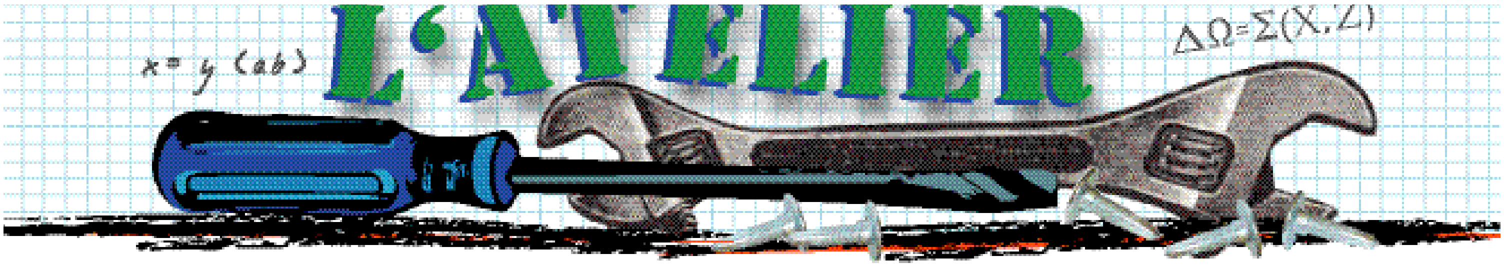
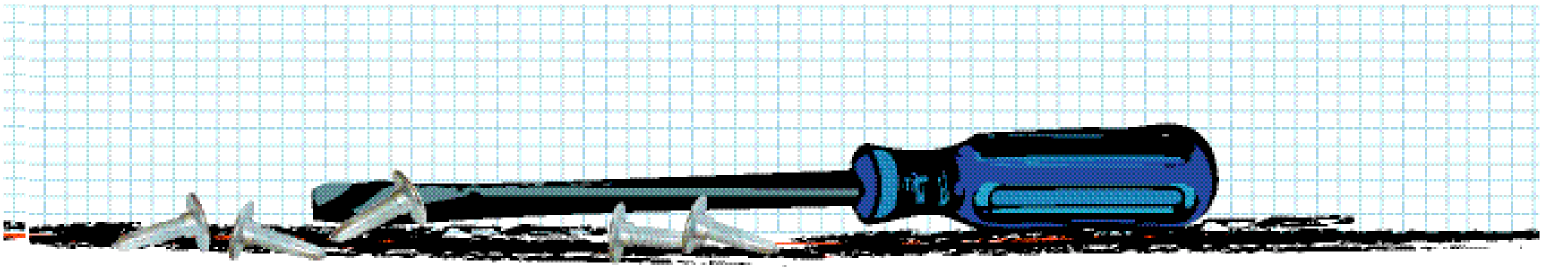


SUSPENSIONS PART II:

Welcome back to Part II of our in-depth look at snowmobile suspensions. We will now move on to complete our overview of the basic workings and physics involved before covering the more practical and hands-on aspects of suspensions. As promised, we called on renowned and respected suspension expert Robert Véronneau, owner of Star Suspensions, to help put this article together. A long-time snowmobiler, Robert has extensive experience setting up, calibrating and modifying snowmobile (and other types of) suspensions. We recommend that you have a look at his Web site at : www.starsuspensions.com as it contains a wealth of useful tips and information.

Robert Véronneau at work during the Snow Shoot held in Munising, Michigan, in March 2006.

It should be mentioned that while very similar, different snowmobile suspensions all have their own particularities. In other words, it would be virtually impossible to provide advice that covers every specific model. We will thus explain, in general terms, how to apply the underlying principles to your own snowmobile. It is a fairly technical article and, as such, you will surely benefit from re-reading it as your experimentation and calibration progresses.



FROM THEORY TO PRACTICE

By: Michel Garneau, in collaboration with Robert Véronneau

Weight distribution and handling

Every single aspect of a snowmobile's handling relates back to weight distribution. As you will see, it is a very dynamic element. In other words, while it is static with your sled sitting immobile on your garage floor, out on the trails it is constantly changing and what we have come to call handling is, in fact, the way in which we feel this very process occurring beneath us.

As we know from the last issue, there exists four contact points on every conventional snowmobile, however, for our current needs, you can take the skis as a single unit.

In light of this then, let us begin our examination of a sled's behaviour by looking at the different possible weight distribution scenarios. Given that it is physically impossible for an overriding majority of the weight to be placed at either extremity, we are faced with four possibilities:

i) majority of the weight spread between the skis and front of the track
ii) majority of the weight spread between the front and rear of track
iii) weight concentrated at both extremities
iv) majority of the weight at the front of the track

We will now analyse the effects and results of these options strictly in terms of handling traits. Why, you ask? Well, quite simply, optimal handling is the result of the skis and track being in maximum contact with the snow. If this is true, comfort will be a welcomed side-effect.

So, getting back to scenario (i), our handling traits would be the following:

- heavy steering
- ability to change directions quickly
- tendency to understeer (excessive weight over skis would cause front end to push)
- poor traction
- tendency to dart
- tendency to "fishtail", especially under deceleration

To sum up, this is hardly an ideal situation.

Scenario (ii) traits:
- very light steering
- tendency to both understeer (when initiating turns), then rapidly turn to oversteer mid-turn
- excellent traction
- tendency to dart (insufficient ski pressure would have the skis "skimming" the surface and being taken off course very easily)

Again, not a desirable scenario.

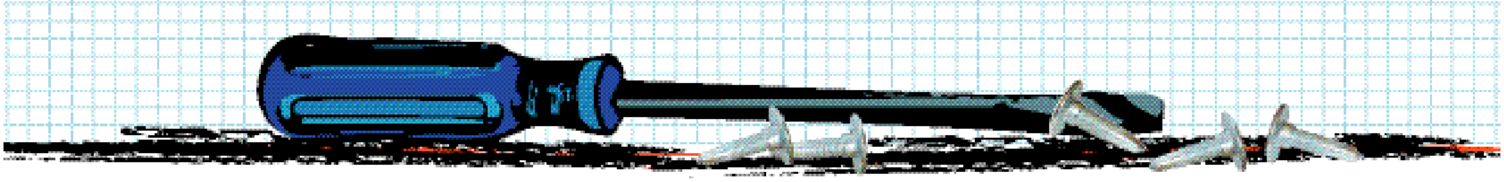
Scenario (iii) traits:
- heavy steering
- straight line stability
- poor traction
- tendency to dart
- dangerous and alarmingly unpredictable tendency to oversteer

This is, again, not a desirable outcome.

Finally, scenario (iv) handling traits:
- light but responsive steering
- rapid directional changes possible
- neutral cornering behaviour
- excellent traction
- optimised weight transfer capabilities

In this case, the front of the track becomes a pivot point. You can also see how each and every characteristic is quite desirable and will result in a predictable sled that is both safe and easy to ride (especially so in the case of modern rider-forward sleds). Also, the sled will perform better under braking as the natural front weight transfer under deceleration will help to "push" the front of the track into the snow thereby increasing traction and improving braking. Consider also that on decelerating upon approaching a corner, the weight shift, in addition to helping the skis to dig in harder for better tracking, will also slightly ease pressure from the rear of the track, thus creating optimal conditions for the sled to initiate a quick and easy change of direction.

To put it into concrete numbers, for riding trails you should have about 15% of the weight (with rider aboard) over the skis, roughly 60% over the front of the track and 25% over the rear of the track. Those riding in powder snow may want to position slightly more weight over the skis to improve floatation.



The dynamics of turning

Understanding what happens, and how it happens, when turning will also be useful in helping to further understand how to properly set-up and diagnose your sled's handling. As most of you know, when turning, the inner ski has a tendency to "get light" and lose some degree of traction while the opposite is true of the outside ski as it gets weighed down more and actually digs in harder. Essentially, the center of gravity of the snowmobile, which is above the ground, wants to keep going straight despite your intention to force the sled around the corner. This very fact causes weight to transfer to the outside ski, it's really that simple.

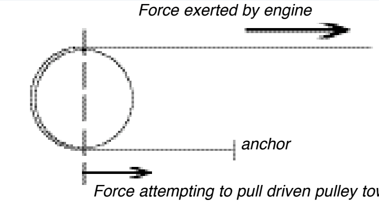
To a lesser degree, there is also the effect of "counter-steering". To better understand this concept, recall how when running in deep powder you need to turn the skis in the opposite direction of the side you want the sled to lean into. This effect also exists when riding on trails.

Toe-out

Toe-out is likely the single greatest contributing factor to a sled's straight-line stability. To grasp how it works you must first be aware that anytime you are riding, the two skis are constantly exchanging dominance over the conduct of the sled. With this in mind, let us examine how toe-out (both skis are pointing slightly outwards) works. Imagine if you will that it's the right ski's turn to dominate. It tries to pull the sled right and this, in turn, causes the sled's weight to shift to the outside ski (left). It, however, is pointing slightly left and so it tries to pull the sled left, which, again, shifts weight to the outside ski which is in this instance the right. This back and forth weight transfer occurs very quickly and subtly, so much so that the rider, for all intents and purposes, doesn't notice it. The end result, however, is a sled that, through auto-correction, goes straight. The only downside to toe-out is slightly increased drag as the skis are both being pulled apart at the tips during driving, a very small price to pay for stability and peace of mind. A sled with toe-in is in constant need of correction by the rider. It may, in fact, be a good comprehension exercise to work with the weight transfer concepts to help you understand how and why this is true. How do we set it? Well, you should first refer to your owner's manual to see what the exact spec is for your sled (usually in the range of 1/16 to 1/8"). Now, position your sled on a flat surface with the skis as straight as possible. Next, use an elastic tie-down (or some other means) to take up the slack in the steering system by bringing the ski tips in toward each other. Measure the distances between skis (preferably in middle of the runner or keel) at the front and back and compare the results. The distance at the front should be at least as wide as the rear measurement and the excess of the front measurement over the rear is your toe-out. You can adjust toe-out by using the steering adjustment rods.

Dynamic transfer explained

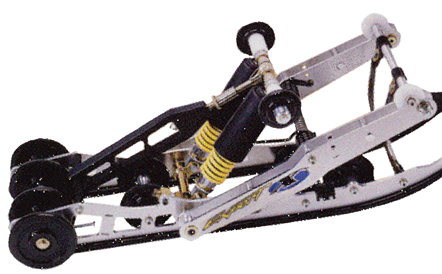
We mentioned in the last issue that dynamic transfer works to try to raise the front of the sled under acceleration. We will now explain how it works. The easiest way to explain this force is by comparing it with a pulley/conveyor belt system for, in the end, that is what a snowmobile track and drive system is. Imagine then a typical conveyor belt system with a driving pulley at the front (analogous to the drive shaft and sprocket on a snowmobile) and an idling or driven pulley (rear idler wheels on a sled) at the back. The force being exercised on the belt is applied as a pulling



motion at the top of the drive pulley. Under zero load conditions, the belt will turn quite freely and there is virtually no force acting on the rear idler. Now, imagine if you were to grab hold of the belt on the underside and stop it from moving. Is such a case, the motor turning the drive pulley wants to keep driving and pulling the belt in, but suddenly is unable to do. At this point, the force being exercised by the motor would have to end up somewhere, but where? Well, in holding back the belt, you are effectively acting as an anchor. In other words, you have changed the pulley system to one in which one end of the belt is now stationary and, as we learned in high school physics class, the force will now try to pull the idler pulley towards the driven. Now, to put it in snowmobiling terms, the ground under the sled is akin to your hand holding the belt. So, as the engine tries to move the track, the force being exerted will try to pull the rear idler forward. As the rear suspension is mobile (pivots in the frame), the entire rear suspension gets pulled forward, towards the drive sprocket. This, then, causes the suspension to arc forward and extend, causing the snowmobile to rise. That, in a nutshell, is dynamic transfer.

Dynamic transfer and modern rear suspension design

In light of the above, it is not hard to see how dynamic transfer can really unsettle the pressure being exerted by the sled's various contact points. It stands to reason, then, that reducing (or better managing) its effect would help to improve stability and predictability. Without getting into long drawn-out physics formulas, you can see how the steeper the front arm angle is (that is, the closest to vertical), the more easily the front of the sled will come up. Conversely, the shallower the angle, the less unwanted dynamic transfer you will have to contend with, all other things being equal. A close examination of new suspension designs reveals quite clearly a move to longer front suspension arms that are laid increasingly flat. Whereas on previous designs' dynamic transfer was being



Clearly the best and most obvious example of a rear suspension designed with minimizing dynamic transfer is the Expert (and its derivatives) by AD Boivin with its extremely long and very shallow angle (front) arm.

managed (or bandaged over) with the use of coupling, it is now being handled in the actual designs.

Changing weight distribution

Suspension engineers have provided us with various tools for altering weight distribution. We will now go over these and explain the effect that each adjustment makes (classified in terms of primary and secondary effect) as these are the very tools you will need to use to get your sled to handle right for you.

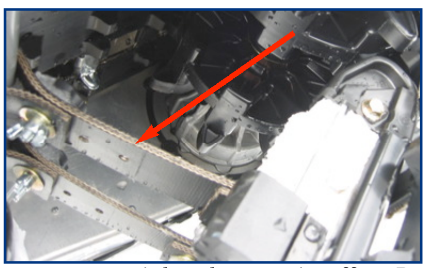
changing front suspension spring pre-load
Increasing pre-load results in :
- additional ski pressure (P)
- decreased pressure front of track (S)
- slight increase at rear of track (S)

Decreasing pre-load has the opposite effects.

changing front shock (rear suspension) spring pre-load
Increasing spring pre-load:
- increases pressure at front of track (P)
- reduces it on skis and rear of track (S)

Decreasing the pre-load would do the opposite.

changing limiter strap length



Lengthening the strap, in general, would tend increase front track pressure (P; this is certainly true if the strap is snug when the sled is immobile with the rider aboard, a no-no according to Robert), while also decreasing pressure at both extremities (S). Shortening it has the opposite effect. Remember also that shortening the limiter strap effectively reduces suspension travel thereby negatively impacting ride quality.
Robert notes that limiter strap length is much less critical on newer suspensions and it can largely be left alone, or used as a very last resort if you are attempting to change ski pressure.

changing rear spring pre-load (rear suspension)
Increasing pre-load :
- increases rear track pressure (P)
- decreases front track pressure (S)
- increases ski pressure slightly (S)

As expected, reducing pre-load would have the opposite effects.

Basic suspension calibration

Any and all proper suspension calibration should begin with setting the static sag. The generally accepted rule is that 1/3 of the available travel should be used up as sag with the rider aboard. For this to be useful, you first have to determine the amount of travel. In the case of the rear suspension, you will notice upon inspecting the slide rails that there are typically rubber stoppers designed to provide a "soft" cushion for those times when the suspension does fully collapse. Logically then, you only need to measure the distance (at full extension, with the rear of the sled off the ground) between the top of this stopper and the part that will be contacting it at full compression. In the case of a torsion spring-equipped unit, simply measure between the bottom of the torsion spring and the top of

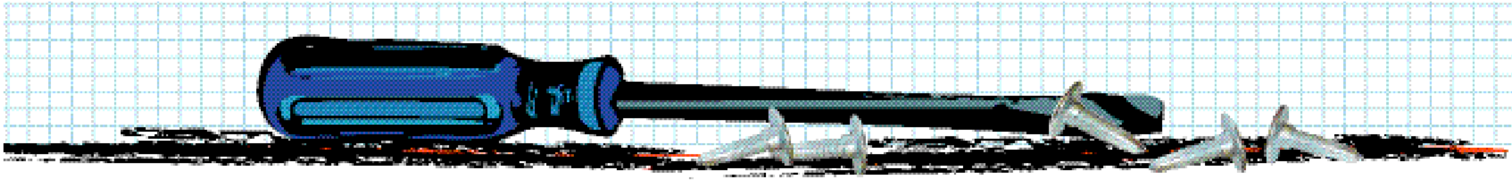
the rubber stopper. Now, placing the rear of the sled back on ground, slowly lift until the track just starts to come off the ground (you will need a jack or someone to assist

you) and measure the distance between the ground and the bottom of the torsion spring (or a point of reference on the sled in this general area). Now, have the rider sit aboard the sled and re-measure. Subtract this distance from your earlier un-laden reading and compare the result to your previously calculated sag requirement. Add or remove pre-load until the required sag is achieved.

Measuring travel in the front suspension is a bit trickier and so for this reason, and actually perhaps moreso to try to reduce dynamic transfer as much as possible, Robert recommends setting the front end as soft as possible as a starting point (thereby reducing the angle of the front suspension arm). On sleds with notched spring positions, set pre-load to the softest position. On sleds with threaded adjusters, raise the front end of the sled and loosen the adjusters until the spring just stays in place with no load (this will ensure it stays in position).

Once this is done, you now need to assess the weight over skis. Robert states that you should have between 80-160 lbs (on average) on the two skis. We should note that this will vary from sled to sled. Of course, this is difficult to accurately measure but you will develop a feel for it over time as you gain experience. You can fine-tune the weight over the skis by adjusting the front spring pre-load in the rear suspension. Of course, making any change to this setting will require you to re-verify the sag in the rear suspension as it will have changed. Be patient as you may have to repeat these steps a few times.

This now takes us to adjusting transfer and coupling in the rear suspension. The general rule here is to ride the sled and adjust it to your liking. It is recommended, however, that you start at minimal coupling settings and work up from there. Just remember that your suspension's action will stiffen considerably as soon as it begins to couple. Note as well that older suspension designs tended



to rely on rear-to-front coupling as a means of controlling dynamic transfer so you may have to explore this avenue as well.

Finally, for those sleds equipped with adjustable damping shocks, this is the point where you can now start to tamper. It is recommended that you use the manufacturer's recommended settings as a baseline and work from there.

Troubleshooting

If you make the adjustments and follow the steps laid out previously your sled should handle quite well and deliver a comfortable and stable ride. Any attempt at troubleshooting should first begin by having a quick look at mechanical items such as seized pivots or joints, the condition of the runners (bent? worn? missing?), the ski bottoms (damaged?) and track alignment as deterioration in any or all of these can adversely affect handling. There are issues, however, that may arise which lie outside the scope of what has already been covered and these are more generally related to shock and/or spring action. We will now attempt to shed light on some of these.

bottoming (front)
The first thing you need to know is that some bottoming is good; it means that you are using all of your suspension's travel. However, it should only occur in more extreme conditions. In diagnosing the issue, it is important to note when and how it occurs as it could be spring or shock related (or both). In the case of an overly soft spring (or one which has lost its tension), you will note an inability to set reduce sag to the prescribed amount. Note that increasing pre-load is NOT a remedy for a weak spring as trying to compensate in this way will result in a suspension that delivers a stiff ride on small bumps but still bottoms on bigger ones. A worn shock can be tested by bouncing front end (similar to how you test shocks on a car). If shock is spent, the front end will pogo (worn shock will typically lose compression and rebound damping, hence bouncing on rebound). The special case of insufficient high-speed compression damping can be a bit trickier to diagnose as it can cause bottoming much as a soft spring can. If you are able to set your sag properly, chances are your high-speed compression is the cause of the bottoming.

Finally, there is the cause of bottoming caused by excessive rebound damping, a condition known as "packing". In such cases, the suspension gradually collapses over a series of long and repetitive bumps, causing it to eventually bottom. This is caused by excessive rebound damping which does not allow suspension to recover and extend sufficiently in between hits.

bottoming (rear)
In this case, you use virtually the same diagnostic procedure as for the front but you must pay close attention to determine which end (front or rear) of the rear suspension is the main culprit. The only possible complication in a proper diagnosis is the coupling function so it may be wise to reduce it as much as possible in order to better isolate the action of the two ends of the rear suspension.

unresponsive suspension (front and/or rear)
This condition too may be either shock or spring-related. You will need to note when and under which conditions the stiffness is problematic. An overly stiff spring rate will produce a suspension that rarely, if ever, bottoms, and will generally make it impossible to achieve adequate sag settings. Excessive compression damping may also be the cause. In the case of high-speed damping, the stiffness will be felt on ripples (washboard) and square-edged bumps, things that require rapid suspension response. If the low-speed setting is at fault, it will be felt on longer rolling bumps that do not require such rapid suspension compression.

suspension kicking
It is important to note that this is not the same thing as an overly stiff suspension. In this case, the impact is absorbed properly but things go amuck when the suspension rebounds too violently, essentially pitching the sled into the air. This is usually caused by insufficient rebound damping which results in the shock not restraining the spring adequately on the rebound stroke.

In terms of understeering or oversteering, if, after having adjusted your sled's suspension as laid out previously, you are still faced with either condition, it is likely related to mismatched skis/runners and track (especially if your sled has studs), or the ski's inherent design (some are too aggressive, some not enough). Still on ski design, some are inherently more prone to darting (the more aggressive the more prone) and correcting this tendency may call on resorting to a different runner design (dual runners for example) or some type of corrector.

Finally, it may be wise to "start from scratch" if you are faced with a lingering handling problem as attempts to fix just this one item may very well simply transfer the problem elsewhere. So, in such cases, pull the sled into the garage and start from the beginning, you will likely save yourself much time and frustration.

So there you have it. Remember that barring any mechanical issues, virtually any undesirable behaviour can be corrected if you take time to analyze what is going on in terms of weight distribution and transfer. It is not magic, so be patient and don't be afraid to try things. Look at it as an investment in getting to know your sled, and in getting the most out of it.

Next month:
Kevin Cameron will guide us through the history, development and workings of ignition systems. Modern electronics have revolutionized more than just your cell phone and digital camera. Find out what it has done for your sled and what we hope to see it do in the future.