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MODIFYING MILITARY TIRES FOR IMPROVED WINTER TRACTION

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ABSTRACT

As a continuation of previous collaborative efforts between several US Army organizations and industry leaders which led to the procurement of a National Stock Number (NSN) for a near commercial-off-the-shelf winter tire/wheel assembly for the High Mobility Multipurpose Wheeled Vehicle (HMMWV), this study investigates a low-cost, postproduction modification known as 'siping' which may incrementally improve standard tires deployed on the Joint Light Tactical Vehicle (JLTV) in cold regions. Data from engineering tests will quantify performance differences as well as driver feedback from the 11th Airborne Division Soldiers in Alaska show moderate improvement from cutting razor-thin grooves known as 'sipes' on conventional winter tire sets. However, Army winter performance specifications developed in 2021 from HMMWV testing quantify greater available improvement to traction available, necessitating further development for winter traction in the JLTV family of tire sets as well as future procurements for additional Tactical Vehicles. Providing Soldiers with state-of-the-art winter tires which are effective at decreasing roll-over and other loss of control incidents increases safety and mobility in northern operations and is the objective of this research.

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1. INTRODUCTION

1.1. Objective

In 2021, a new set of US Army specifications was developed for winter tires which enabled procurement of commercial-off-the-shelf (COTS) tires for the High Mobility Multipurpose Wheeled Vehicle (HMMWV) family of Light Tactical Vehicles (LTV). This effort led to a 93% improvement in longitudinal traction on snow and subsequently the assignment of a National Stock Number (NSN) for a near COTS winter tire for the HMMWV. [1] As a continuation of those efforts, modifying standard JLTV tires by cutting sipe patterns into the tread blocks are investigated as a low cost, postproduction method to increasing traction on winter surfaces.

1.2. The Importance of Winter Operations

Mobility in northern winter climates has been the deciding factor in many wars throughout history. Although the presiding examples for the last century have predominately been of well-known World War II failures or even earlier, these examples do not show a modern battlefield with modern vehicles or understanding of modern maneuvering tactics.

However, perhaps the most remindful of the importance of winter mobility has been none other than the stark failure of the Russian invasion of Ukraine in February 2022. Countless videos and photos show combat and logistics vehicles stuck in snow, ice, and perhaps most prevalently, thawing transition season soils. Convoys stretching miles were blocked by stuck vehicles and left vulnerable to rocket attack. [2]

Why did so many vehicles get stuck, experience mechanical failures, or simply end up waiting on the road for fuel? These are questions that must be answered both through technical examination as well as operational planning. For the purposes of this study, the example serves to remind us of the importance of investigating

Figure 1: Russian Logistics Stuck in Snow (AP News)

improvements to the US Army's winter mobility at every level of detail.

The United States as part of its new Artic Strategy began looking at key gaps in mobile superiority in northern regions several years ago, as concerns grew that its adversaries were gaining a technological and therefore territorial edge when or where temperatures dropped below freezing. [3]

1.3. Winter Tires for the JLTV

The Joint-Light-Tactical-Vehicle (JLTV) is the direct successor to the mass-produced High Mobility Multipurpose Wheeled Vehicle (HMMWV) in the Light Tactical Vehicle (LTV) family. Approved for full scale production and deployment in 2019, around 1700 JLTVs have been delivered and just under 20,000 JLTVs have been ordered. [4]

The JLTV was designed at a time when the United States was primarily engaged in desert warfare. It therefore has many considerations for operation in that environment and less considerations for the Artic. It is not intended to traverse excessively deep snow. However, as the Army's new predominant wheeled LTV, it is deployed in cold regions such as Alaska to provide armored mechanized squad and payload support and therefore operates on both on and off terrain there in subzero conditions described the Army Regulation 70-38 (US Army, 2020) [5].

Much of US Army Alaska's (USARAK) vehicular movement in Alaska is over snow and ice covered paved or dirt roads. These roads are plowed and therefore present as a

Figure 2: JLTV On Hard Pack Snow in Alaska

slippery hard surface without substantial snow depth. Because temperatures in this region rarely reach above freezing during wintertime, the roads particularly in Alaska will be partially or completely covered in a snow and ice layer. Alaska can be frozen for over six months and ice-covered roads are often the norm since road salt is ineffective for usage below 0F (the freezing point of saturated salt water).

In northern climates such as North Atlantic Treaty Organization (NATO) held territories or even the northern continental United States, JLTVs operators are expected to drive to their destinations on paved and unpaved surfaces throughout the year, where the roads may be slushy or partial snow cover during active weather conditions. These conditions are parallel to what standard consumer vehicles will drive during daily commuting. Consumer vehicles have access to a broad array of available winter tires with the Three Peak Mountain Snowflake (3PMS) rating, which is an industry rating that designates tires as performance tested and capable on winter surfaces. The 3PMS snowflake rating is useful to identify COTS solutions in the consumer market which the Army could make use of, and it is worth pointing out the standard JLTV tires sets are based on mud and sand 'NATO style' tread block patterns, and all-season military rubber compounds not assigned with a 3PMS rating as in the COTS market. The tread patterns evaluated in this research are the standard legacy XZL, siped XZL, and newer design X FORCE and siped X FORCE patterns of 365/80R20 tires. A unit issued set of standard XZL tires and new set of siped XZL tires were tested in Alaska in 2022 as a preliminary test. New sets of all four tire and tread combinations were then tested in Michigan in 2023. The standard JLTV tire treadblock pattern is pictured in Figure 3. For proprietary reasons the specific sipe pattern used during this testing cannot be shown.


Figure 3: Standard Unsiped JLTV Treadblock

2. APPROACH

2.1. Experiments at CRTC, Alaska and KRC, Michigan

The standard JLTV tire/wheel assembly is a 365/80R20 size assembly which contains a runflat and Central Tire Inflation System (CTIS) wheel valve. The JLTV is meant to operate at different tire pressures depending on the surface, road conditions and payload parameters, and is user selectable.

When running in slow off-road conditions, the user may place the vehicle into either Cross Country (CC) or Mud/Sand/Snow (MSS) settings which substantially lower tire pressures and increase the tire contact patch. When running on road, or when it approaches a high enough speed, the JLTV operates in Highway (HWY) mode, which inflates the tires to their highest available level for cooler running and optimized fuel economy. This is dependent on payload, but typically around 46 psi.

Because of feedback from military commanders, the objective of this experimental setup was to test primarily at Highway (HWY) settings where the most on-road accidents are occurring. Most on-road incidents have reported to be at high speed (25+ mph), and while maneuvering or braking into slippery turns or over poorly cambered roadways.

Using prepared surfaces at the Cold Regions Test Center at Fort Greely in Delta Junction, Alaska and the Keweenaw Research Center in Hancock, Michigan, engineering tests for both longitudinal and lateral traction were conducted on packed snow, and ice.

Figure 4: Drawbar Pull Testing with JLTV

The engineering tests consisted of Hard Surface Rolling Resistance (HSRR), Motion Resistance (MR), and Drawbar Pull (DBP) to measure longitudinal tractive force. A detailed overview of these tests and derivation of their calculable results is available by the authors of this study in previous proceedings [1].

Straight line accelerations were measured in standard straight line full throttle and full braking tests.

To measure lateral accelerations, a circle break-out test was performed on a spin pad.

2.2. Gathering Feedback from the 11th Airborne Division, US Army Alaska

Soldiers from 11th Airborne Division (ABN DIV) stationed at Ft. Wainwright were invited to attend testing conducted by researchers from the Cold Regions Research & Engineering Laboratory (CRREL). CRREL is one of seven research laboratories operated by the United States Army Corps of Engineers and the only research organization in the Department of Defense (DoD) wholly dedicated to research and development in cold climates. Testing in Alaska was conducted using two JLTVs owned by 11th ABN DIV which were transported to the United States Cold Region Test Center (CRTC) in Delta Junction, Alaska.

The team of Soldiers included six personnel who had all prior experience driving JLTVs as part of their normal duties.

After initial training from CRREL engineers, the soldiers performed the specified tests which constitute the data reported for all tests which were conducted in Alaska. This is in contrast with the data which was taken in Michigan with very experienced test drivers operating the vehicles.

In addition to the engineering tests, the soldiers also performed slalom maneuvers and several laps on each tire set of a preplanned route over snow, ice, and pavement.

Subjective feedback was collected from the soldiers to qualify their opinions on the tire sets after being able to directly compare them on snow and ice surfaces and through the various tests.

2.3. Vehicle Instrumentation

The four door General Purpose JLTV variant was used for all testing in both Alaska and Michigan.

All JLTVs feature CANBUS which is the electronic system protocol responsible for transferring information between sensors, controls, and other important electronics consisting of the vehicle's computer (ECU) network. The ECU therefore becomes responsible for monitoring and issuing commands relevant to such parameters as vehicle speed, accelerations, brake pressure, engine speeds, fuel-air sensors, payload sensors, and so on.

Engineers at CRREL used data from the vehicle's CANBUS simultaneously with an external logger, GPS, and Inertial Measuring Unit (IMU). This allowed the time-synced capture of the following parameters of interest:

1.) Individual Wheel Speeds
2.) External Load Cell to Measure Hard Surface Rolling Resistance, Drawbar Pull, and Motion Resistance
3.) Pitch, Roll, Yaw Orientations and Rates
4.) Lateral and Longitudinal Accelerations
5.) GPS Vehicle Speed
6.) Brake Input
7.) Throttle Input
8.) Steering Angle
9.) Vehicle Traction Control States

3. RESULTS

3.1. Hard Surface Rolling Resistance

As cutting sipes into the tires does not change the footprint of the tire the rolling resistance is seen to be similar between the two sets, with no visible difference on pavement between the tire sets. Changing the footprint, rubber compound, or otherwise the overall dimension of the tire can positively or negatively impact the resistance when rolling on a hard surface, leading to changes in fuel economy.

3.2. Longitudinal Traction Performance

Overall, mixed to modest improvements were seen in longitudinal traction ranging from -3% to 33% improvement between standard and siped XZL and X FORCE tires respectively during testing in Michigan, and 18% improvement between standard and siped XZL tires during testing in Alaska. The siped X FORCE tires only marginally outperformed the siped XZL tires in gross traction at 4% average over testing on packed snow.

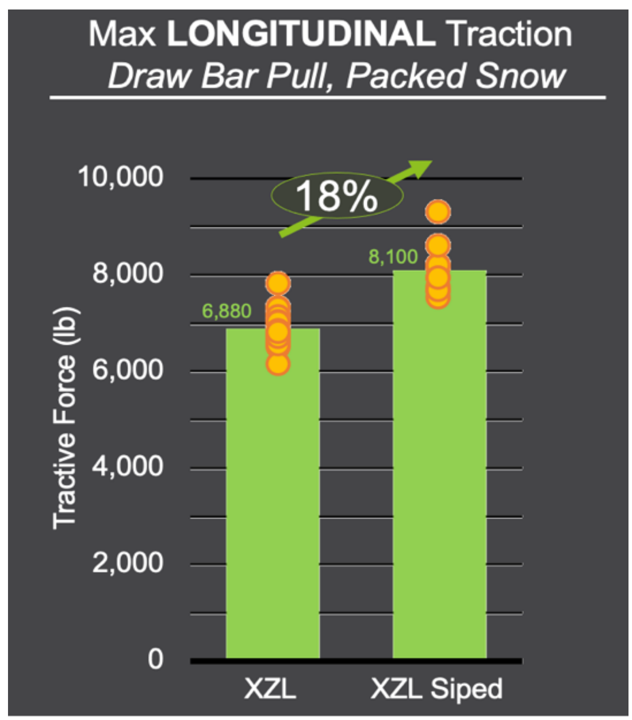

Figure 5: Drawbar Pull Results from Alaska

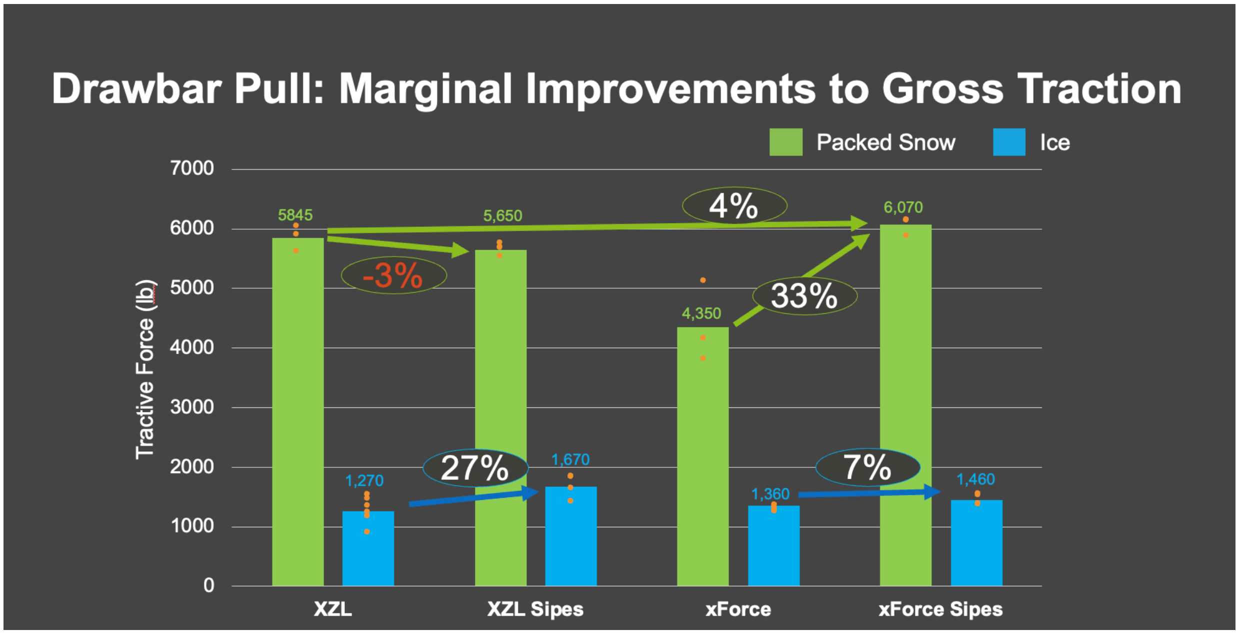

Figure 6: Drawbar Pull Results from KRC, Michigan

It is important to note from Figure 7 that the sustained traction during slip events is consistently higher for the tires with sipes. This indicates the siped tires provide better control during slip events, as more traction is available to the driver for more time.

Drawbar pull is a constant-speed continuous slip test designed to measure traction on various surfaces according to SAE J2914 [6] similar to measurement techniques conducted on a single tire. [7].

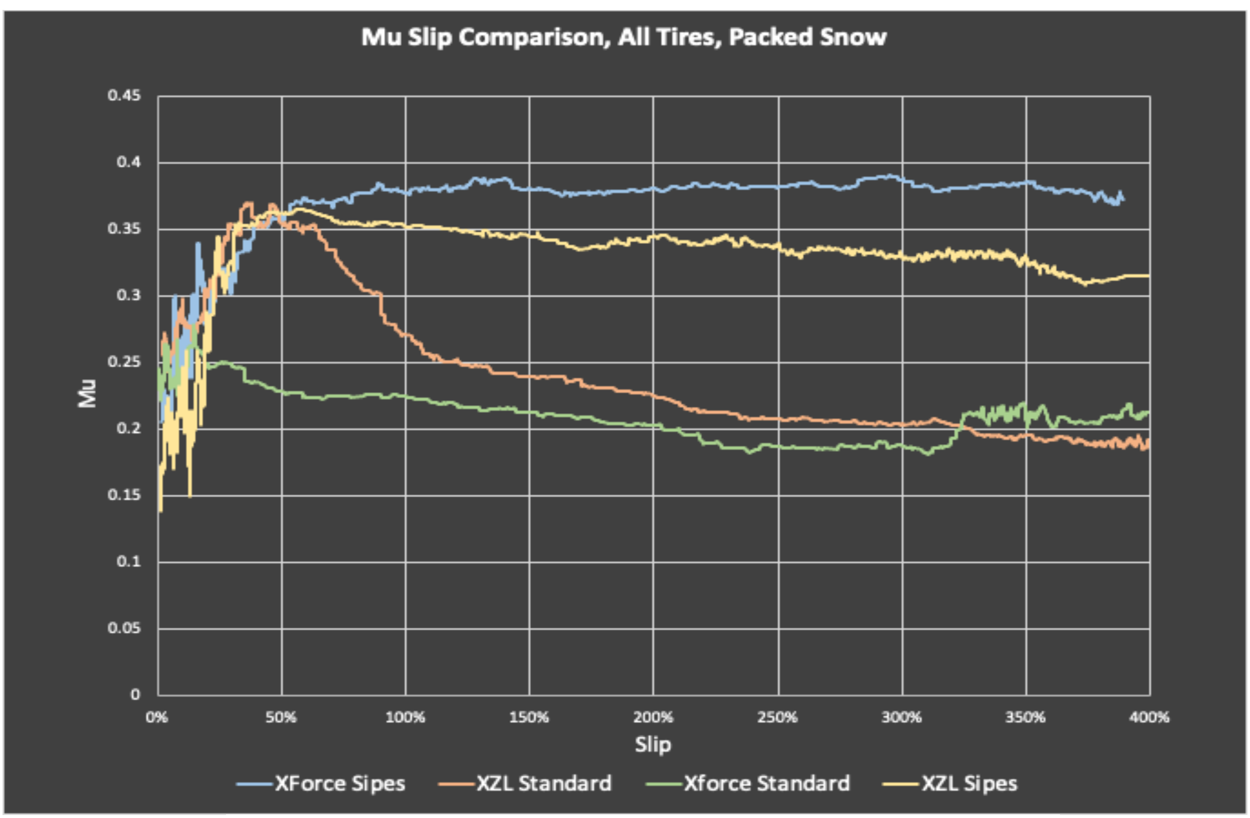

Figure 7: Sample Traction Mu Slip Plot, High Values Represent More Traction

3.3. Lateral Traction Performance

Mixed performance results are reported for lateral traction, where improvement during testing in Alaska was found to be 3-5% and 5-36% in Michigan on packed snow surfaces. Similar to the longitudinal tests the siped xForce tire performance was indistinguishable from the siped XZL tires.

Conversely on ice, there was a noticeable performance decrease when switching to the siped tire sets. This may be accounted for by the lack of lateral siping on the test tires. It is therefore considered that this negative performance may be improved before a final design for siping would be shipped for deployment.

Lateral traction was measured using a Circle Breakout (CBO) test. The CBO is conducted using a fixed radius circle with cones on the surface of interest. The driver is instructed to maintain a constant steering angle around the circle while slowly increasing the speed of the vehicle until it no it longer maintains a controllable constant radius and begins to skid, 'breaking out' of the circle.

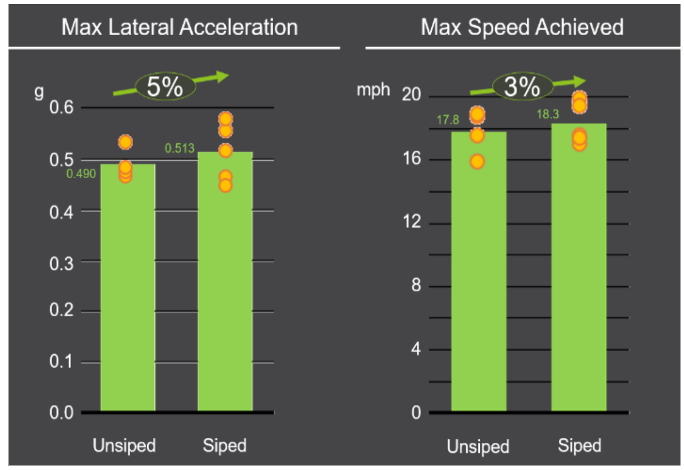

Figure 8: Circle Breakout Results from Alaska

The CBO test primarily compares lateral acceleration and top speed as metrics for tire performance.

3.4. Soldier Touchpoint and Driver Feedback

Soldiers reported with overall optimism that the siped XZL tire sets performed better and were more controllable than the standard

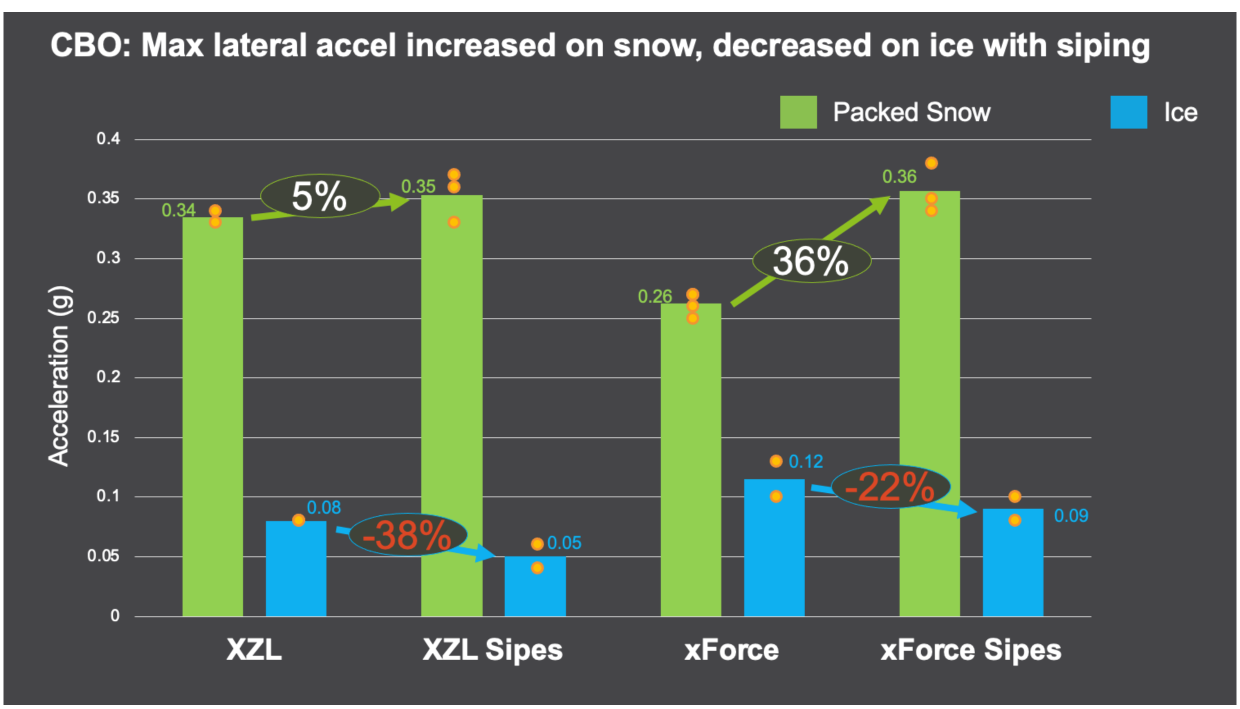

Figure 9: Circle Breakout Results from KRC, Michigan

XZL tire sets, particularly under periods of acceleration or braking. When directly compared with the HMMWV tire sets the soldiers reported a much larger difference and better control with the HMMWV winter tires than was felt comparing the JLTV standard vs. siped XZL tire sets. Soldier feedback was not available for the 2023 testing in Michigan.

3.5. Conclusion and Future

Although siping produces measurable improvement and feedback is overall positive about increased vehicle control, the requirements specified by the Army for winter tire performance demand more improvement, especially in lateral traction where control may be most apt to be lost. Lateral traction is important in cold weather driving because it is the force which keeps the vehicle pointed where the operator is attempting to steer. As many rollover incidents occur on corners or while sliding out under braking, it is imperative that the upgrades provide substantial improvement in the key area of lateral traction.

In addition to conventional two-dimensional post-production cut siping of non-winter military tires, the adoption of a more traditional winter type tire (tread of winter design with a cold temperature rated compound, etc.) would likely significantly improve both the lateral and longitudinal performance. Copious modern molded-in three-dimensional (3D) interlocking wave-siping geometry variations (in circumferential, lateral, & diagonal directions) could provide further improved winter traction. Moreover, 'Self-regenerating' tread utilizing grooves with hidden 3D raindrop geometry cross-section void features at-depth that evolve and manifest as the tire wears would better maintain tread-void volume over the tire's lifecycle and would be especially beneficial for higher-wear rate softer-durometer winter tread compounds.

It should be noted that for the before-mentioned technologies, more comprehensive developmental testing would have to be done to iteratively optimize an integrated design and to also confirm the contributing incremental efficacy of each item.

4. REFERENCES

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