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COMPOSITE RUBBER TRACK TRIAL RESULTS FOR WARRIOR IFV

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ABSTRACT

Tracked vehicles are known to provide excellent off-road mobility, but traditional steel tracks do come with some important compromises. The recent introduction of Composite Rubber Tracks (CRT) on the CV90 IFV (77,000 lb) has shown that this robust and operationally proven CRT technology significantly reduces the vehicle weight, fuel consumption, noise, and vibration levels. Inspired by this new enthusiasm for tracked vehicles, provided by CRT, armies and original vehicle manufacturers initiated a series of independent trials confirming the benefits and reliability of CRT. The author's objective is to present the conclusions of these independent CRT trials, more specifically focusing on the Warrior IFV, providing substantiation data on how CRT technology enhances tracked vehicle performance.

INTRODUCTION

The current CRT technology is TRL7 at up to 14,000 lb per road wheel station (i.e.: GVW of 85,000 lb to 100,000 lb. depending on 6 or 7 road wheel stations) and rapidly increasing at a steady pace.

Armoured Trials and Development Unit (ATDU) conducted a private venture trial on behalf of Soucy Defense, sponsored by the Head of Capability – Ground Manoeuvre. The trial aim was to build United Kingdom Ministry of Defense (UK MoD) confidence in Composite Rubber Track (CRT) technology by validating manufacturer performance claims, in order to inform future Armoured Vehicle Programme (APV) capability decision.

The Composite Rubber Track System has been tested on the Warrior variant 510 vehicle (60,000 lb) at ATDU in UK from September to December 2017.

CONVERSION AND WEIGHT SAVINGS

Specializing in providing engineered track kit solutions, Soucy Defense delivered a turnkey track conversion kit for the Warrior IFV to the ATDU of the UK MoD, in the summer of 2017. This tailored kit, which required no intrusive work to the vehicle, comprised of the CRTs and all associated components (sprockets, idler wheels, road wheels, etc.). The CRT kit allowed a direct weight savings of 3,306 lb, confirmed by placing the vehicle on a weight bridge, before and after the conversion. Considering a Warrior IFV has an average Gross Vehicle Weight (GVW) of 66,000 lb, this represents a 5.0% GVW reduction, which is a typical impact of CRT conversion.

BUOYANCY

The CRT is 50% lighter than the current in-service steel tracks. Furthermore, the CRT is 79% lighter than steel track when submerged in water. This will increase the overall vehicle buoyancy by roughly 5,220 lb-f when submerged in fresh water.

$$Submerged\ track\ weight = Track\ weight * (1 - \frac{Water\ density}{Track\ density})$$

Assuming T157i Steel Track

- Weight: 1792 kg (3,950 lb)
- Density: 6207 kg/m^3 (387.5 lb/ft^3)

T157I Holistic Density
weight in water = 1503 kg (3,313 lb)

Composite Rubber Track

- Weight: 896 kg (1,975 lb)
- Density: 1552 kg/m^3 (96.90 lb/ft^3)

CRT Holistic Density
weight in water = 319 kg (703 lb)

Buoyancy
(3,313 lb – 703 lb) * 2 Tracks = 5220 lb-f

FUEL CONSUMPTION AND VEHICLE RANGE

With the help of fuel consumption tests over the course of the 3,107 mile trial, ATDU observed a fuel consumption reduction of 16% on road and 24% on cross-country (see Figure 1). Fuel readings were taken at the start of each terrain type test and calculated at the end to determine the amount of fuel used during that period.

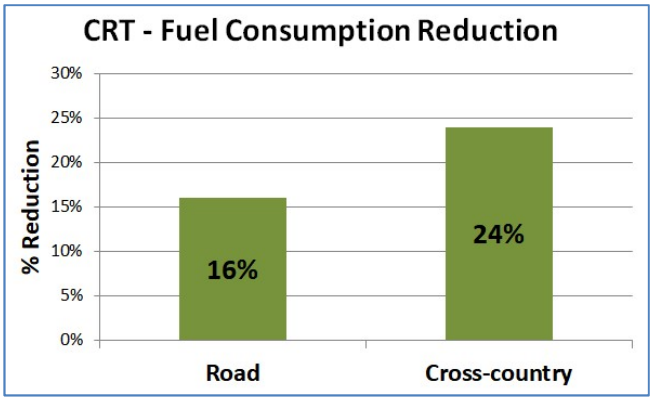


Figure 1: Fuel Consumption Reduction

This represents a vehicle range increase of 19% and 31% respectively (see Figure 2 and 3). The compounding effect of consuming fuel more efficiently (reduces fuel required, leaving "extra" fuel in tank) and consuming remaining fuel in tank more efficiently produces further enhanced vehicle range.

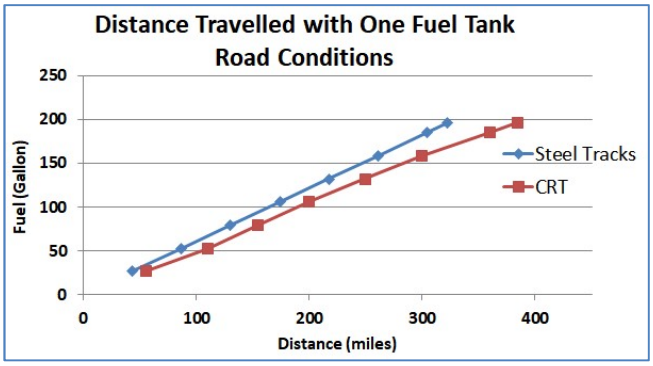


Figure 2: Vehicle Range – Road conditions

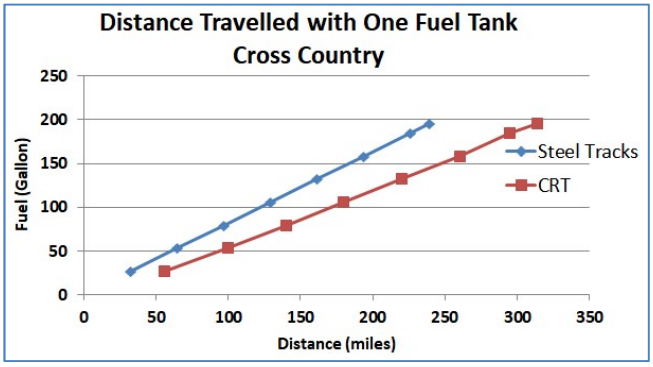


Figure 3: Vehicle Range – Cross country

Assuming 25% road and 75% cross-country, this allowed the vehicle range to increase from 260 mile with steel tracks, to 332 mile on CRT (+28%).

Steel track – Vehicle Range		
322 mi	25% Road	81 mi
239 mi	75% Cross-country	179 mi
		260 mi (1.3 mile/gallon)
CRT – Vehicle Range		
384 mi	25% Road	96 mi
314 mi	75% Cross-country	236 mi
		332 mi (1.66 mile/gallon)

For the design of a new vehicle, assuming a preserved vehicle range of 260 mile, this represents a potential weight reduction of 300 lb in fuel (43 gallon), bringing the total GVW reduction to 3,606 lb (5.5% of average Warrior IFV GVW).

NOISE REDUCTION

"A" Frequency Weighting

This is a standard weighting of the audible frequencies designed to reflect the response of the human ear to noise. At low and high frequencies, the human ear is not very sensitive, but between 500 Hz and 6 kHz the ear is much more sensitive.

The "A" weighting filter covers the full frequency range of 20 Hz to 20 kHz, but the shape approximates to the frequency sensitivity of the human ear. So the "A" weighted value of a noise source is an approximation to how the human ear perceives the noise. Measurements made using "A" weighting are usually shown with dB(A).

"C" Frequency Weighting

The "C" weighting is a standard weighting of the audible frequencies commonly used for the measurement of Peak Sound Pressure level. Measurements made using "C" weighting are usually shown with dB(C).

CRT noise levels, in the Warrior IFV, measured (by an independent firm in December 2017 and January 2018 – See Reference 2) in the crew station with hatches opened at 31 mph on road showed a reduction of 10 dB(A) to 14 dB(A), compared to the original steel tracks.

In cross-country, for speeds between 9 mph and 12 mph, the noise reduction in the crew station was measured to be 6 dB(A) to 7 dB(A), regardless of hatches opened or closed (see Figure 4 and 5).

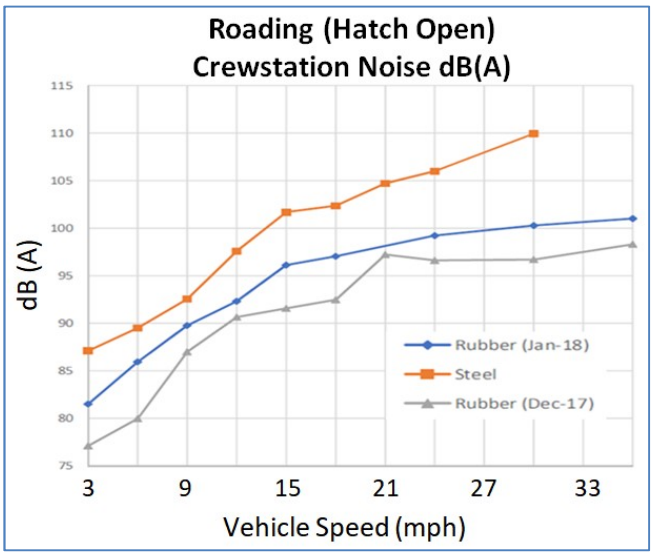


Figure 4: Noise reduction Crewstation – Roading (Hatch Open)

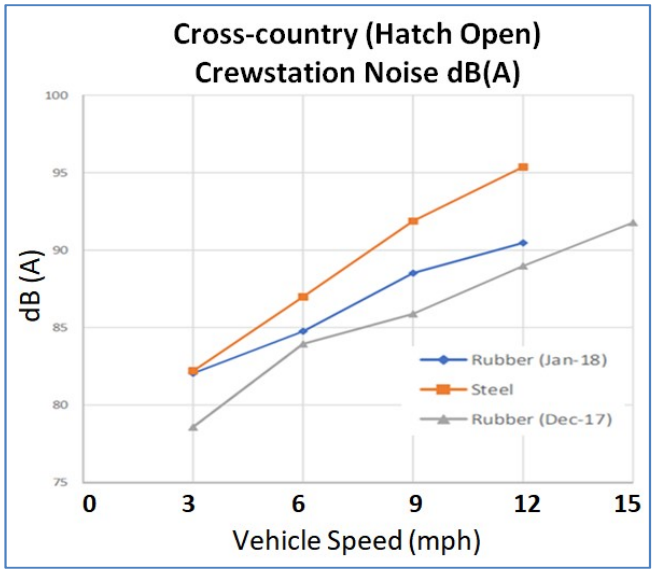
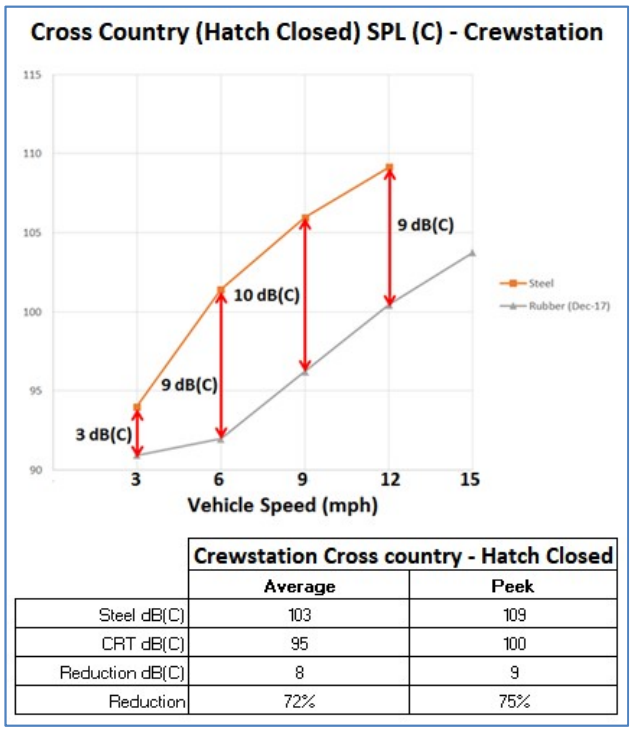


Figure 5: Noise reduction Crewstation – Cross country (Hatch Open)

When looking at dB(C), the above conclusions on road and cross-country are virtually identical. (See Figure 6)



	Crewstation Cross country - Hatch Closed	
	Average	Peek
Steel dB(C)	103	109
CRT dB(C)	95	100
Reduction dB(C)	8	9
Reduction	72%	75%

Figure 6: Sound Pressure Level – from 3 to 12 mph

Considering the logarithmic scale of the dB(A) decibel units, CRT technology simply represents a breakthrough in operators' health and safety with an average noise reduction of 57% (see Figure 7). When combined with hearing personal protective equipment (PPE), CRT can allow most vehicles to reach or surpass regulatory requirements.

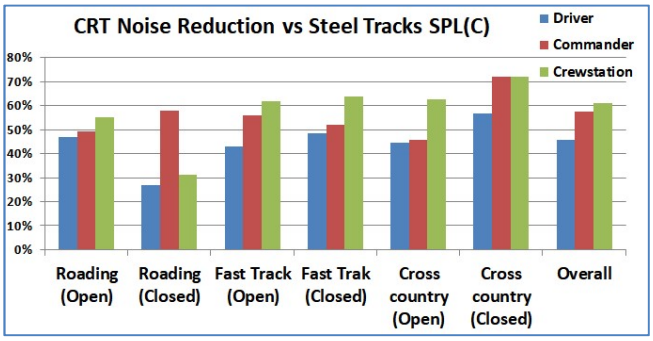


Figure 7: CRT – Sound Pressure Level Reduction

VIBRATION REDUCTION

Warrior's CRT track reduces up to 75% of vibration when compared to the original steel track, with an average reduction of 42% (see Figures 8 and 9).

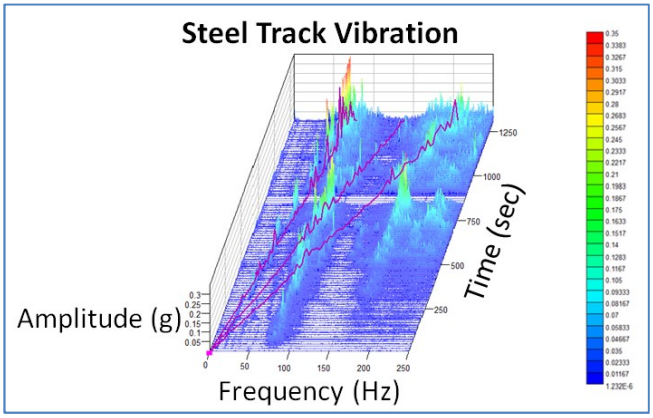


Figure 8: Vibration Amplitude (g) Z Direction at Rear Seat

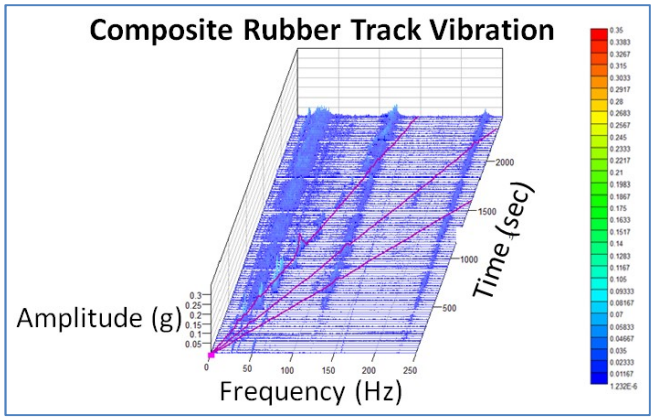


Figure 9: Vibration Amplitude (g) Z Direction at Rear Seat

In fact, considering the complete Warrior vehicle speed range, hatches open and closed, the average vibration reduction is 45% for the Commander, 28% for the Driver, 39% for the Gunner, and 57% for the Rear Crew (see Figure 10).

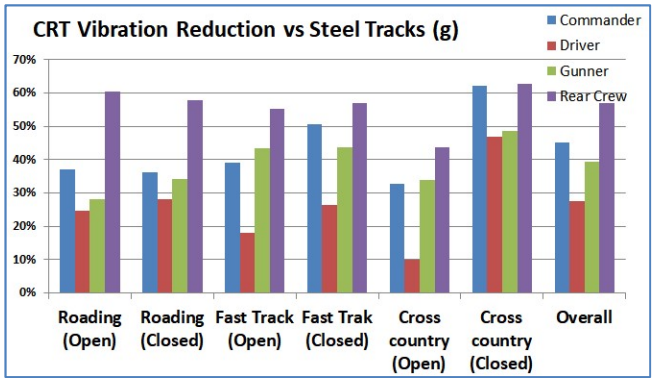


Figure 10: Vibration reduction - Baseline Composite Rubber Track

As an example, the CRT impact on vibration level at the rear crew seat pad, hatches open at 31 mph on road was measured, by the same independent firm, at 75% vibration reduction, bringing the vibration from 3.45 g for steel track, down to 0.86 g for CRT (See Figure 11).

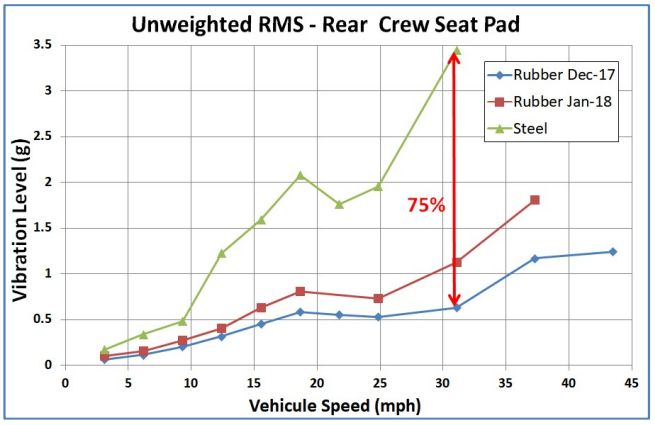


Figure 11: Graph of vibration level on rear crew seat pad for steel tracks (Steel) and CRT (Rubber) relative to the vehicle traveling speed on road, with hatches open.

"Although not measured specially, it is highly likely that the reduced vibration will also increase the durability of the sensitive platform components as well as munitions such as 40mm CTA and Anti-tank missiles." (Ref.1)

"From the user (crew) perspective there is a noticeable difference between CRT and Steel Track, noting that there were no physical feeling of vibration and the noise heard is that of the engine at all speeds over varying terrains." (Ref.1)

DURABILITY AND VEHICLE WEIGHT CAPABILITY

The Warrior CRT trial at ATDU ended at 3,107 mile due to limitations on vehicle availability. Running at a GVW of 60,000 lb (30 ton) and based on the condition of the CRT (see Figure 12) the full Warrior track kit has an extrapolated durability of 5,000 mile. Soucy estimates the mean durability for a 75,000 lb vehicle (37.5 ton) to be greater than or equal to 3,000 mile (see Figure 13).

Figure 12: CRT Condition after 3,107 mile Trial

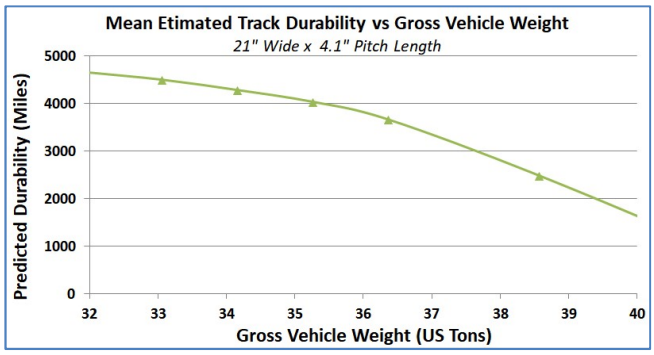


Figure 13: Estimated Mean Durability

More specifically, the sprocket was rotated at mid-life; its durability is estimated to be between 5,000 mile and 6,000 mile. The same conclusion applies to the road wheel (typically the CRT triples the road wheel durability in comparison to the Steel Track), the idler wheel and the top roller, as none were retired and all appeared to be good at mid-life.

MOBILITY

This Soucy Defense CRT kit was designed and optimized for a GVW of 73,000 lb (36.5 ton) with potential weight growth up to 80,500 lb (40.25 ton), with reduced performance. The UK MoD has used the Mean Maximum Pressure (MMP) parameter for many years as a performance specification. Whereas, the US Army developed Vehicle Cone Index (VCI) as a metric for directly quantifying the ability of vehicles to traverse soft-soil terrain.

The CRT performance has been calculated in accordance with both methods.

The CRT Nominal Ground Pressure (NGP) and the MMP are below the maximum limits in all Warrior Variants (see Figure 14 and 15).

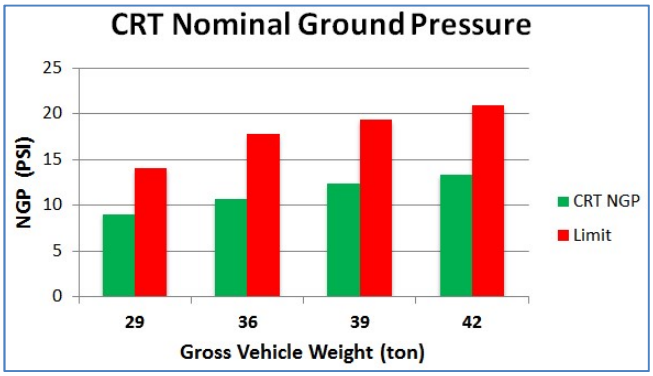


Figure 14: Warrior IFV Nominal Ground Pressure

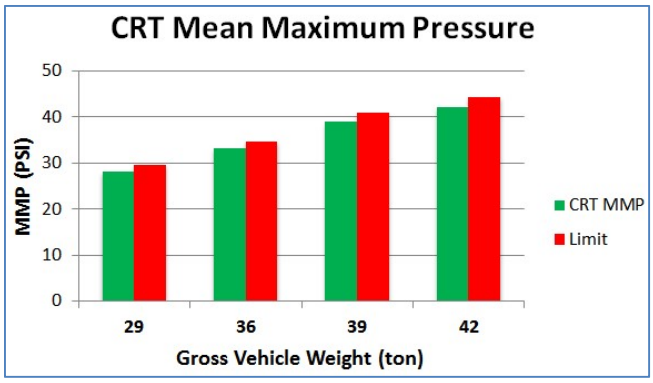


Figure 15: Warrior IFV Mean Maximum Pressure

When calculated with the Warrior GVW of 73,000 lb, the CRT has better results than the same vehicle fitted with the in-service Steel Track for both the Mobility Index and Vehicle Cone Index (see Figure 16). This calculation was made without the weight saving of the CRT System.

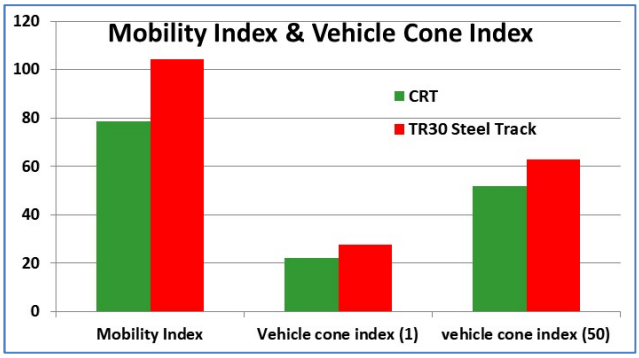


Figure 16 – Mobility Index & Vehicle Cone Index

$$\text{Mobility Index} = \left[\frac{\text{Contact Pressure Factor} \times \text{Weight Factor}}{\text{Track Factor} \times \text{Grouser Factor}} + \text{Bogie Factor} - \text{Clearance Factor} \right] \times \text{Engine Factor} \times \text{Transmission Factor}$$

Cone Index

$$VCI_1 = \left[7 + 0.2\,MI - \frac{39.2}{MI + 5.6} \right]$$

$$VCI_{50} = \left[19.27 + 0.43MI - \frac{125.79}{MI + 7.08} \right]$$

(See Reference 3)

The same vehicle using the CRT System has an improved Mobility Index of 24% and an improved Vehicle Cone Index of 17% (average between $VCI_{(1)}$ and $VCI_{(50)}$) over the in-service Steel Tracks.

"*All crew members stated that there was a noticeable difference with the way the vehicle responded: When the driver put in a steering demand at any speed over a varying terrain the vehicle responded immediately. On initial set off it was apparent that the acceleration was much quicker compared with the Steel Tracks (ST) and the vehicle stopped more sharply.*" (Ref.1)

MAINTENANCE AND LOGISTICS

The maintenance of the CRT system is simple and mostly requires a visual inspection, saving a combined total of 415 hours for level 1 and 2 maintainers (1 vehicle for 3,000 mile). Daily maintenance procedures only require a visual inspection of running gear components and after use inspection of the complete track carried out by slowly reversing the vehicle.

The CRT kit pallet was packed onto a 9T MAN SV and there were no difficulties securing it to the load bed. There is potentially the capacity to fit 2.5 complete CRT kits on the back of the vehicle.

The CRT does not stretch – no need for retightening or removing a track link. The other benefits of the CRT are:

- No shoe pad replacement
- No need to re-torque the end connectors
- 3 times less Road Wheel replacement

The CRT system was removed and replaced easily by the crew in both the work shop and in the field. It took 6 men approximately 2 hours 20 minutes to complete the task by hand in both instances.

CONCLUSION

The current Composite Rubber Track technology is TRL7 at up to 14,000 lb per road wheel station (i.e.: GVW of 85,000 lb to 100,000 lb. depending on 6 or 7 road wheel stations) and rapidly increasing at a steady pace.

The CRT System was operated for 3,107 mile during in an intensive 10 weeks test on the Warrior IFV Variant 510 (60,000 lb).

The CRT demonstrated several benefits over the in-service Steel Tracks:

- Has a direct weight savings of 3,306 lb which represents an overall 5% GVW reduction.

- Increases the vehicle average range by 28%.
- Reduces the overall noise by 57%.
- Reduces the average vibration by 42%.
- Has a better Mobility Index by 24%.
- Has a better Vehicle Cone Index.

"The CRT trial has been extremely successful. The trial achieved the aim of completing 3,107 miles on one set of tracks and could possibly have gone well beyond this if it had not been for the vehicle availability. Having this track system deliver up to 5000 miles is realistic, with the caveat that the track was not tested beyond 3,107 miles. The objective data collected during the trial validates Soucy's claimed benefits (based upon a wider fleet in service with NATO nations) including reliability, durability, N&V (Noise and Vibration), automotive performance, much reduced maintenance time and fuel efficiency. Confidence in CRT technology has thus grown significantly and the trial has identified several possible exploitation opportunities in the current and future UK AFV fleet where CRT should deliver programme efficiencies (time and cost) and enhanced capability to the user." (Ref.1)

"There is evidence that the Noise and Vibration produced by having CRT fitted is significantly reduced which will have a genuine effect on the health of our soldiers." (Ref.1)

REFERENCES

1. W. Brennan, Maj., Armoured Trials and Development Unit, "Composite Rubber Track Trial – Sept 2017 – Dec 2017", UK, 2018

2. C. O'Shea and K. Gleeson, NPRIME, "Soucy Defense – Rubber Band Track Noise and Vibration Assessment – Warrior FV510", UK, 2017

3. J.Y. Wong, "Theory of Ground Vehicles", Fourth Edition, John Wiley & Sons Inc., New Jersey, USA, 2008