ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1161821

INNOVATIVE RUN FLAT SYSTEMS

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Abstract

One of the most essential threats to the mobility of wheeled vehicles is their relatively high sensitivity to tire damage. Tires can be damaged as a result at vehicle-targeting fire, after running on a mine or an improvised charge. The purpose of the article is to analyze the current technical solutions in wheeled vehicle tires, allowing for the unobstructed use of the vehicle despite the damage of one or several tires (RUN FLAT systems). Since RUN FLAT systems have become increasingly popular in passenger cars as well, the article contains partial references to civilian solutions.

One should remember that RUN FLAT systems are not only to guarantee vehicle mobility following the loss of pressure in the tire in straight-line motion, but also crew safety providing sufficient driving level and stability at longer distances. The article presents solutions of this type, applied not only in military vehicles, but also considers research-structural works implemented by ROSOMAK S.A. in cooperation with other centres.

The works presented in this article were financed by ROSOMAK S.A. and National Research and Development Centre (NCBiR) (project SPB – RolRes, agreement no PBS1/A6/1/2012).

Keywords: *military vehicles, RUN FLAT tires, composite wheel*

1. Introduction

Guaranteeing the mobility of military vehicles during combat activities is the key issue for the constructors of military equipment. We are currently witnessing a trend involving the construction of a growing number of vehicles based on wheeled chassis. In comparison to caterpillar-based vehicles, these vehicles present a wide range of advantages. However, one of the major threats to their mobility is their relatively high sensitivity to tire damage. Tires can be damaged through vehicle-targeting fire, after running on a mine or an improvised explosive device (IED). Even though the first wheeled military vehicles were used as early as during World War II, where all-rubber tires were commonly applied in vehicles (Fig. 1), one should remember that such solutions would fail to fulfil the current standards in terms of driving comfort, road grip and wear resistance.

In order to avoid the possibility of losing tire grip, tire manufacturers have been applying increasingly innovative RUN FLAT (RFT) systems, which may provide considerable vehicle mobility after the loss of pressure in the tire. The article presents solutions of this type that may be applied not only in military vehicles. It also mentions work carried by ROSOMAK S.A. in cooperation with other research centres, such as the Gdansk University of Technology.

Fig. 1. A view of a solid-rubber wheel and tire from the 30s/40s of the 20th century (Fig. www.odkrywca.pl)

2. RUN FLAT systems

Nowadays there are several systems, which allow driving vehicles after tire damage, resulting in the loss of tire pressure. The most popular ones include:

1. For minor damages, there is a possibility of correcting tire pressure using central wheel-pumping systems. Such solutions are used in military and off-road vehicles.
2. RUN FLAT tires which, due to their reinforced load-bearing structures, allow for continuing the drive despite pressure loss in the tire. The pressure loss results in the reduction of static/dynamic radius of the tire (additional bend of the lateral walls – Fig. 2 and 3); however, there is a possibility of continuing the drive for several dozen kilometres, according to declarations made by the majority of manufacturers.
3. Systems of additional pads and inserts manufactured in the majority of cases, from solid rubber materials, intended for transferring the load by a given wheel despite the lack of pressure in the tire (Fig. 4).

Fig. 2. View of side wall bend for a RUN FLAT tire and a serial tire 205/55R16 Bridgestone. The tire on the left has nominal pressure, the tire in the middle is a depressurized RUN FLAT tire and the tire on the right is a depressurized serial tire (Fig. P. Stryjek, ROSOMAK S.A.)

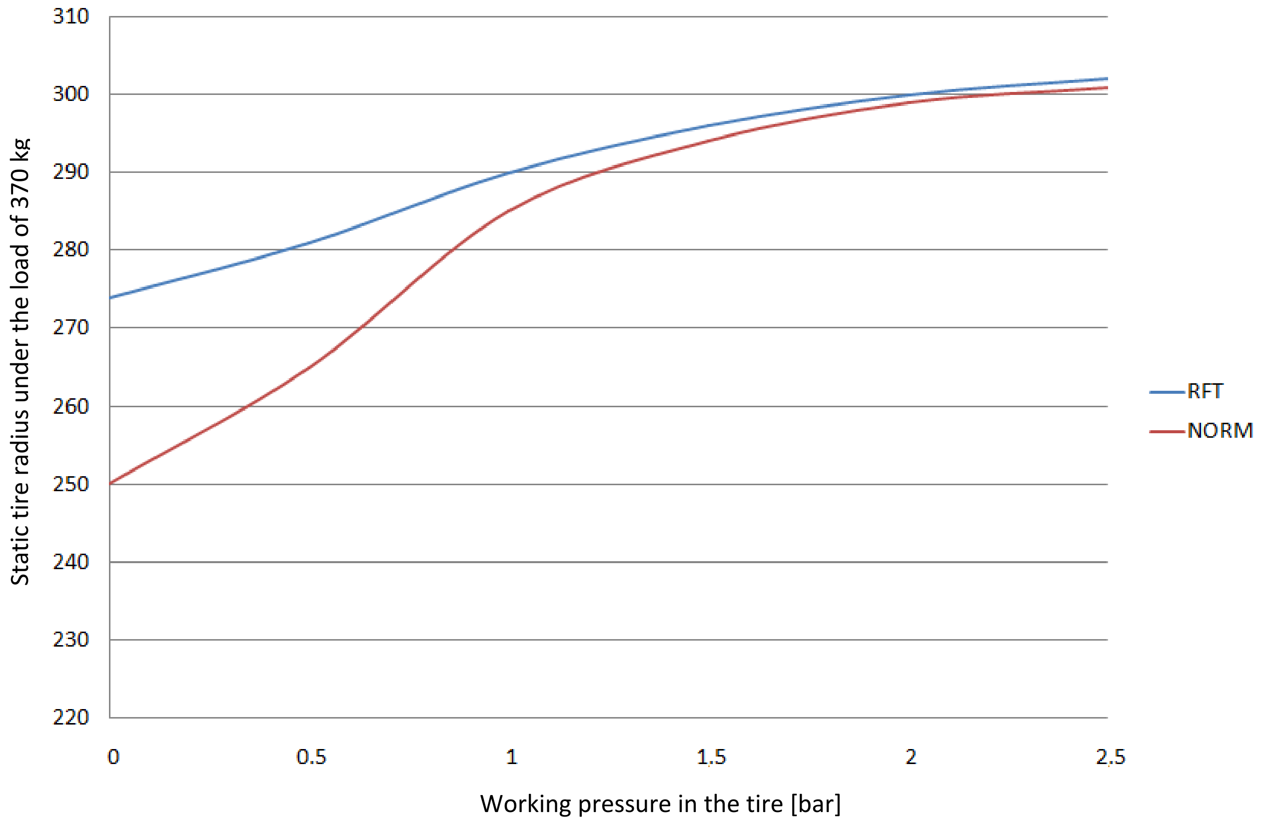

Fig. 3. Specification of the static radius of a 205/55R16 tire with the RUN FLAT system and a serial (NORM) tire, depending on working pressure (Fig. P. Stryjek, ROSOMAK S.A.)

Fig. 4. On the left: view of a KTO Rosomak tire for 0 bar – with a RUN FLAT insert, on the right: a layout of the RUN FLAT system (Fig. T. Nikisz ROSOMAK S.A. / HUTCHINSON)

At this point, the aforementioned systems have become a standard solution for military vehicles, as they allow the crew to leave the hazard zone safely with even a few wheels damaged, or, in the case of minor damages, to drive for even several dozen kilometres. However, tire manufacturers have been developing and implementing increasingly innovative systems, as exemplified by Tweel solutions by Michelin (Fig. 5). Such systems do not use gas pressure to carry the vehicles load. In result, the possibility of damaging the tires in combat conditions is considerably lowered. At the same time, according to data provided by the manufacturer, the vertical rigidity of the tire is selected to provide sufficient driving comfort and vehicle steering control conditions.

Fig. 5. View of vehicles with the Tweel system by Michelin (Fig. http://wkqsfm.com/featured/5932/michelin-tires-air-valve-stems)

A similar solution was developed in Sweden by H. E. Hansson (Fig. 6). At this moment, it is dedicated to passenger cars only. Research of such composite wheels has been conducted in Sweden and in Poland since 1989. Successive prototypes of this type of wheels have been created so far. One can therefore expect that such solutions will be implemented for mass use in the future.

Fig. 6. View of a composite wheel developed in Sweden (Fig. from the archives of the Gdansk University of Technology)

Other systems implemented particularly in automotive sports are the so-called mousse systems. These are special materials which fill the space of the tire with a special mousse either within the entire period of use of the tire or upon detection of pressure loss (Fig. 7). They allow for continuing the use of the sports vehicle even at high speeds and dynamic loads affecting the tire. According to data provided by Michelin (BIB MOUSSE SYSTEM), the rigidity of fixed inserts with the mousse system is adapted to provide a pressure of c.a. 0.9 bar for cross-type sports motorcycles. In turn, the ATS system by Michelin, dedicated to race tires, is not activated as long as the tire is filled with sufficient air pressure. When assembling the tire, a dedicated rubber pad is installed on the rim, which is stored in cooled rooms beforehand. After assembly is completed, the tire is pumped with air to reach c.a. 2 bar, which then presses the ATS pad to the rim, reducing its volume approximately by half. The rubber pad is not activated. When the drivers start, in a special stage, both the tires and the mousse system heat up, changing the chemical composition and density of the rubber pad. ATS is then activated and ready to work. When the tire suddenly loses air due to e.g. rim damage, the mousse ring immediately fills the interior of the tire (Fig. 7, right-hand). Thanks to its specific properties, particularly in terms of flexibility, the ATS system takes the role of air in the tire. The driver can continue the race without reducing the speed.

Fig. 7 View of the BIB MOUSSE system for motorcycle tires (permanent system) and a sports vehicle tire after damage and activation of the system (Fig. Michelin / www.automobilsport.com/race-categories-24,23584)

3. RUN FLAT system testing

As regarding a combat vehicle, it is important not only to ensure the continuation of emergency drive after the tires have been damaged, but also to control the behaviour of the vehicles in emergency states in various conditions. One should remember that the vehicle should retain its proper steering capacity and stability despite tire damage. Therefore, ROSOMAK S.A. has launched research projects and has conducted its own works on the development of RUN FLAT tires, as exemplified by the project regarding explosive tire damage in multi-axle; special vehicles (project no R00008312). The project was financed by the National Research and Development Centre. ROSOMAK S.A. has implemented this project as part of a consortium headed by dr. Wieslaw Pieniążek, cooperating with the Krakow University of Technology, Gdansk University of Technology, Warsaw University of Technology, Military University of Technology – Faculty of Mechanics, and Military Institute of Armoured and Automotive Technology. As part of the tests, the project partners verified the stability and steering capacity of the vehicle following sudden change of pressure in the tires. Depending on the trials adopted, micro-loads caused an abrupt pressure loss in one or two wheels of the steering axle when driving ahead, braking or when driving on a curve at varying speeds (Fig. 8). The results of the project were used by ROSOMAK S.A. in the vehicle operators training process, and their results were implemented in the training simulator system.

Fig. 8. View of two wheels on the steering axle of a transporter destructed as part of the project (Fig. from the archives of the Gdansk University of Technology)

The research conducted with the Gdansk University of Technology also concerned the rolling resistance of various tires, including RUN FLAT systems applied in KTO Rosomak. Insofar as fuel consumption in military vehicles is of secondary important, however according to research conducted by the authors, rolling resistance coefficient can vary considerably for tires supplied by various manufacturers (Fig. 9), which can be essential for civilian vehicle tires.

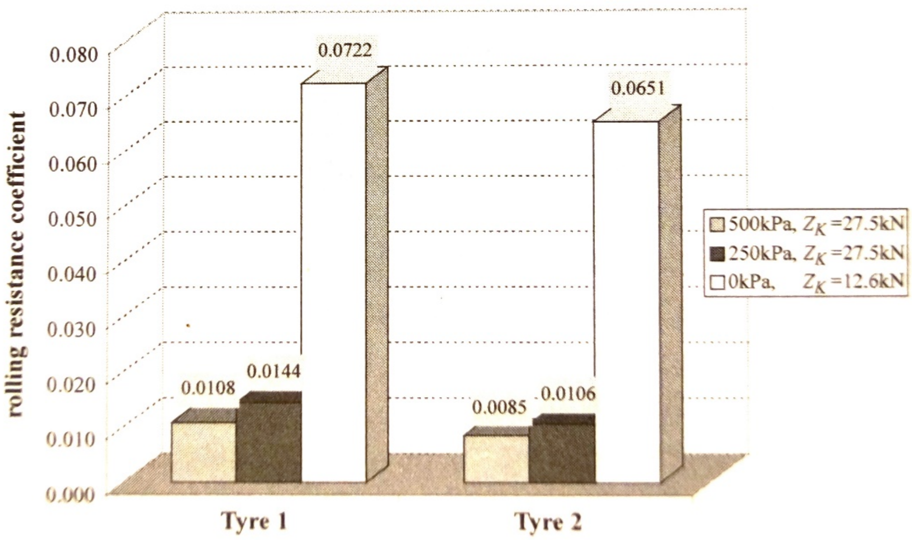

Fig. 9. Rolling resistance specification for two types of RFT tires 14.00R20, applied in a military vehicle [1]

Analysing results presented in Fig. 9, one can clearly notice that for both tested tires, after the activation of the RUN FLAT system (inflation pressure = 0 kPa), the rolling resistance was significantly increased. This results from the pad ring itself, which is made of solid rubber, as well as from tire tread friction on the pad, and internal friction of strongly deflected tire sidewalls. With the simultaneous damage of several tires, this resistance becomes a significant obstacle and can deteriorate the dynamic of driving. Tests of prototype composite wheels prove, in contrast, that the rolling resistance for these wheels, due to the nature of the laminated structure, can be significantly lower to current standard tires (Fig. 10).

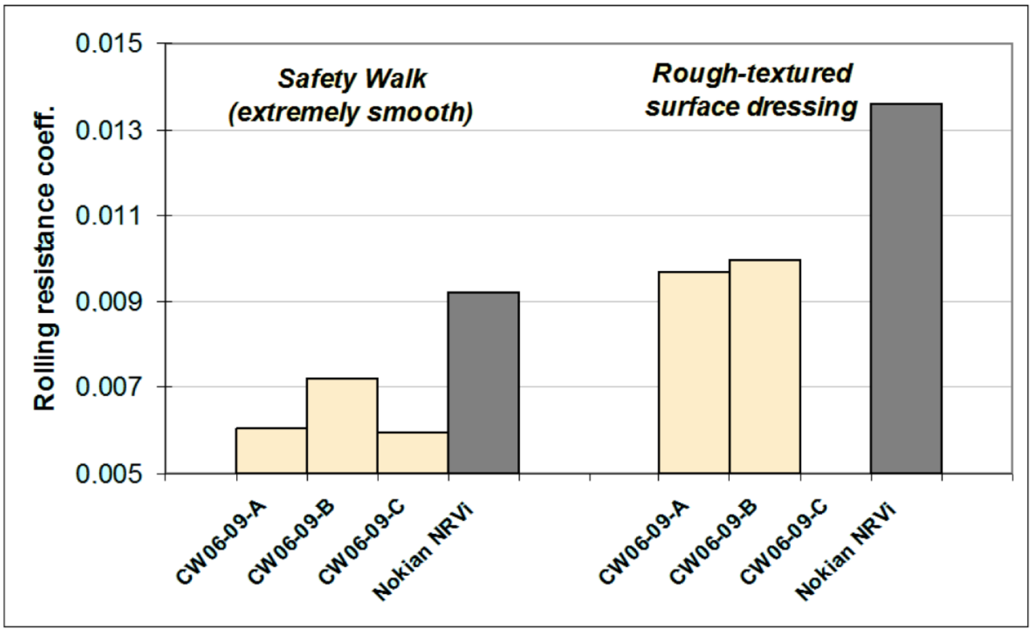

Fig. 10. Composite wheel rolling resistance (CW06-09...) developed in Sweden, compared to a conventional tire (Fig. from the archives of the Gdansk University of Technology)

During the tests, thermal conditions of the tires when driving without the required working pressure were investigated. One should remember that internal friction in the tire during a drive generates a considerable amount of heat, which leads to premature wear of the tire. This is particularly important when the damaged vehicle is to travel a long distance (e.g. to arrive in a remote military base).

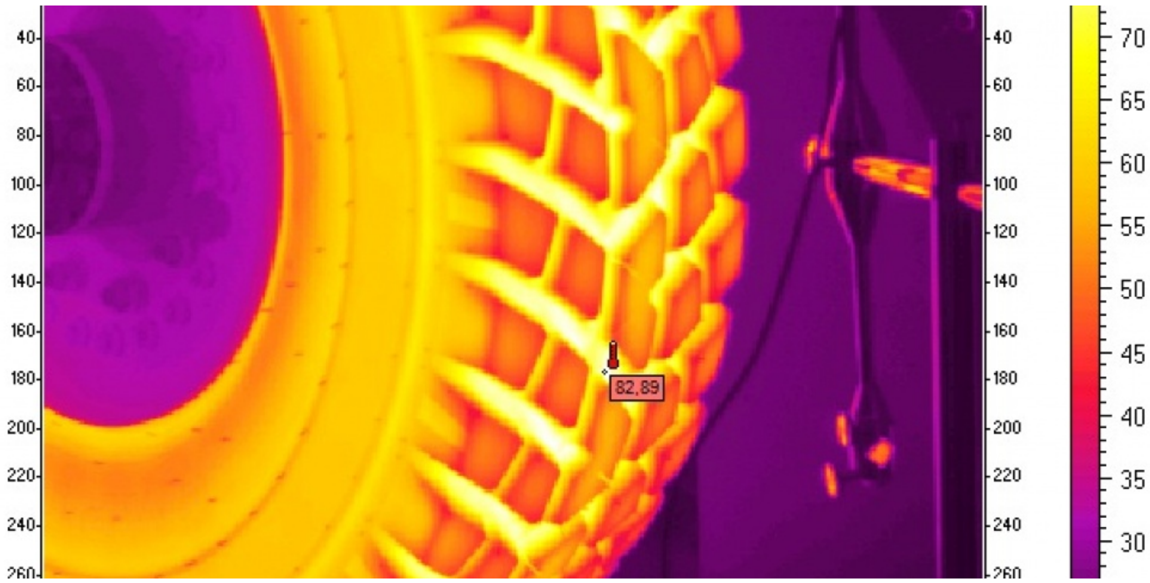

Fig. 11. View of a 14.00R20 KTO ROSOMAK tire from a thermal vision camera, during air-less use on the Gdansk University of Technology road wheel facility (Fig. from the archives of the Gdansk University of Technology)

ROSOMAK S.A. also monitors use of the tires in different conditions. Extensive experience in the use of the vehicles in extreme conditions (such as military operations in Afghanistan) is a precious reservoir of knowledge about tire wear. To verify e.g. the effect of inflation pressure on tire footprint several tests were performed (Fig. 12).

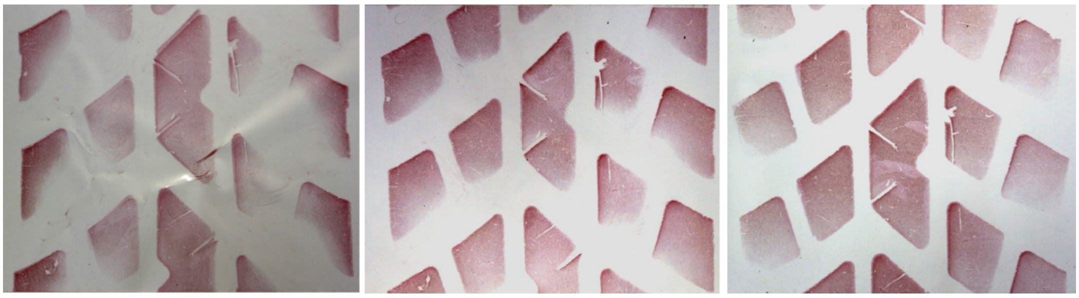

Fig. 12 Comparison of 14.00R20 tire treat marks in the KTO Rosomak transporter equipped with additional RunFlat insert (Fig. T. Nikisz ROSOMAK S.A.)
left-hand photo: inflation pressure 0 bar – visible increased pressure in the central section of the tread (RFT ring action) and in the external sections (pressure produced by the rigidity of tire walls)
central photo: nominal pressure for field driving – visible even distribution of loads
right-hand photo: high pressure – visible increased pressure in the central section of the tread, reduced on the sides.

Fig. 13. Pressure distribution for RFT 205/55R16 tire tread section (tire without rubber insert) – visible increased pressure on the side sections of the tread, resulting from the reinforcement of tire sidewalls, which are in charge of transferring the forces during air-less driving (Fig. P. Stryjek ROSOMAK S.A.)

4. Conclusions

The current RUN FLAT systems applied in military and civilian vehicles allow for traveling distances of several dozen kilometres at approx. 60-80 km/h without inflation. We should remember, however, that during this time, the vehicle should always exhibit very good steering and stability capacity.

The works performed by ROSOMAK S.A., in cooperation with numerous research centres, including the Gdansk University of Technology, have clearly indicated that despite a very good technological level, such systems should undergo further tests. The data cannot be only used in the construction process. In additon what is more important – in the process of training vehicle crews.

The works presented in this article were financed by ROSOMAK S.A. and National Research and Development Centre (NCBiR) (project SPB – RolRes, agreement no PBS1/A6/1/2012).

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