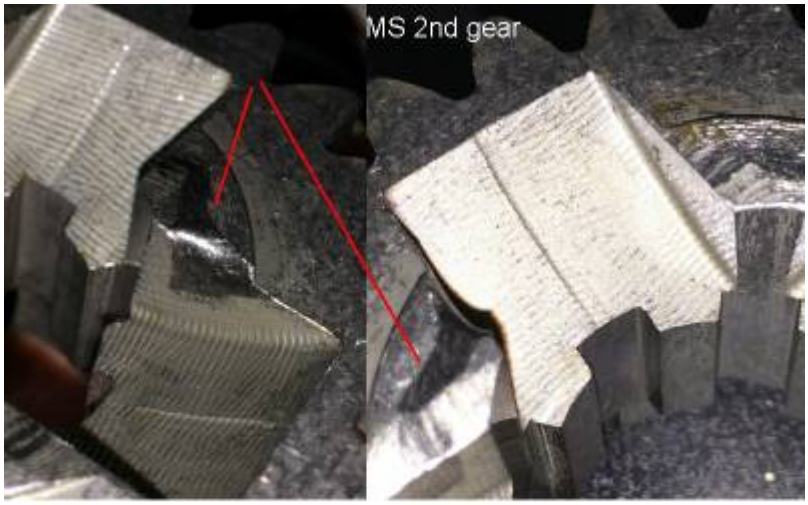
Damage that requires replacement:
Any gear dogs or mating pockets that are chipped and worn is just asking for trouble. If you have the means, replace them. [11)]
It's expensive, but you can change out everything for new Andrews parts: gears and shafts. [12)]
Then you don't have to worry about a weak link in the trans that could blow up later causing very expensive damage.

Below are pics of various dog wear. Either are candidates for replacement.
Click on any pic to enlarge.

You can see the damage on the (L) clutch gear dogs and the (R) MS2nd slots.
The clutch gear dogs mate into MS2nd slots when the transmission is in 4th GEAR.
Eventually, the wear will grow until they become the only area of contact between the gears. [13)]
When that happens, the bike will jump out of 4th gear under power. Dogs are like tires and chains - they are only new the 1st day.
The way to tell how much good surface material is left between dog engagements;
Look at how much the gears engage with each other when the transmission is together and hanging from the door on bench.
4th gears take a beating on stock ratio (as opposed to c ratio) wet clutch bikes.
The clunk into 4th gear is the dogs banging together, taking a little more dog with them each time.

These are different dogs on the same clutch gear.
The damage is obvious on the dogs.
Also note the damage is different on each dog

[14)]



This is the female "slot" side of MS 2nd showing the rounded corners from the Clutch Gear backing out of it.

[15)] \

How Dogs Get Damaged

From Dr Dick on the subject of gear dog damage

Hammer from the Rotating Mass of the Clutch Hub: [16)]
There are 8 gears in the gearbox. 4 are connected to the engine thru the primary drive and 4 are connected to the rear wheel thru the secondary drive.
With that in mind, how many gears are rotating when the bike is parked? Correct,none.
Start the engine. Now what happens? The 4 gears connected to the running engine also rotate. How fast are the remaining 4 rotating? Correct.
They aren't rotating because the rear wheel is stationary.
Let's reverse that scenario. Your motor is not running and your pushing the bike out of the garage.

Now the 4 connected to the secondary are rotating and the 4 connected to the engine are stationary. Got that so far? 4&4.
Now that your in the driveway, you're gonna start the bike and go for a ride. Prior to firing the engine you check that you are in neutral.
Then boot the engine to life. Now you have the 4 engine side gears turning and the 4 wheel side gears stationary.
If you toe the shifter into first without disengaging the clutch what happens? Bike jumps a foot and stalls. What happened in the gearbox when you did that? The rotating engine side dogs engaged with the stationary wheel side dogs.
Think about how that engagement came about. Dogs slid from zero to 100% engaged.
And the speed difference of the 2 needed to become the same—- instantaneously. Think about that. It's a violent situation.
To illustrate what happens to the dog faces when this violent collision happens, you're axle is stuck fast. So you hit the stationary axle end with a moving hammer. The axle gets 'peened'. So do your dogs.
“But wait Dick, I don't shift my bike unless the clutch is disengaged. So the above isn't true in may case”. Yes it is. But it's less extreme.
In the no-clutch 1st gear engagement scene the entire rotating mass of engine stops. That's a big hammer getting swung on your dogs.
When you disengage the clutch you have disengaged the rotating mass of engine from the gear box.... But,
You haven't disengaged the rotating mass of the clutch hub and steel clutch plates as they are solidly keyed to the 4 input gears.
It's the thousands of little tap hammer shots the clutch hub and steels apply to the dogs at each shift that peens the dogs away.
C ratio transmissions reduce the relative speed change during gear changes because the ratios are numerically closer together.
So the hammering is lighter. C boxes last longer because of this.
The bang you hear in certain shifting situations is the dogs getting hammered by the clutch hub and steels.
A quiet shifting transmission is a longer lived transmission.

Jumping out of 4th Gear.....or.....The Wide Ratio Gap between 3rd and 4th GEARs: [17)]
On 1972< bikes, this was the most common trans malady. 1973> would break gears or jump out of 4th with about the same frequency.
So what is the root cause of all too common bad 4th you ask? It's the overly wide ratio difference from 3rd to 4th.
Almost every ironheader will say there is a speed where 4th is too tall and 3rd is too short.
Most guys ride around that speed as habit. It's like your transmission is a great 3 speed with 4th as a tall overdrive.
That's what HD wanted in the early years (three low and nicely spaced gears for streetfightin and an overdrive for ride to the next standin start run thru the gears). That wide 3-4 jump has an undesirable long term side effect. Ya know that 3 to 4 clunk/bang? That's caused as the 4th gear dogs engage. When shifting, the fork slides mainshaft 2nd along the mainshaft splines. The sliding disengages 3rd dogs, trans goes into a neutral state until the 4th dogs engage. When any dogs are engaged, the dogged gear pair spin as one. When shifting, gears are spinning at two different speeds. On upshift, engagement of one gear has to change speed instantaneously. On the 3-4 shift, that gear is the clutch gear (since MS 2nd gear, that mates to the clutch gear creating 4th GEAR, is being driven by the rear wheel). Now out in the primary, the clutch hub, steel clutch plates, clutch springs, and pressure plate are splined directly to the

clutch gear. So when 4th dogs engage all that mass has to change speed instantly. The bang/clunk is the hammer-like shock the 4th dogs undergo as the mass changes speed. Guys get hip and learn how to match clutch speed to sliding gear speed through finesse on the clutch lever, shifter, motor speed and road speed to minimize the banging. But it ain't possible to do that in every scenario.

Now you can see that the bigger the gear speed change (read as wider the ratio jump) the bigger the dog hammering gets.
Each blow rounds off the drive faces of dogs and receiver slots a little. After long enough, the drive faces wear to the point where they begin to 'ramp' out of engagement under power. Get on the gas and your jumping out of gear. Back off and they re-engage. In order to disengage, the sliding gear pushes on the shift fork, fork pushes on the top hat, top hat pushes on the cam plate, cam plate flexes the tower. Bet that hits home, don't it?

Before the dogs wear to actual jumping out, they try to jump out but the fork/hat keeps the dogs engaged.
This heats and bends the fork. This is when guys say “my fork bent and that allowed dogs to wear until my bike jumped out of gear”. Sorry. That's probably not what happened. Instead, the worn dogs bent the fork. The fork isn't the problem. It's a casualty of worn dogs. Forks just don't bend for no reason.

Where am I going with this? The wide 3-4 ratio gap sucks to ride with and it beats up your transmission. If you could raise 3rd ratio closer to 4th, the speed change will be less abrupt on each 3-4 shift and the dog hammering gets reduced. Your 4th gear dogs last much longer. Good deal. And the new higher 3rd ratio increases road speed at any given motor rpm. The crappy “4th too high-3rd too low” thing disappears. Good deal #two.

If you're gonna buy a new clutch gear, buy one that works better. One that raises 1st/2nd/3rd ratios as a group closer to 4th. The beloved “C-ratio” option. You will love it.
I won't own a bike with out it.

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https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-era-specific-and-model-specific/ironhead-sportster-motorcycle-talk-1957-1985/127032-getting-this-78-back-to-the-way-it-should-be/page17#post2849730
2)
IronMick of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-era-specific-and-model-specific/ironhead-sportster-motorcycle-talk-1957-1985/181127-mick-s-transmission-shifter-refurb/page5#post3879370
3)
Jeff of the XLFORUM
https://www.xlforum.net/forum/sportster-motorcycle-forum/sportster-motorcycle-era-specific-and-model-specific/ironhead-sportster-motorcycle-talk-1957-1985/203948-3rd-gear-another-

nuetral/page2#post4581041
4)

Drawings by Hippysmack with help from IXL2Relax with graphic design
5)

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6)

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7)

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8)

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10)

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