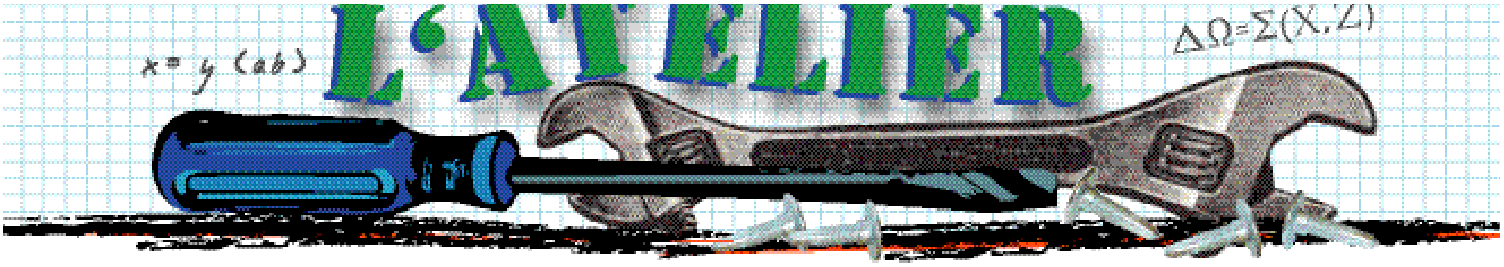


SUSPENSIONS : PART 1

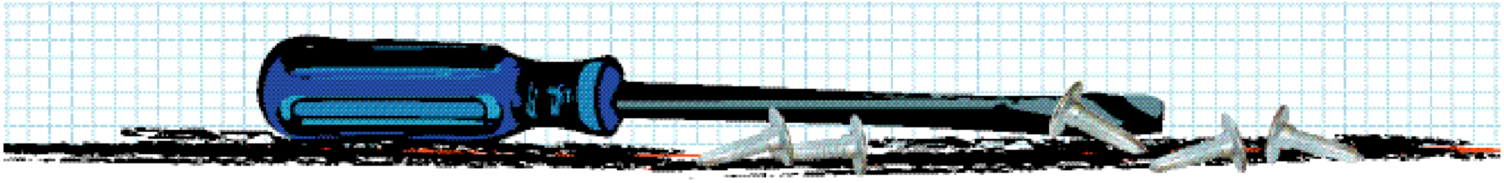


Text Michel Garneau, photos Michel Brault

Snowmobiles have evolved greatly over the years. While the recent introduction of new exhaust emissions standards has clearly put the focus of late has been on engine development, one cannot help but notice how much chassis and suspensions have changed too. Gone are the various leaf spring and bogie-wheel systems that graced sleds in the 60's and 70's. In their place, we now find sophisticated and highly adjustable dual A-arm front ends and slide-rail rear suspensions that have revolutionized handling and comfort. In fact, it could be said that modern snowmobiles have what are quite possibly the most sophisticated suspension systems of any current mass-produced vehicle. Sadly, it seems that only a small percentage of snowmobilers truly understand how they work, and consequently know how to properly adjust these engineering gems. What this means, unfortunately, is that many are not getting the most from their investments.

In order to attempt to redress this situation, we will be taking a detailed look at modern suspensions, explain and show you how to use all of the adjustability that manufacturers have worked so hard to build into their sleds. Reading and understanding these concepts could be the single biggest improvement you could make to your snowmobile, and the best part of this is that it is free.

This month, in part 1 of our two part series on suspensions, we will present basic concepts and terminology to help provide you with a sound understanding of just what a suspension truly is, what it does, and how it functions. Along the way, we'll touch on theoretical notions, all in an effort to de-mystify this critical component of every modern snowmobile. Next month, in part two, we will provide you with set-up advice and help you to troubleshoot some common problems and conditions that prevent you from getting the most from your sled. So, without further ado....



Basic purposes

Ask 100 people what are the primary purposes common to all suspensions and chances are the vast majority will inevitably reply that it is to provide comfort to the operator. Unfortunately, all of these people would be wrong. While we all value the fact that an effectively designed and well-tuned suspension system does indeed shelter the vehicle's driver from the imperfections of the road/trail/terrain, the primary purpose of any and all suspension systems is, first and foremost, to maintain traction and thus control. Need proof? Look at a Formula 1 car. Comfort is the last concern for the designers. Instead, the suspension is tuned to ensure maximum adhesion (traction) at all times, thus ensuring the fastest possible times around the race track. In essence, a wheel that is not in contact with the ground cannot give drive out of a corner, cannot slow down the vehicle under braking, and cannot be used to guide it through a corner. Now, some naysayers will say that is a unique case since a F1 car is a specialized vehicle but the fact of the matter is that this simple concept applies to all vehicles.

If you are still not convinced then ask yourself why snowmobile manufacturers would go to the expense and trouble of designing and building such complex systems as we have on modern snowmobiles when, if comfort was the only objective, they could simply build sleds with suspended seats (akin to the 1997 Sea-Doo XP 785, or a typical spring-loaded bicycle seat post for that matter) and spring-loaded handlebar columns (remember the SnoBug?). Yes, they could forget all about the complex issues of rear suspension coupling, weight transfer management, track tension and all the other stuff that has surely caused more than one engineer to develop premature grey hair over the years. What you would have then, in theory, is the same level of rider comfort as you do now but absolutely no control on anything other than table-top smooth trails. This also leads us to the second function of a suspension system: to ensure component durability and longevity. Imagine if you will just how long our fictitious suspended seat prototype would stay together if traversing bumpy terrain. Answer? Not long! Suffice to say you would be losing parts in no time.

Finally, and not to demean its value and importance, the last key function is to provide comfort. It just so happens that an effective suspension that performs its first two tasks well will also, almost as an indirect benefit, isolate the rider from the irregularities of the road/trail/terrain.

Terminology

Now that we have clearly established just what it is that a suspension is designed to do, we will explain some of the key concepts (in a snowmobiling context) involved in understanding how it goes about achieving these functions.

Camber: A term that applies to the front suspension, it is the angle at which the front suspension spindle meets the trail when viewed from directly in front or behind the sled. The affect of camber angle is somewhat less important on a snowmobile than on most other vehicles due to the design of the runners. Camber angle is usually non-adjustable although some oval racers (on ice), for example, will modify it in search of particular cornering behaviour.

Caster: A term that applies to the front suspension, it is the angle at which the front suspension spindle meets the trail when viewed from the side of the sled. Caster angle is critical in determining a sled's straight line stability and how quickly it responds to steering input. The closer to vertical (or perpendicular to the trail) the spindle is set, the more quickly the sled will respond to input and the less stable it will be in a straight-line (will have less of a self-straightening tendency). To help understand it better, think of a bicycle with a raked out front end and how difficult it is to turn. Caster angle is also typically non-adjustable (although it may vary over a suspension's travel).

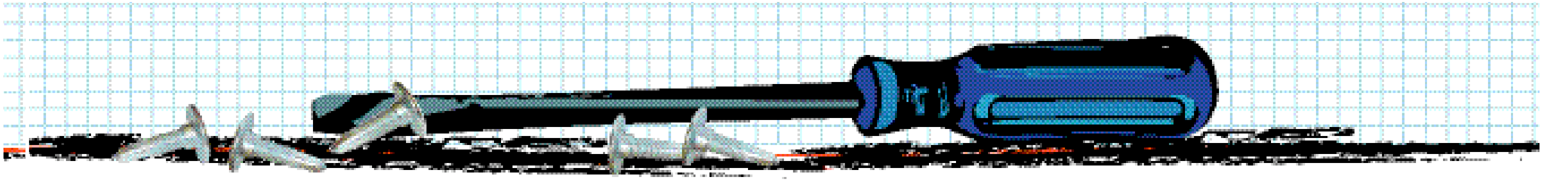
Toe-in/toe-out: A term that applies to the front suspension, it is the distance out of parallel that the skis are set to. In the case of toe-in, the tips of the skis are pointing inwards towards each other and in the case of toe-out, the skis tips are pointing outwards away from each other. With very few exceptions, toe-out is the preferred setting as it gives the vehicle stability in a straight-line and helps to provide slightly quicker initial turn-in when cornering. This can be set on modern snowmobiles by adjusting the steering rods.

Scrub: A term that applies to the front suspension, it is the change in ski stance experienced in a front suspension as it compresses. For example, if your ski stance at rest is 42" yet grows to 43" when the suspension is fully compressed, you have 1" of scrub. While in and of itself scrub is not necessarily bad, it can create a situation known as "bump steer".

Bump steer: A term that applies to the front suspension, it is a situation created when the relative position of the skis to each other changes as a result of the compression of the suspension. Bump steer is undesirable as it typically creates instability. To help illustrate, imagine hitting a bump in the middle of a corner which would cause the skis' parallelism to change dramatically. In this instance, both skis would be attempting to carve a different arc through the corner, hardly a desirable situation.

Coupling: A term that applies to the rear suspension, it refers to the practice (or phenomenon) of having both the front and rear of the suspension working as a unit, effectively creating a parallelogram if you will. This factor has become critically important in this age of long-travel suspensions as it is an essential tool in determining weight transfer and comfort.

Dynamic transfer: A term that applies to the rear suspension, it is essentially a torque effect produced by the accelerating track. It is a reaction in which the front arm of the suspension attempts to extend. It can be felt by the rider as a tendency to lift the front of the sled. The actual



amplitude of this effect is determined by the suspension's components and geometry as the shorter and more angled the front arm is, the more acute this effect will be.

Approach angle (track): A term that applies to the rear suspension, it refers to the angle at which the track meets the rails at the front of the suspension. In recent years there has been a pronounced tendency for the approach angles to become more gradual as it helps to reduce friction and, in the case of mountain sleds, is an important factor in determining how easily a sled "climbs on top" of the snow.

Progression curve: A term that applies to any suspension and refers to the ratio that exists between the rate of compression of the actual suspension and shock(s) and/or spring(s) that regulate its movement. It is worth nothing in the case where the shock and spring are a single unit (coil spring equipped shock) the shock and spring progression curves will be the same but in cases where the two components are separate, the curves may differ, sometimes substantially. Also, with very few exceptions, the progression curve is not static, that is to say it changes by some amount over the course of the travel. It can be progressive (also known as rising rate) in which case the suspension will compress the shock and/or spring at an ever-increasing rate as the suspension collapses (causing the suspension to become "stiffer"). Alternatively, it may also be regressive (or falling rate) which means that the compression of the shock and/or spring will occur at a decreasing rate (felt as the suspension becoming "softer"). Finally, the progression curve may be linear (changing at a constant rate) or non-linear (sometimes known as curvi-linear) in which case the curve will change at a changing rate. For example, a suspension could be relatively linear for the first portion of its travel then get dramatically stiffer as it approaches the end to guard against excessive bottoming.

Travel: A term that applies to any suspension and is essentially a measurement of the available stroke of the suspension from fully extended to fully compressed. While typically measured in a straight line (sometimes referred cynically as "true" travel), it can sometimes be measured in an arc, a practice which leads to higher numerical readings (and makes for great marketing hype)

Damping: A term that applies to any suspension, or more specifically to any shock absorber. It refers to the controlling or slowing down of a suspension's action by (typically) hydraulic means. Compression damping relates to the management of the rate of compression of a suspension (exists in both high-speed and low-speed types) and rebound damping to controlling the rate at which a suspension is made to extend by the spring after having been compressed.

Neutral steering: This expression is used to explain a vehicle's reaction to steering input. In the case of a vehicle described as having "neutral" steering, it means that the vehicle in question will react predictably and in commensurate manner with the amount of steering input being applied by the driver. "Oversteer" refers to a behaviour in which the vehicle reacts excessively to steering input. This is generally felt by the driver as an outward slide by the rear of the vehicle. The opposite condition, "understeering", relates to a vehicle's tendency to under-react to steering input. This is generally felt as a pushing of the front-end of the vehicle (or tendency to want to continue going straight despite steering input).

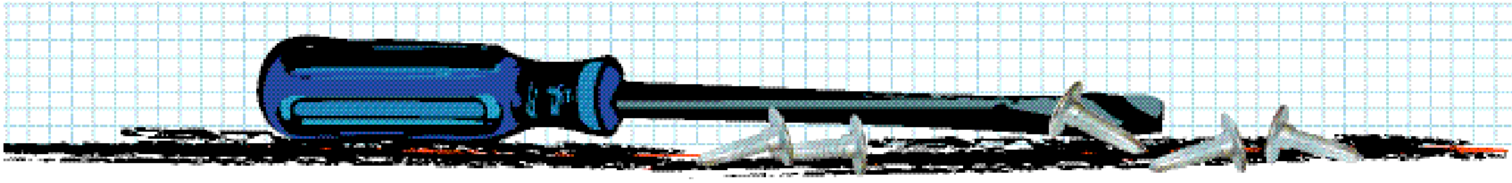
Spring rate: This term is a measure of the energy potential of a spring. It is typically expressed in units of force needed to compress it by a certain amount.

Coil spring: A type of spring made up of a wound section of wire. These are compressed in a vertical plane (collapsed top to bottom). They may be straight rate, meaning that the rate remains consistent over the travel of the spring. They can also be progressive which infers that the rate will become stiffer as the spring is compressed. Progression can be built into a spring by either using tapered wire (expensive) or by changing the pitch of the windings. The rate for coils springs is commonly expressed in either lbs/in or kg/mm.

Note how progression is achieved in this coil spring through the use of progressive windings at the upper extremity.

Torsion spring A variety of spring that exerts its force in a rotary fashion. These are anchored at both ends and the load causes one or both ends to move in either a clockwise or counter-clockwise manner causing the spring to compress. Rates are commonly expressed in lbs(or kg) per degree of rotation (or compression).

Spring pre-load: This is a measure of the energy stored into a spring. For example, a coil spring with a rate of 100 lbs/in that is "pre-loaded" a distance of one inch has a pre-load of 100 lbs. Explained differently, it means that the spring is exerting 100 lbs of pressure against its upper and lower mounts. It also means that a load of over 100 lbs will have to be placed on it before it begins to compress ("pre-load" must be overcome before compression can begin).



Two methods used for setting pre-load on coil springs.

Sprung weight: This expression is used to describe weight that is supported by a spring. Generally, any weight that is located "up-line" from the spring is considered to be "sprung weight". Consequently, "unsprung weight" is, logically enough, weight that is not supported by a spring, or any mass that is "down-line" from the spring, or put differently, that is located between the spring and the ground. To help illustrate the difference, the ski is unsprung weight while the engine is sprung weight. Unsprung weight is undesirable as it slows suspension reaction due to inertia (to better understand think of trying to move both a bowling ball and a basketball quickly). This explains why engineers usually make a concerted effort to lighten "unsprung components" as much as possible.

Static sag: This is a measure of the amount of suspension travel used up by the weight of the sled (with or without driver) while the sled is stationary. This factor has taken on greater importance in the modern age of long-travel suspensions since the sag is used to provide the suspension with some means of extending when encountering dips, for example, thereby keeping the chassis more stable.

Free length: When used in the context of a coil spring, it is a measure of its length when there is no load placed on it.

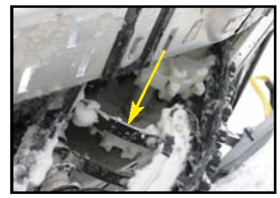
A-arm (or wishbone) suspension: This term applies to a front suspension design and refers to one which uses two triangulated arms anchored at the base and moving in a quasi-parallel fashion.

Trailing arm suspension: This refers to a front suspension type in which a long arm (trailing arm) is placed behind the shock actuation structure and is used to control the arc of movement.

Bottoming: This term refers to a condition that is produced when all of a suspension's travel has been used up due to an excessive load being placed on it (either static load or the encountering of a bump, for example).

Sway bar: This applies to the front suspension and is a mechanism which is used to link the action of the front suspension units on both sides of the sled. It effect, it is a torsion rod (spring) which helps to channel the load from one side to the other. It is used to stabilize the vehicle in bumps and during cornering. These may be linear, progressive or regressive in effect depending on the characteristics sought by the suspension's designers.

Limiter strap: The component located on the front arm of the rear suspension that allows you to limit its stroke. Essentially, shortening the strap shortens the stroke by limiting full extension of the front part of the suspension. At the same time, it also tends to shift weight onto the front of the sled by reducing pressure at the front of the rear suspension.



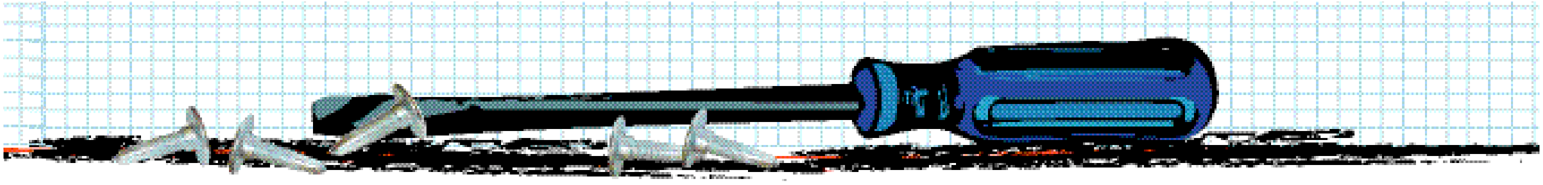
Snowmobiling's unique demands

As we all know, snowmobiling is a business. All romantic notions aside, this means that the manufacturers are in it to make money, pure and simple. In light of this, then, why are snowmobile suspensions so complex? For one simple reason: they have to be. In effect, moreso than virtually any other vehicle, snowmobiles must be adaptable to wide range of operating conditions and unpredictable environments. While your car's operating theatre may change from pavement to gravel (not much of a stretch really), your snowmobile may run on firm and hard trails in the morning, slush and loose, granular snow in the afternoon, and deep powder in the evening. Throw in some bumps and maybe a passenger for good measure and you begin to get an idea of what snowmobile suspension engineers are up against.

Things get even trickier when you look at the rear suspension in particular. While the front suspension must control the skis, their attributes, while not identical, are relatively close to those of wheels (think cars, motorcycles, ATV,...). The rear suspension, on the other hand, must deal with a track, a traction medium with a sizeable length and massive contact patch (surface area). That alone makes it unique. Consider as well the need to maintain track tension constant while all of this other stuff is going on. Not so easy huh?

Wait, it gets better. In addition to serving the purposes we discussed at the beginning of this article, the rear suspension is also responsible for managing weight distribution, and by extension weight transfer. This fact truly sets it apart from other vehicles and really complicates things.

To help understand this issue, remember that a snowmobile contacts the trail and thus exerts pressure at four points: the two skis, the front of the track, and the rear of the track. The rear suspension, by altering the pressure exerted at both the front and rear of the track, implicitly changes it on the skis as well. As you can logically ascertain, changing where the pressure is exerted can and does have dramatic effects on the sled's handling characteristics. Building a sled and rear suspension



combination that works in one set of narrowly-defined conditions is challenging enough, but building versatility into it such that it can competently handle the conditions cited earlier is some undertaking not for the faint of heart. Thankfully, there are some very talented people working on our behalf and the tremendous capabilities of modern snowmobiles are a testament and tribute to their hard work and ingenuity.

The trend to A-arms

Unless you've been living a sheltered life in the middle of an African jungle for the past ten years you can't help but notice that front suspension design has migrated to A-arms in the past few years. Surely there are reasons for this, especially since they are more expensive and technically demanding to build.

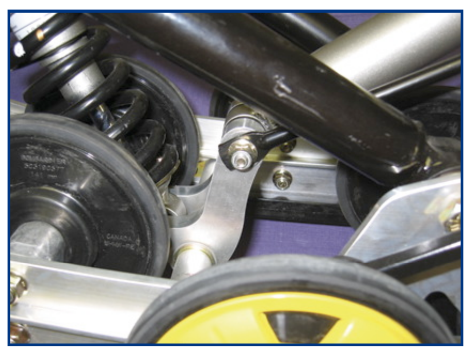
While some will try to sway you with talk of roll centers and other complex and abstract physics principles, the most obvious reasons are fairly easy to comprehend. To begin with, the predecessor of the A-arm suspension, the trailing-arm design, did a wonderful job in its own right. However, when encountering a bump, the fore-aft arc created by the trailing arm resulted in the spindle being "pushed" into the bump. To help understand, visualize a trailing arm suspension as it compresses. Notice how the spindle, in moving up, is also arcing in a forward direction, in essence being pushed directly into the path of the bump. If you are thinking at this time that this doesn't sound like an ideal scenario you are be correct.

The other reason has to do with the dynamic duo of friction and stiction. In the case of a trailing arm set-up, you have the arc formed by the path of the radius rods (equivalent to that made by the A-arms) but you also have the fore-aft arc made by the trailing arm. The resulting dual arcs make for a complicated motion that spells trouble for a rigidly mounted shock designed to travel in one plane only.

The impact of the rider-forward revolution

Now that all of the four major manufacturers have jumped on the rider-forward ergonomics bandwagon, it seems it is with us to stay. Of course, anyone who has ridden a sled with this ergonomic arrangement can attest to its superiority in the bumps and its contribution to sled handling in general. However, if you suspect that moving such a heavy element (the rider) has to have an effect on suspension design you are correct.

Whereas in the past, with so-called "traditional" ergonomics, the rear shock in the track suspension was largely responsible for setting rider comfort, moving the rider forward (virtually right over the front shock) has meant that the jobs descriptions have changed somewhat As you would expect, this means that the front shock now plays a much more important role in the rear suspension's role. It is no coincidence, then, that both Ski-Doo with its SC-4 and Yamaha with its latest second-generation Pro Active suspension (mounted in the new Phazers) have developed mechanisms to make the front track shocks work in a progressive (as opposed to their inherently regressive) fashion.



Ski-Doo's SC-4 rear suspension utilises a system of levers and a rocker to obtain progressive movement in the front shock's action.

Arctic Cat has joined the race too with the introduction of its new Sliding Action rear suspension which provides for movement in the, you guessed it, front arm.

Next month: We will be calling on the expertise and assistance of Coaticook-based suspension guru Robert Véroneau of Star Suspensions www.starsuspensions.com) to help us to set-up and troubleshoot the suspension on your sled. Concrete examples. Specific cases. A real hands-on article not to be missed!