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SURVIVABILITY ENHANCED RUN-FLAT VARIABLE FOOTPRINT TIRES

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ABSTRACT

The military has a unique requirement to operate in different terrains throughout the world. The ability to travel in as much varying terrain as possible provides the military greater tactical options. This requirement/need is for the tire to provide a variable footprint to allow for different ground pressure. Much of the current run-flat technology utilized by the military severely limits mobility and adds significant weight to the unsprung mass. This technology gap has allowed for the development of new run-flat tire technology. New tire technology (fig 1) has been developed that substantially increases survivability, eliminates the need for heavy run-flat inserts, significantly reduces air pressure requirements and provides full (or near full) speed capability in degraded/damaged mode (punctured tire). This run-flat technology is built directly into the tire, yet maintains the normal variable footprint of a normal pneumatic tire. This makes the tire/wheel assembly much lighter and far more survivable than normal military run-flat technology. Safety, logistics, economics, and fuel economy are additional benefits this tire technology provides over current military tires with run-flat inserts.

Fig 1. Survivability Enhanced Run-Flat Variable Footprint Tire Sectional View

INTRODUCTION

The current state of the art tire technology utilizes a run-flat insert sometimes weighing over 100lbs. Fig 2 shows a cut-away showing the run-flat for a military tire/wheel. The stability of the vehicle running on a run-flat is significantly reduced and the operator is limited to a maximum speed of 30 mph, and sometimes less depending on stability. The distance that a vehicle can travel with a run-flat tire is also limited to typically 30 miles. This is also very similar to the NATO standard of 50 km [1]. The purpose of the run-flat is to allow the vehicle to have limp home capability and that's it. Logistically the run-flat has further drawbacks. Unless you buy the wheel, run-flat, and tire as a package, you have to get the run-flat into the tire. This requires
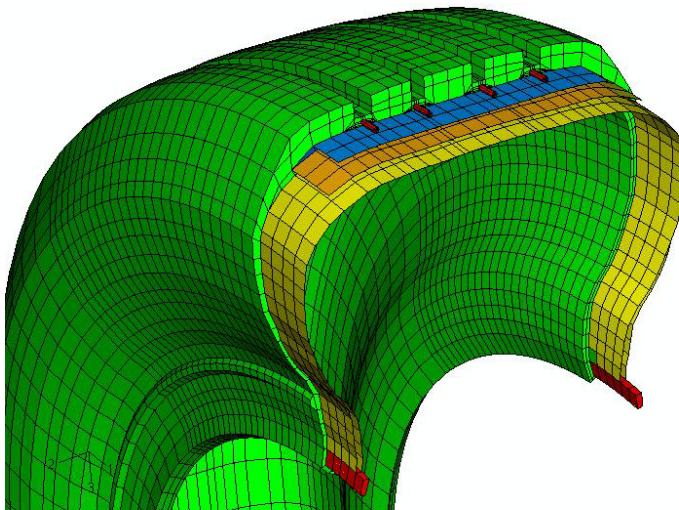
Figure 2. Military Run-flat Tire with Insert [1]

a special tool to compress the run-flat and get it into the tire [2]. One such tool used on a HMMWV tire is shown in Figure 3 [2]. The larger the run-flat the more difficult this becomes. This process further adds to the maintenance burden on the military that has limited resources.

Although run flat technology has been around for a while, very little improvement has been made over the past 25-30 years. The current requirement of the run-flat tire for the HMMWV is the same as it has ever been.
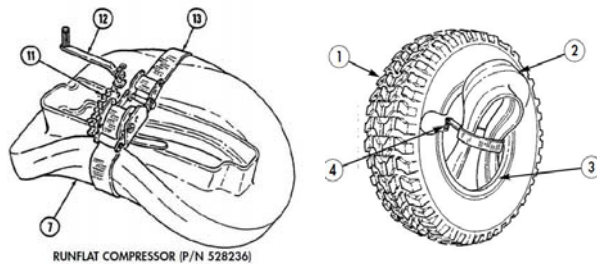

Figure 3. HMMWV Run-flat Insert Special Tool and Installation [2]

To make a run-flat insert better than what is currently produced is extremely difficult. The commercial application for run-flat inserts is limited because of cost and performance. The systems typically costs a lot more because of the additional hardware of the insert and the wheel needs to be specially designed for the run-flat insert. Still, the premise of the run-flat insert is running on a small solid tire. The insert can only be so large or it will act as a bump stop for the tire and the width of the run-flat is going to be significantly less than the width of the tire. This limits the surface area that the load can be distributed over. Also, the flat tire must either flop along or degrade due to the heat buildup of running directly on the tire and run-flat insert. This could lead to stability issues, smoke and possible flammability issues. There is a way to sum up the difficulty in making the run-flat performance significantly better, physics.

Aside from physics, another reason the development will be slow for the run-flat insert is that the commercial market has different requirements. Most military vehicles need to have the capacity to change the tire pressure for the different terrain

profile encountered for different missions and theaters, plus run-flat capability. New military wheeled vehicles systems such as the Stryker or M-ATV have on-board CTIS systems to enable these vehicles to quickly transition from highway mode to off-road, or vice versa, within the safety of the vehicle [3]. Most of the commercial market needs only one tire pressure setting for highway usage. Automobiles benefit the most from proper tire inflation pressure, resulting in premium fuel economy, extended tire life and proper handling. This has lead to the development of stiff sidewall tires that provide similar handling and perform with or without air. However, the tire reliability and durability are significantly worse without air pressure. Consumers of these tires have actually complained that when the tire lost air pressure they had no degradation of performance so they kept running the tires until they were damaged beyond repair. This problem is the reason why some cars have tire pressure monitors to notify the driver of a flat tire. This is a far different experience of riding on a tire with a run-flat insert.

The stiff sidewall tire requires a very low aspect ratio so the tire can be supported properly by the sidewalls. "The sidewalls can't be very tall, so most are low-profile designs. Because of this, they are typically used on sports, though they're also available for regular passenger cars and even minivans."[4] The drawback with this tire is that the stiff sidewalls tend to put more energy into the vehicles suspension system and ultimately the vehicle. For new car designs, this can be designed up front. However, the military has vehicles that are in inventory for extensive periods of time and cost to swap out suspension systems along with the tires can be a cost that is hard to justify. Since the runflat is built into a stiff sidewall, how much can the footprint can changed to provide different ground pressure for different terrain may be an issue that prevents this technology from being used for the military.
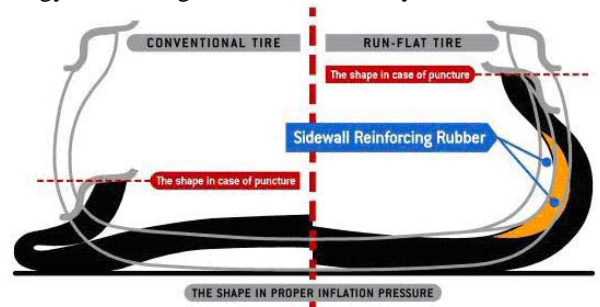

Figure 4. Comparison of Conventional Tire to a Stiff Sidewall Tire [4]

To improve the runflat capability of the United States military legacy systems, technology needs to be developed that provides a variable footprint, can operate at zero air pressure with the carcass severely damaged/punctured, provide the same dynamic deflection as the normal pneumatic tire, and provide similar tread life. Could a tire be developed that would provide the same ground pressure requirements as a normal pneumatic tire such that it could meet the military demands of operating in sandy soft soil with zero or minimum air pressure, add air pressure for proper highway speeds and handling, and yet be able to provide enhanced run-flat capability. Could all this capability be developed in the tire to reduce the logistical burden associated with the run-flat inserts? From modeling, simulation, FEA, and laboratory testing the answer appears to be yes.

Tire Development

How does the pneumatic tire work? The load for the axle is resisted by the road. The body plies of the tire between the axle and the road have reduced tension (resulting in the tire bulge). The cords above the axle are in higher tension and as a result pull up the axle. The means of putting the cords in tension is through air pressure. What other means could be utilized to put the cords in tension.

- **Stiff Sidewalls**
- **Spring Molded Tire**
- **Spring Inserted Tire**
- **Hoop Ring Molded Tire (Metal)**
- **Hoop Ring Molded Tire (Fiber Glass Rods)**
- **Carbon Fiber Molded Tire (Layer)**
- **Hoop Ring Molded Tire (Carbon Fiber)**

To simplify development and test the concept, spiral springs were developed and inserted into the tire. This was done on a small automotive tire to quickly and economically evaluate the concept and help correlate stress analysis conducted on CAD models and actual lab testing. Sizing of the springs was determined utilizing FEA software (Figure 5 shows how FEA was utilized to evaluate the stress loading of the springs). One assumption made was that the carcass would not provide any addition support and all the support would have to come from the spring stiffness. Upon load deflection testing on the concept, the load carrying capability was significantly greater than computed in the FEA analysis. This meant that the cords in the tire were being put in significant tension to support the load of the simulated axle loading. Meaning the size and

weight of the springs could be reduced making the concept more desirable.
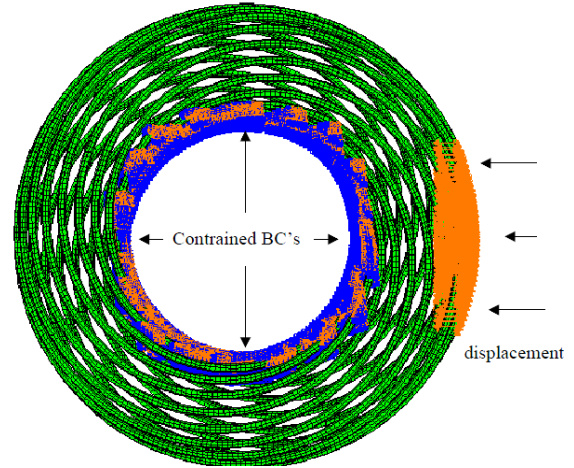

Figure 5. Load and Boundary Conditions Applied on the Model for a First Order Foot Print Analysis

Further prototype development required integrating the run-flat support into the tire. This would require the development of rings or cylinders imbedded in the tire. The shape of the ring could be optimized utilizing CAD and FEA analysis.

The balance for the ring is going to have to be achieving proper bonding between the ring and the tire rubber yet having the stiffness to support a pre-determined load with a desired change in the vertical diameter to produce the desired ground pressure. Formulas and analysis for circular rings is much more straight forward.

Assuming no deformation, the change in height is as follows:

$$\Delta Dh = -0.1488 \, \frac{WR^3}{EI} \quad [5] \tag{1}$$

The ring can fail by either excessive compressive forces or by buckling. The critical stress in the ring for buckling can be estimated by replacing the ring as a cylinder and doing the stress equation for a hollow cylinder. The basic equation for column buckling is:

$$P_{CR} = \frac{\pi^2 EI}{(Le)^2} \quad [5] \tag{2}$$

Where:

P_{cr} = critical load where buckling occurs
E = Young's modulus, 30x10^6psi for most steels
I = moment of inertia. For a round hollow section:

$$I = \frac{\pi (OD^4 - ID^4)}{64} \tag{3}$$

Again the stress in the ring can be estimated by replacing the ring as a cylinder and doing the stress equation for a hollow cylinder. The basic equation for critical compressive stress due to these loads:

$$\sigma = \frac{P}{A} \quad [6] \tag{4}$$

Where:

$$A = \frac{\pi(OD^2 - ID^2)}{4} \tag{5}$$

The equations above are going to provide ROM estimates as to the deflection and loading for a specific shape. FEA analysis combined with CAD can provide a much more detailed result and allow for different shapes. The equations do serve as a check to help certify that the boundary conditions in the FEA analysis are correct. The real check is actual test results. These results can be pluged back into the modeling and simulation analysis to provide better theoretical results for design optimization.

One such shape considered is the round ring hoop. The one drawback with the shape is that it has little surface area for bonding the carbon fiber to the rubber.
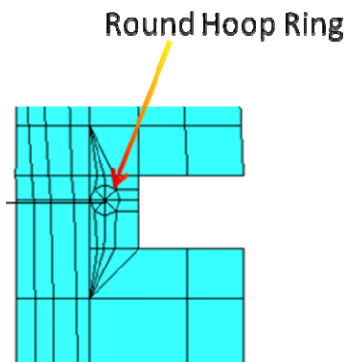

Figure 6. Round Hoop Ring Cross-Section

To improve bonding area yet maintain adequate volume between the rings to distribute the loading a more rectangular shape with rounded edges was developed to maximize the contact area and yet have enough rubber material to distribute the loading. Fig 7 shows a sketch of what the preferred shape of the rings would be for an optimized shape. Fig 8 shows the actual process applied to a current tire. The carbon fiber was added by removing the tread, cutting the grooves for the carbon fiber and then retreading the tire.
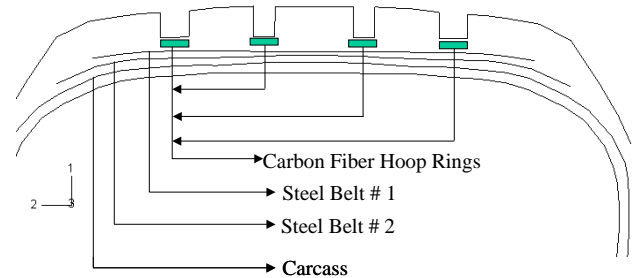

Figure 7. Rectangular Hoop Ring Cross-Section

Figure 8. In Process Prototype Carbon Fiber Hoop Ring Molded Tire

Two different military tires were developed using the carbon fiber hoop technology and tested. The most encouraging result was how well the load deflection curve matched the normal pneumatic tire. However, it was able to accomplish this at a much lower air pressure. Fig 9 shows how the load deflection of the baseline tire and the tire with carbon fiber rings imbedded in the same tire. And Fig 12 shows the test results that were achieved on a HMMWV tire with carbon fiber hoop technology imbedded into the tire. The run-flat mileage achieved was 800 miles at rated load at a speed of 50 mph.
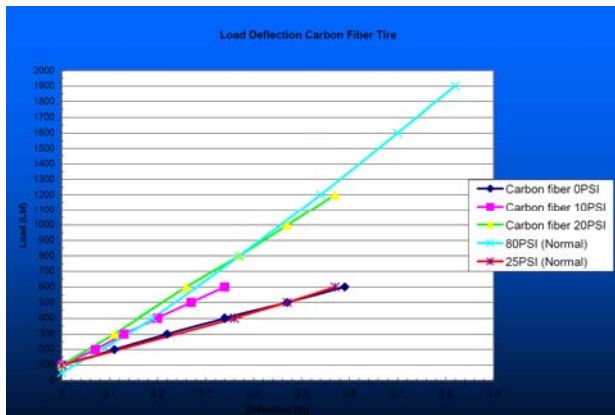
Figure 9. Load Deflection Curves

For the tire analysis, FEA was used to help baseline the tire. Fig 10 shows the stress analysis results of inflating a tire to 50 psi.
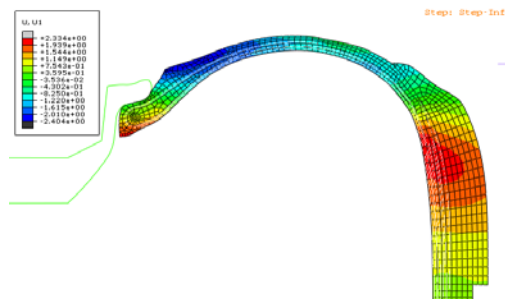

Figure 10. FEA of Inflated Tire Model

The important analysis and correlation is determining the footprint and resulting contact pressure from a given load or tire deflection. An analysis was performed assuming a deflection of 1.2 inches that resulted in a rated load of 4,167 lbs. The resulting FEA analysis (ref fig 3) provided an average contact pressure of 56 psi, which is very close to the inflation pressure of 50 psi. This proves that the FEA model is close to the physical model of the tire and can be used as a start for the more advanced models that will incorporate the carbon fiber rings.

R&D

While the R&D of run-flat tires has been based on pneumatic tires, (mainly focused on protecting the tires' side walls or supporting metal rings), with limited operational capacity in case of a mechanical damage & deflated tire, h*oop tire* technology is a completely new concept that eliminates the use of pressurized air. It consists of a system of elastic elements and possesses all the features of a pneumatic tire. This system enables the tire to retain its working capacity without need to reduce speed or limit travel mileage even when the rubber-cord shell is mechanically damaged due to a puncture, rip or bullet hole. The main advantages of the *Hoop Tire* over the traditional pneumatic tire and other run-flat solutions are:

- Resistance to physical impacts & mechanical damages
- Retention of its physical properties throughout operation
- Better thermal characteristics
- Durability & safety
- No need for pressure sensors or alarm indicators
- Explosion of a hoop tire is an impossible event
- Cost-effective (in compare to run-flat solutions)

Prototypes & Technology

The *hoop tire* technology consists of a unique internal system of elastic elements, vulcanized into a rubber-cord shell. Based on a mathematical algorithm developed by a team of scientists models of spring configurations were built and tested in order to define the optimal parameters of the elastic structure, such as: wire diameter, the number of elastic elements & type of materials. Various types of rubber were tested and special techniques for assembly & vulcanization were developed.

The R&D process was based on FEA software, using the 'Finite Elements Method' (FEM) to predict following features: weight, radial and lateral stiffness, stress level in tire components & vibration frequencies.

15 *Hoop tire* prototypes were manufactured and have undergone a variety of static, dynamic & road tests. Based on the tests' results & findings, a methodology was established for the development of various tires, (types & dimensions), for different applications.

Test Results & Findings

During March, June & December, 2000, 3 sessions of indoor tests were conducted. The tests were conducted on 13 prototypes of h*oop tire* models, in comparison to conventional pneumatic tires. The tests were conducted, even if not to the letter, in accordance to the following specifications:

- **M81 Static Test (for tire stiffness)**
- **H12 DOT Endurance FMV SS 109 Test**
- **H02 FMVSS 109 High Speed Performance 5.5.5**
- **H24 Plunger Energy Certification – GMVSS 109 & 117**

The tests results & findings indicate that the h*oop tire* has approximate, or in some parameters, even better characteristics than the comparative-tested pneumatic tire.

The hoop tire technology leads to a puncture tolerant & lighter weight system, eliminating the need for pressurized air. This unique technology might be first targeted at military, off-road & agricultural vehicles and further developed for light trucks and even passengers' cars.

The continued R&D program of the h*oop tire* should be focused and oriented at the following issues:

- Improving the capabilities of the elastic elements by using advanced composite materials towards optimal characteristics.
- Developing & analyzing various structure models that are based on the h*oop tire*'s elastic elements construction.
- Improving the vulcanization process for a better performance.
- Developing prototypes for various sizes & carrying capacity.
- Developing a mass-production technology.

The next stage of development is the Military Tire-Wheel (MTW) Assembly for future tactical and combat vehicles. This program is placing emphasis on handling, traction, and cornering tire performance for the light trucks. In order to meet these high performance standards, solid tire with aspect ratio lower than 0.35 have been developed

- Tire Size: LT225/35R19
- Rim Width: 7.0 inches
- Tread Width: 7.6inches
- Overall Diameter: 25.0 inches
- Speed rating:60mph

This tire aims to eliminate tire blowouts with its integrated Carbon Fiber Ring-Wheel "MTW" assembly, a solid one-piece wheel-and-tread system that could soon enter manufacturing. The MTW's rim is bonded to soft polyurethane foam that provides the shock-absorbing property of a traditional pneumatic tire. The circumference of the soft polyurethane foam layer is bonded to a Carbon Fiber ring along with tire tread. By varying the thickness and geometry of the polyurethane soft layer, this unique tire-wheel assembly can generate a wide array of ride and handling performance.

MTW's vertical stiffness (ride comfort performance) and lateral stiffness (handling and cornering performance) can both be optimized, pushing the performance envelope in various military applications. The purpose of this paper is to illustrate the effectiveness of integrated footprint analysis using FEA in the designs of "pneumatic tires", "high aspect ratio airless tires", and "solid foam tires". This research work is development of a military airless tire using carbon fiber and Polyurethane. This paper provides an integral step by step approach to model the footprint analysis using FEA standard software. The computer simulation developed in this paper is divided into three tire designs according to the type of tire applications.

Finite Element Analysis as a Tool for Tire Development

Finite Element Analysis (FEA) not only saves time and resources in the tire development process but also provides very good insight into the stress strain distribution of the composite tire. This leads to better understanding of the functionalities and failure modes of tire by revealing the critical regions. Various studies like stress and deformation of the tire (Ridha, 1980), transient analysis of tire (Nakajima & Padovan, 1987), rolling analysis (Shiraishi et al. 2000) has been instrumental in the application of Finite Element Analysis (FEA) in the Tire design process. This paper addresses the importance of footprint analysis in tire design and presents a complete description of tire modeling using commercial software. There are several publications on the tire modeling such as Zamzamzadeh et al, in the literature that provides the outline of the footprint analysis and its importance. But very few discuss the challenges associated with analysis and the precautions needed to overcome non-convergence issues in the simulation. This paper presents step by step modeling of the footprint analysis of a pneumatic tire and further extends the analysis to "airless" solid tire design.

Model Description

This part of the paper presents the design and analysis of a pneumatic radial P265/65 R 17 tire using FEA software. Numerous assumptions were made in the model definition to achieve computational advantage by reaching converged solutions in reasonable time. An integrated footprint analysis consists of three steps:

1) The first step is the modeling of the core of tire for the axisymmetric analysis. A simplified 2D half model can be used as the base model and later it can be revolved and reflected to obtain the full tire model. Initiating the simulation with a 2D half model saves memory and simulation time for the analysis. The simplified full tire obtained by this process can be called a smooth tire as the tread geometry is kept simple and smooth with a few radial grooves. The output results from the footprint analysis like load-deflection, total footprint area and average contact pressure of the tire depends on the core and the reinforcements design and does not depend on the tread design. The actual tread should to be used in place of the smooth tread in order to obtain accurate values of the maximum contact pressure and the total footprint contact area.

2) The second step is to mount the 2D tire geometry on a rigid rim and perform inflation analysis. The standard inflation pressure of 30 psi, 40 psi and 50 psi are used. In this analysis the stress and strain energy distribution of different tire regions can be observed and recorded.

3) The third step is to revolve the 2D geometry using the symmetric model generation (SMG) and obtain half 3D tire model. The footprint model can be setup by defining the rigid road using analytical rigid geometry and defining the contact interaction of the tire and road. The footprint analysis includes 4 load steps:

   a. Bring the inflation analysis results in equilibrium by transferring the results from the 2D analysis to 3D analysis.
   b. Apply displacement controlled loading on the rigid road surface to establish contact with the tire.
   c. Apply the actual static vertical loading of 2335/2 lb on the half tire
   d. Reflect the tire to obtain the full 3D tire.

Modeling of 2D half model:

Constructing the core of the tire and modeling of each component is the first step into the modeling of the half 2D axisymmetric model. A general tire has the following major components
   1. Rubber materials - Tread, Belt Region, Inner Liner, Sidewall Region, Inner Carcass Region, Bead Filler Region, and Apex/Chafer Region.
   2. Reinforced materials - Beads, Nylon Cap Ply, Steel Belts, Carcass Ply and Carbon Fiber Hoop

The choice of elements and material properties for each component in the tire plays significant role in the convergences and simulation time. It is known that a full structural quad mesh is needed for accurate results in any FEA analysis. This study includes the 2D tire models meshed with lower order tetrahedral elements which is capable of producing reliable results in less computational time. Applying tetrahedral mesh also saves considerable time that would be needed to mesh the tire with structural quad elements.
Both the axisymmetric quadrilateral and axisymmetric triangular elements with twist, are suitable for meshing. It should be noted that using full order elements rather than reduced order gives much faster convergence and accurate results.

It is a standard practice to use incompressible hybrid elements for modeling the rubber regions of the tire. But when undergoing large compressive stress in the area under the belt region elements sometimes force the solver to create convergence problems. Also the hybrid elements have been observed to perform well in 2D model but fails in 3D model. Based on the experience gained a compressible full order element with Poisson's ration of 0.495 was used. Neo Hooke model and Mooney-Rivlin model were used for modeling the rubber components. The reinforcements i.e. belts, carcass plies and nylon chords can be modeled as the surface elements with rebar properties defined and embedded in the belt region. The rebar definition allows the analysis to control parameters like orientation angles of steel belts, diameter and number of strands, distance between strands. The bead regions can be modeled as a single cross sectional area of steel embedded inside the rubber to represent the cluster of

strands of small diameter steel wires. The material property of the bead can not be represented as the material property of the steel as it should represent steel strands embedded in rubber, so the young's modulus can be modified using a ratio of total cross sectional area of steel wires with the total area of the bead. In this study the Young's modulus of the bead is assumed to be half of the Young's modulus of steel. The material property for the Nylon and Textile material for the carcass ply is defined as a Marlow model.

Tire analysis is a pure nonlinear analysis comprising of geometric nonlinearity, material nonlinearity and also nonlinearity arising from contact interaction between tire and rim and tire and road, so the large deformation effects should be included. The rim can be modeled in more than one ways, but in all cases an axisymmetric analytical rigid surface is used. The road is modeled as analytical rigid surface and the interaction between the road and tire is modeled based on a small value of friction (< 0.2). For any type of contact interaction it is a very good practice to use a small initial loading to establish contact in the first step of the analysis and then engage the full load or displacement to complete the analysis. Study has shown that the software needs such a gradual approach to overcome convergence issues during contact analysis.

Footprint Analysis of pneumatic tire

The footprint analysis consists of inflation and the application of rated load on the tire. The 2D inflation analysis results can be transferred into a 3D model. The application of the rated load can be done in two steps, first step is displacement controlled loading, where the road can be displaced and brought in contact with the tire. In the second step the actual load can applied on the road, keeping the rim fixed. If half of the tire model is used, the rated load should be half too. During the second step the rim boundary condition can be kept free in z direction to record the displacement of the tire center due to the rated load. The load-displacement diagram of the tire is one of the important tools for the verification of the model by using test data. Other parameters important for observation is the total footprint area, average footprint contact pressure and the maximum contact pressure. By recording the stress strain in the compressed footprint region and the tire region just opposite to the footprint region, a fair idea of the periodic values of the stress/strain in the tire can be obtained. These values provide extremely important insight into the performance of the tire.
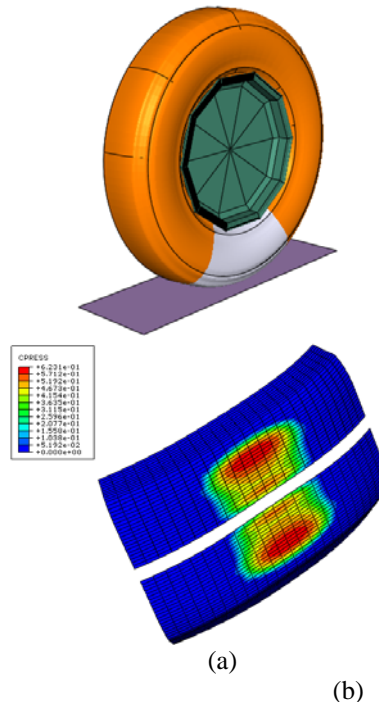

(a)

(b)

Figure 11: (a) Footprint analysis of half tire model (b) Contact pressure distribution of the footprint area

Figure 11 shows the footprint analysis of the half tire model. From this analysis the deflection of this tire was recorded to be 1.2 inch for the rated load of 4167.5 lbs and inflation pressure of 50 psi. The average contact pressure in the footprint region should be same as the internal pressure of the tire, i.e. inflation pressure. The observed average contact pressure is 56 psi, which is very close to the internal pressure of 50 psi , that proves that this FEA model is close to the physical model of the tire. From test results of a similar tires and the footprint analysis results it is understood that a tire with nominal ride comfort should have the characteristic stiffness corresponding to displacement of 1.2" to 1.5" for a rated load of 4335 lb. Also it is understood that a large value of footprint area is needed for stability of the tire.

A comparison of the footprint analysis of tire is provided in Table 1. The three parameters presented in this table are footprint area, maximum displacement and the maximum contact pressure.

Table 1: Footprint Analysis

Model Rated load: 4335 lb	Footprint Area (sq inch)	Max Displacement (inch)	Max Contact Pressure (psi)
Pneumatic tire	41.48	1.2	90.37

Conclusion

This paper discusses a number of unique ideas for the development of run flat tires to enhance the survivability of military vehicles in a variety of terrains and theatres throughout the world. The ability to travel in as much varying terrain as possible provides the military greater tactical options. This requirement/need is for the tire to provide a variable footprint to allow for different ground pressure. The displacement of the tire with rated load and the footprint area in contact with the road surface was found to be a very good parameter to be used as the design criterion. The deflection of the tire corresponds to the stiffness of the tire and the footprint area corresponds to the ride comfort of a performance tire. Commercial software has been used as the modeling tool to prove the effectiveness of the integrated footprint analysis for the design process of

the tire. Conceptual designs of airless tires were modeled and validated very quickly and optimized design selected at the end. Effect of different material properties has also been studied and proper combination of material selected for the analysis. The result shows that run-flat technology can be incorporated into the tire easily that provide the same ride comfort as normal pneumatic tires.

A discussion of finite element analysis applied to tires was included to show how various design parameters of a non-pneumatic tire can be optimized in new designs rapidly. The run-flat technology is built directly into the tire, yet maintains the normal variable footprint of a pneumatic tire. This makes the tire/wheel assembly lighter and far more survivable than normal military run-flat technology. Logistical, economic, and fuel economy are additional benefits this tire technology provides over current military tires. This new tire technology has been developed that substantially increases survivability, eliminates the need for heavy run-flat inserts, significantly reduces air pressure requirements and provides full (or near full) speed capability in degraded/damaged mode (punctured tire).

JOB NO.	L7-830		DATE	10/8/07
SPEC NO.	CMVSS 119		TEST NO.	AME7-0001
TEST DURATION	47 HRS.		STATION NO.	11
TIRE NUMBER				

TIRE NAME	HMMWV UNICURE			LOAD RANGE	D
TIRE SIZE	37 X 12.50R16.5LT	ID.NO.	RDYB375	TT/TL	TL
MAX.INFLA.SINGLE	50	MAX.LOAD.SINGLE	3850	D.O.T.	Y
DUAL	N/A	DUAL	N/A	T.W.I.	Y
CARCASS CORD MAT.	P	BELT CORD MAT.	P,S,N	RIM NO.	
NO. PLIES SIDEWALL	2	NO.PLIES TREAD	5	CONSTR.	R
TEST RIM SIZE	16.5 X 8.25				

CONDITIONING REQUIREMENTS

CONDITION TIRE ASSEMBLY FOR A MINIMUM OF 3 HOURS 100° F.						
	DATE	TIME	ROOM TEMP		INFL PRES.	
START	10/8/07	2130	97	deg. F	50	PSI (Set)
END	10/9/07	0330	98	deg. F	51.7	PSI
TOTAL TIME		6.0 Hrs.			50	PSI (Adjusted)

MEASURE INFLATION PRESSURE IMMEDIATELY AFTER TEST
AFTER TEST- DEFLATE TIRE AND ALLOW TO COOL AND INSPECT

TEST DATA

INSPECTION							
AIR PRESSURE (psi)	50/50	0	0	50/50			
AMBIENT TEMP (°F)	90.1	97.4	96.3	97.6			
TEST LOAD (lbs.)	2,888	2,888	3,735	4,389			
ACTUAL LOAD (lbs.)	2,888	2,888	3,735	4,389			
TEST SPEED (mph)	0	50	50	50			
TECHNICIAN	DS	PS	MB	MB			
DATE	10/9	10/9	10/10	10/10			
CHECK TIME	0340	104	0240	1810			
TEST MILES	0	350	1150	2350			
TEST CYCLE HRS	0	7	16	24			
TOTAL HOURS	0	7	23	47			

Figure 12. In Process Prototype Carbon Fiber Hoop Ring Molded Tire

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