

Development of Shock Absorbers for Snowmobile Racing

TANAKA Shin

1 Introduction

KYB Motorcycle Suspension (hereinafter "KMS") designs and manufactures shock absorbers (hereinafter "SA") for domestic and overseas motorcycle manufacturers. KMS also designs and manufactures shock absorbers for snowmobiles and ATVs and has been in business with BRP Inc.^{Note 1)} and BRP Finland Oy.^{Note 2)} over 30 years. They lineup snowmobiles called Ski-Doo and Lynx^{Note 3)} known as a major brands in North America and Nordic Countries and they gained to have a majority share of the global market in 2020.¹⁾ High-performance SA used in the high-end snowmobiles of both brands are designed and manufactured by KMS.

As snowmobiles have become technologically innovative, many state-of-the-art technologies have been reflected in their SAs. All of these technologies were originally developed for snowmobile racing and they can be found everywhere in today's mass-produced SAs for snowmobiles.

This paper introduces development of technologies that can be found in our high performance SAs.

Note 1) BRP Inc. originated with the invention of the first ever vehicle that can travel on snow by Joseph-Armand Bombardier at Valcourt in Quebec, Canada. L'Auto-Neige Bombardier Limité was established in 1942. In 1959, the Ski-Doo brand was born. In April 2003, Bombardier Inc. announced the sale of the Bombardier Recreational Products division.

Note 2) A forerunner of BRP Finland Oy was Nordtrac, which was the only snowmobile manufacturer in Nordic countries and became BRP Finland in 2005, it has continuously produced the Lynx brand. Lynx is still the only snowmobile brand in the Nordic countries.

Note 3) Ski-Doo and Lynx are the trademarks of BRP.

2 Snowmobiles Information

2.1 Vehicle Lineup

Snowmobile manufacturers offer a wide variety of vehicles that suit riders' preferences such as sport/utility models used as heavy duty work horses on snow, comfort-

able touring models, trail models for high-speed aggressive rides on groomed trails, crossover models that shine both on and off the trails, and deep snow models specifically designed for riding in the steep mountains covered with deep snow. Many package options are available for each model and industry's first semi-active SAs (KADS²⁾) can be selected as an option for high-end package of trail and crossover models in order to have advanced shock absorption, handling and stability control. Weight savings are critical for deep snow models so lightweight high-performance SAs are chosen to improve maneuverability in the mountain terrain with steep slopes. Characteristics of snowmobile SAs required in various riding conditions are shown in Fig. 1.

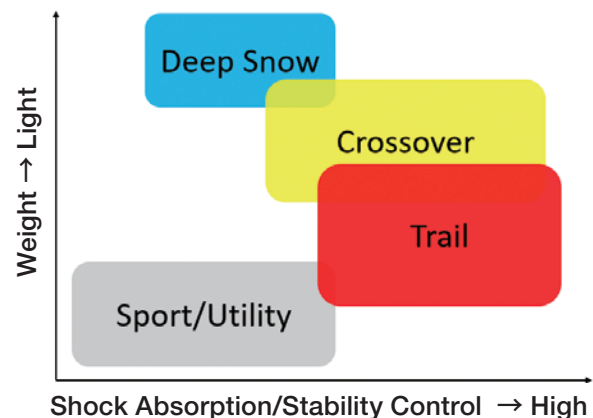


Fig. 1 Characteristics of snowmobile SAs for each models

2.2 Suspension design

Snowmobiles are quite different from motorcycles or ATVs because they have skis and track to be able to drive on the snow (Fig. 2).

The skis will float and steer a snowmobile to be able to be controlled by a handlebar on the snow. Generally, skis are suspended by double wishbone suspension. This design makes it possible to have a wider ski stance while ensuring longer suspension stroke in order to achieve higher steering stability. The right and left skis are both suspended by independent suspensions and front shocks are mounted on each side.

The track will make it drive forward on snow using its

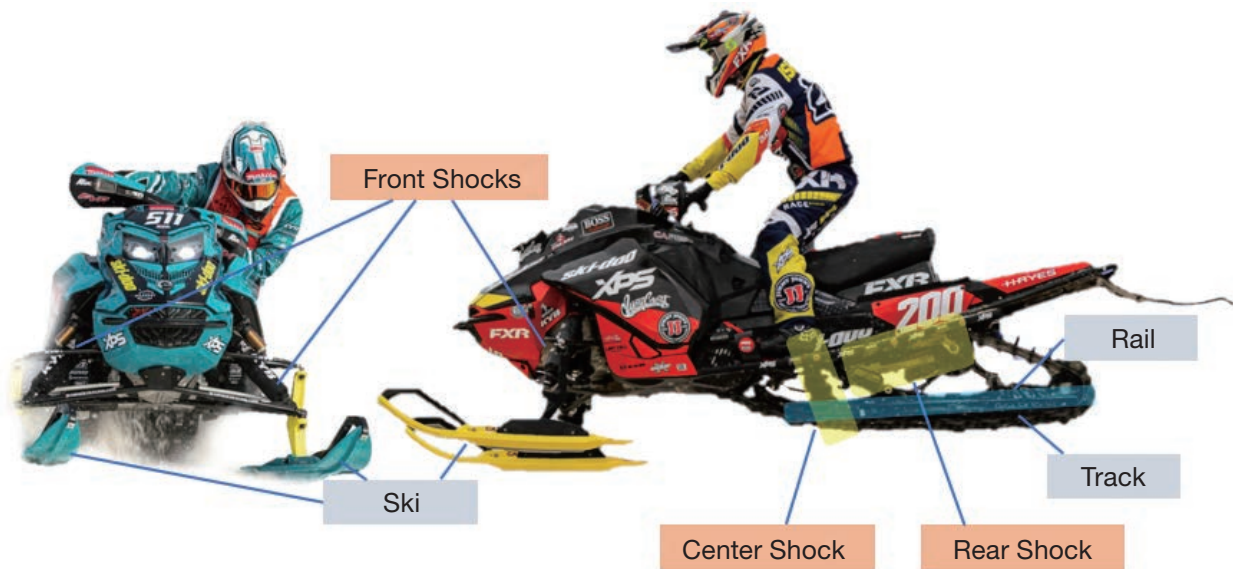


Fig. 2 Components of snowmobile suspension

lugs while keeping it floating on the snow by enlarging the contact area. There are many track styles that suit any riding conditions. Some have studs in order to have traction on hard, icy trail surfaces while some have longer lugs in the paddle form to be able to run on deep snow. Center and Rear Shocks will control the movement of the rail to keep the track in contact with rough, bumpy trails.

2.3 SA Structure

Snowmobiles are equipped with gas filled shock absorbers (hereinafter “Gas SA”) that use a steel or aluminum monotube cylinder as a standard package. (hereafter "gas SA"). All Gas SAs have Spring Preload adjuster but also some have Rebound adjuster to control Rebound Damping Force. (Fig. 3).

For the high-end package, Remote Gas SAs or Piggyback Gas SAs that have Base Valve with Compression Adjuster are equipped since much more shock absorption and stability controls are requested. (Figs. 3 and 4).

Regardless of which package they are used for, all SAs are using specially developed parts in order to be operated in specific environment conditions. The examples are in the following.

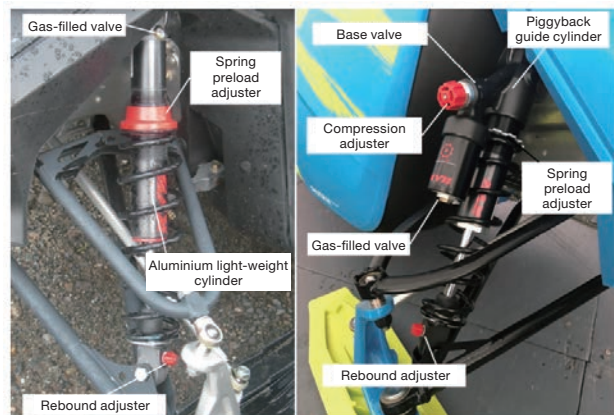


Fig. 3 Lightweight aluminium single cylinder gas SA (left) and piggyback gas SA (right)

- Ice scraper:
Integrated Ice Scraper in the seal head to scrape off frozen snow on Piston Rod surface (Fig. 5)
- Oil:
Specially formulated to ensure fluidity in freezing condition

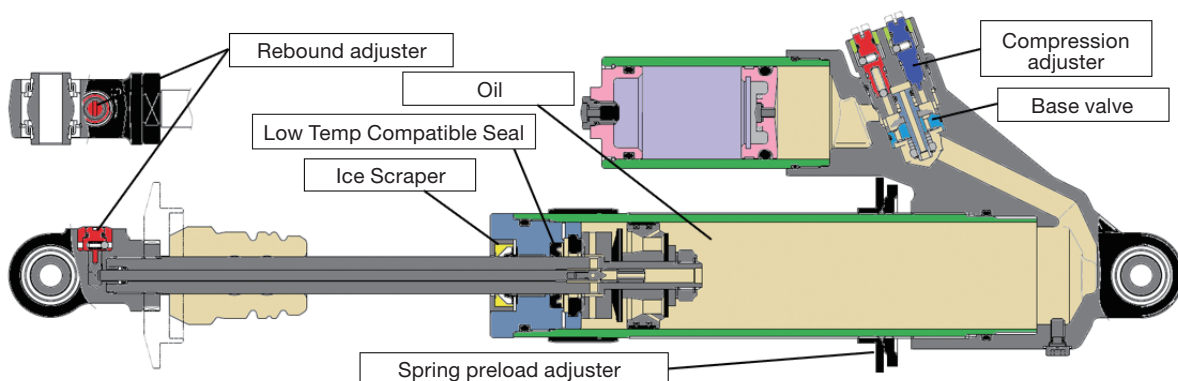


Fig. 4 Components of piggyback gas SA

- Low-temperature seal:
Carefully chosen seal material to keep Oil in SA in freezing condition

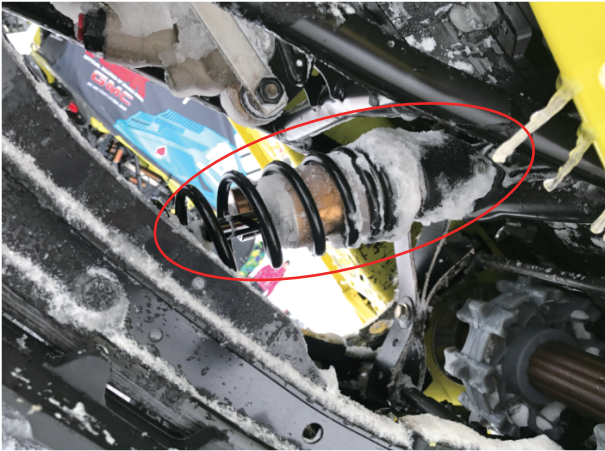


Fig. 5 Frozen ice covered Center Shock at the racing paddock

3 Types of Snowmobile Racing

There are various kinds of snowmobile races as in the case of other motorsports. The following describes major categories of snowmobile races.

3.1 Snowcross

Snowcross was derived from the sport of motocross. Like motocross, riders compete with each other on man-made racetracks with tight turns, banked corners, steep jumps and obstacles.

Today, Snowcross are held at many locations in North America and Nordic countries. Courses in North America include consecutive jumps and tight corners, thereby requiring harder braking and rapid acceleration. On the other hand, many of the courses in the Nordic countries make use of original natural terrains. Since these courses are usually wide, racers are likely to run at higher average speeds. The International Series of Champions (ISOC) Snocross, which are held around Great Lakes in North America, are participated in by famous competitors not only from North America but also from the Nordic countries. The world's premium race riders compete in a total of 17 races at eight racing venues every year vying with each other to clinch the championship title.

Both Ski-Doo and Lynx have lineups for the racing-ready snowmobile specific for Snowcross called 600RS that is only available for snowcross competitors (Figs. 6 and 7). They are developed based on Trail snowmobiles but equipped with a fine-tuned 600cc two-stroke engine and race-proven special suspension system.

KMS has been providing specially designed SAs called “Factory Shocks” to BRP Racing Department and joining BRP’s Racing program to develop better SAs by supporting them technically.



Fig. 6 Ski-Doo MXZx 600RS ^{Note 4)}



Fig. 7 Lynx Rave 600RS ^{Note 4)}

Note 4) MXZx, Rave and 600RS are trademarks of BRP Inc..

3.2 Hill Climb

Riders compete on how fast they can climb up ski slopes with specially modified Deep Snow snowmobiles. The most famous race is the World Championship Snowmobile Hill Climb that is held at Jackson Hole in March.

3.3 Cross-country

Competitors run a long distance toward a specified destination with the Crossover snowmobile like Dakar Rally. The most famous race is the Iron Dog in Alaska. Competitors race over 4,000 km in a week and may be required to ride on dirt, grass or skipping over frozen rivers.

3.4 Others

Oval racing competitors corner on icy oval racetracks at the highest speed with specially modified, lowered snowmobiles. Drag racing can record the highest speed on a short, straight course. Snowmobile racing is not only held in winter; Watercross is getting popular, competitors skip snowmobiles on a lake to race like snowcross.

4 Development of SA for Snowcross

The following are the major functions that are required specially for Snowcross SA.

4.1 Front Shock

To prevent rolling moment during high-speed cornering in order to keep skis in contact on the trail, Front Shocks need to provide a certain amount of damping force from lower piston speed range. In addition, Front Shocks have longer shock strokes to accommodate the larger gaps and jumps found on recent racetracks.

4.2 Center and Rear Shocks

Center and Rear Shocks will stabilize the snowmobile by controlling the rear suspension system and keep the rail tracks on bumpy racetracks. Center Shock attached to the front of the rail needs to be supple enough to help the rail to follow the rough track surface while maintaining a certain amount of Ski pressure to have good handling. However, it also needs to get stiffer to absorb energy to prevent harsh landing after jumping. Thus its damping force will have progressive characteristics that can generate less damping force at lower piston speed range but generate more damping force as it gets higher. Rear Shock is attached on the rear end of snowmobiles to control the vehicle pitching moment during acceleration and braking by providing a certain amount of damping force at lower piston speed balancing with Front Shocks. To provide higher damping force at a higher piston speed range to absorb landing impacts after jumps, it has the longest stroke than the other SAs. So it is essential to have higher rigidity construction to withstand its harsh use condition.

4.3 Adjuster

In Snowcross racing, competitors need to race all day for several rounds of races; qualifying in daytime and the final at nighttime. SAs need to have many kinds of adjusters in order to quickly adapt to any kinds of racetrack conditions because it changes depending on the weather moment to moment.

4.4 History of Development of SA for 600RS

4.4.1 Development in the Early 2000s

Before the 2000s, aluminum monotube Gas SAs were used because of its lightweight construction but they only used to have a rebound adjuster. In the early 2000s, riding style has drastically changed from old-school “sit-on seat” style to revolutionary “stand-up” style that suits modern racetracks. To adapt this, a new chassis; REV and front suspension system; RAS were developed. At that time, BRP requested to develop new Remote Gas SAs in order to improve shock absorption by adding Base Valve and



Fig. 8 Blair Morgan’s racing snowmobile built for X-Games in 2006

Compression Adjusters that can generate higher damping force (Figs. 8 and 9).



Fig. 9 Remote Reservoirs of Front Shocks were fixed in the hood

Later in 2004, piggyback Gas SAs were developed and introduced in all SAs years later by replacing Remote Gas SAs. To further improve shock absorption, the piston diameter got larger from 36 mm to 40 mm and rod diameter was also enlarged for higher strength and rigidity. These racing technologies developed and validated were later used in SAs for consumer models and they are still used in today’s SAs.

4.4.2 Development in recent years

For the Snocross Pro Open; premier class in Snocross, it had been permitted to modify engines, pipes and chassis of racing snowmobiles to gain performance. But in 2018, the regulations were revised to limit the modification. This gained even more attention on the development of the stock racing-ready snowmobile; 600RS. Particularly, improving the suspension performance was considered as a critical challenge to ride faster on modern racetracks.

To do so, suspension linkage mechanisms were fully redesigned and more performance improvements of SAs were strongly requested. As a result, peripheral parts for suspensions have been improved every year and SAs have also been improved every year from 2018.

Following technologies were originally developed for Snocross Factory Shocks and adapted for 600RS.

① Larger diameter piston for Center and Rear Shocks

As stated above, revision of regulations were taken as an opportunity to improve performance of the rear suspension system. Larger Diameter Pistons were already introduced for Factory Center and Rear shocks but evaluation swung into high gear to find good setups. Riders soon highly valued its stability and improved impact absorption performance to prevent harsh landing after big jumps. It was adapted for Center shock of 600RS MY2018 first and for Rear shock of MY2019 later.

② Integral adjuster

An integral adjuster, originally used for motocross racing shocks, was introduced for Factory shocks to be able to be fine-tuned to rider's preferences in a tight racing schedule. It made it possible to adjust high-speed rebound damping force quickly from outside that used to be hard to adjust via conventional adjusters and normally required re-valving (Fig. 10). The characteristics of the check valve were re-calibrated for Snocross after being introduced for Snocross. As a result, it will settle shock movements to maintain a good ride height when shock rebounds from a fully stroked position which gives better handling when riders enter corners right after a jump landing. It showed its value on the racetracks with many jumps and was more useful than conventional adjusters. Finally, it was adapted in all SAs from 600RS MY2020.

③ Larger diameter piston for front shocks

Since the larger diameter piston used for center and rear shocks had been highly valued as stated above, a request arose to apply it for front shocks as well. However, it was even harder for the front shocks because they had to be fit in a very limited space around them. To solve this, related parts needed to be redesigned from ground up. A brand new guide cylinder and bearing were designed and firstly used in 2018-2019 season (Fig. 11) They reduced rider's arms fatigue by absorbing landing impact after huge consecutive jumps and provided better stability that leads to great advantage during racing. Development was further continued to find good setup and the reliability was proved on racetracks. They firstly debut for 600RS MY2021 and also selected as production shocks for high-end Lynx Trail model (Fig. 12).

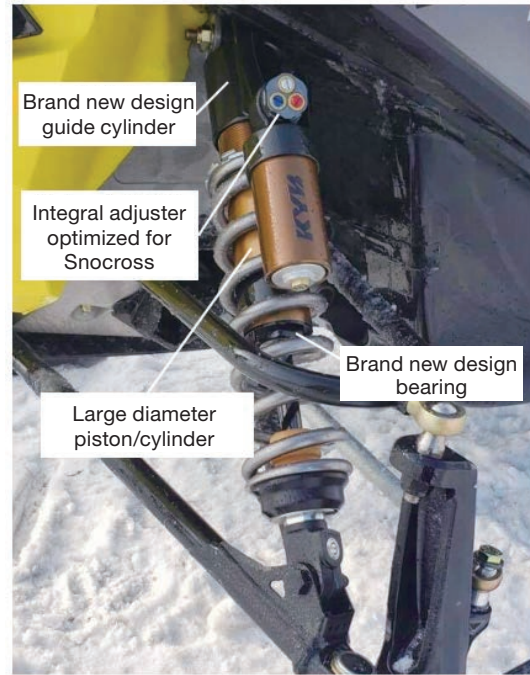


Fig. 11 A brand new Front shocks with large diameter piston debut in 2018-2019 season



Fig. 12 First production trail snowmobile adopted front shocks with large diameter piston

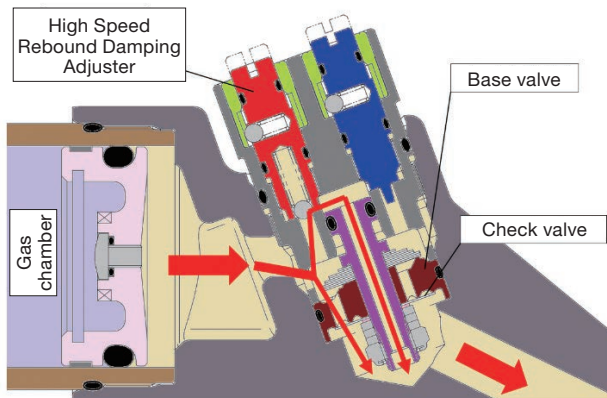


Fig. 10 Rebound Oil flows in the Integral Adjuster and High Speed Rebound Damping adjust circuit

4.4.3 Current Development

They are equipped with new technologies that are expected to be adopted for the next generation of SAs for 600RS and production shocks. Our technologies had already been verified by great racing results as follows.

5 Major Racing Results

2020-2021 Season

#200 Elias Ishoel

Three consecutive championship in Pro Class of ISOC Snocross (Fig. 13)

Won Race 1 and finished 6th overall in FIM Snocross World Championship 2021



Fig. 13 Elias Ishoel won the three consecutive championship along with our technicians; Tim (left) and Gilles (right)

6 In Closing

I would like to take this opportunity to thank all the engineers of BRP and BRP Finland who extended their cooperation into the development field as well as the technicians from Enzo Canada who have been joining our racing support program and provided technical support on our factory shocks for more than 20 years.

Author



TANAKA Shin

Joined the company in 2015.
Group 2, Design Sect. No.2,
Formerly engaged in design and development of motocross racing suspensions and later engaged in design and development of SAs for snowmobiles and ATVs

Finally, I would like to express my deep respect to our predecessors who were involved in the past development and brought those technologies of racing shocks into production that had built the foundation of today's technology and cordially thank all those from the internal related departments who extended their cooperation to us. I am committed to develop products that are even more attractive to riders all over the world and hopefully our latest technologies will be their advantage.

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