# THE IMPORTANCE OF INTRODUCING THE ONE-WAY VALVES AROUND THE FORKS OF THE HYDRAULIC INSTALLATION OF A HYBRID – HYDRAULIC VEHICLE

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**KEYWORDS** – alternative propulsion, hydraulic hybrid, energy recovery, serial and parallel connection, one way valve.

**ABSTRACT –** The sustainability of the environment is one of the biggest problem with which the mankind is confronting today. Cars release 30 percent of the carbon dioxide in the earth atmosphere. These cars account for 76 percent of the carbon monoxide in the earth's atmosphere [1].

The drastic reduction of the green house gases and the usage of conventional fossil fuels has become an important goal for all government institutions and major car producers. In the same time this pollution reduction must not compromise the comfort and safety of the vehicles. So, the propulsion system development has to answer to some special challenges and requirements. Besides the growing potential of the car park, the advanced propulsion system option has to consider as well the covered kilometers in the developing countries, where the price of the car is the major selling criteria.
This paper aims to highlight the importance of introducing the one-way valves around the forks of the hydraulic installation of a hybrid – hydraulic vehicle. Numerical simulations were made using AMESim software. It was observed that by introducing the one-way valves an increase of the speed with 10% was obtained, without influencing other parameters.

## INTRODUCTION

For the modern driven society it becomes more and more important to build a sustainable development for the environment. To assure this sustainability the $CO_2$ emissions have to be lowered. One of the major participants in the $CO_2$ gas emission production represents the transport sector. Cars produce up to 30% of the carbon gases in the earth atmosphere [2], which represents 76% of all carbon monoxide in the earth's atmosphere [2].

In order to reduce the green house gases and the use of fossil fuels, the transport industry has to think of alternatives for the mobility needs. Some solutions have been found in the electrical car department [3], or solutions that use unconventional fuels like hydrogen and bio-fuels [3]. All these solutions have the disadvantage of the implementation infrastructure and cost, meaning that the car has to be major changed in the technological part to sustain such approaches.

A promising solution is the hydraulic hybrid propulsion system, demonstrated by the results presented by the Environmental Protection Agency in a joint research project with UPS and hydraulic component producers [1]. The results demonstrate up to 70% efficiency improvement in urban traffic considering brake energy recovery and more efficient running conditions for the internal combustion engine that allows downsizing of the engine and lower emissions [1]. So the advantage of hydraulic brake energy recovery is given by a relative cheep technology that is able de store up to 70% of the dissipated energy [4]. Shock absorber recovery was report in the USA by the University of Tuffts [4] using electrical principles and at MIT using hydraulic - electrical principles.

The aim of this paper is to present a new hybrid propulsion system, which is based on the recovery of the translation mechanical energy received from the road profile (force x velocity) and transforming it in hydrostatic energy with the help of the recovery cylinders. So this energy is no more dissipated in the vehicle suspension, where it would have been transformed into heat, instead is recovered with the help of the hydraulic cylinders and used further for vehicle propulsion. This paper's objective is to highlight the importance of introducing the one-way valves around the forks of the hydraulic installation of a hybrid – hydraulic vehicle.

## EXPERIMENTAL LAYOUT

To study the behavior of the hybrid hydraulic recovery system an experimental stand was build.

From Figure 1a it can be observed the parallel connection of the recovery cylinders, especially the introduction of the one-way valves introduced in the "T" shaped connection. These valves play the role of directing the hydraulic liquid column, so to insure minimal losses in for the hydraulic power. The energy recovery installation is presented in figure 1b. From this figure it can be observed the hydraulic alimentation line from the pressurized tank of the installation.

a)

b)

Figure 1: Parallel connection of the recovery cylinders: a) mounting of the one-way valves around the "T" connection, b) detail of the pressurized tank integrated in the installation circuit.

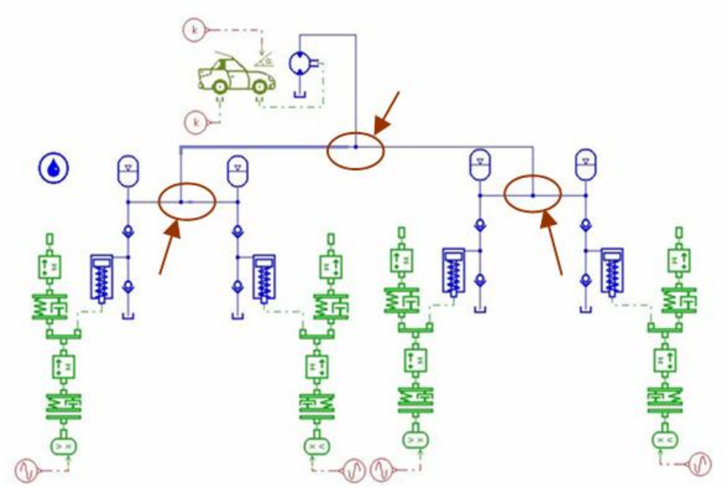

Figure 2: Detail of the “T” zones where the one-way vales must be installed.

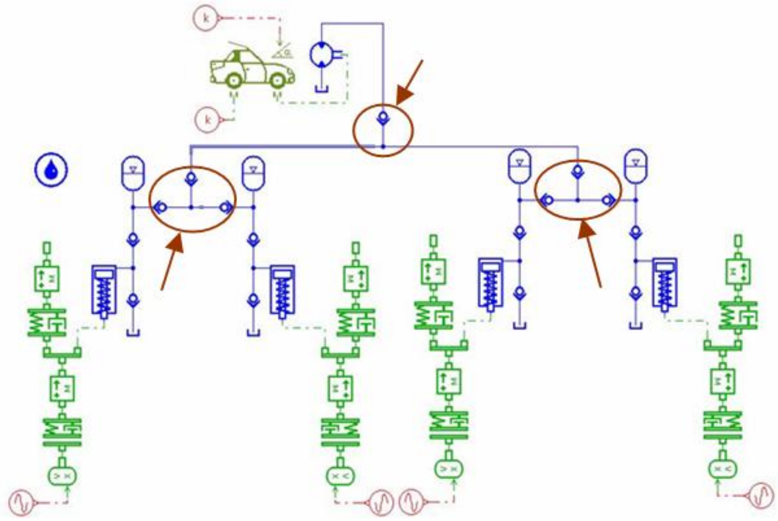

Figure 3: Detail with the installed one-way valves.

Using the AMESim software [5], virtual simulations were made considering as input data, the values shown in Table 1.

Table 1: Input data

| No. | Input data | UM | Value |
|---|---|---|---|
| 1 | Bumper frequency | Hz | 30 |
| 2 | Bumper height | m | 0,005 |
| 3 | Tire mass | kg | 37 |
| 4 | Tire damping degree | N/(m/s) | 560 |
| 5 | Vertical stiffness of tire | N/m | 322 000 Bridgestone Turanza RFT;<br>874 000 Michelin Radial 11R22.5 XZA |
| 6 | Spring Rate | N/m | 39170 |
| 7 | Damper Rating | N/(m/s) | 2000 |
| 8 | Mass of Vehicle | kg | 400 |
| 9 | Recuperative Piston Diameter | mm | 45 |
| 10 | Tank Pressure | bar | 30 |
| 11 | Gas Precharge Pressure | bar | 100 |
| 12 | Accumulator Volume | $dm^3$ | 7.5 |
| 13 | Motor Displacement | $cm^3/rev$ | 33 |
| 14 | Vehicle frontal surface | $m^2$ | 3 |

## RESULTS AND DISCUSSIONS

The numerical simulations were made with the help of the AMESim 8.0 software [5]. Starting with Figure 4 it can be observed the difference between the model with one way valve around bifurcation T and the model without one way valve, when using two types of tires with different vertical stiffness values, 322000N/m for the Bridgestone Turanza RFT [6] and 874000N/m for Michelin Radial 11R22.5 XZA [6] tire. In the case when using a set of tires with vertical stiffness of 874000N/m and one way valve around bifurcation T we obtain a recovered speed of 41.6m/s compared to 38.8m/s when no one way valve around bifurcation T was used. Also it can be observed that the difference between these two models is 6.7% when using Michelin Radial 11R22.5 XZA tire and when using Bridgestone Turanza RFT tire, the difference is 10.9%.

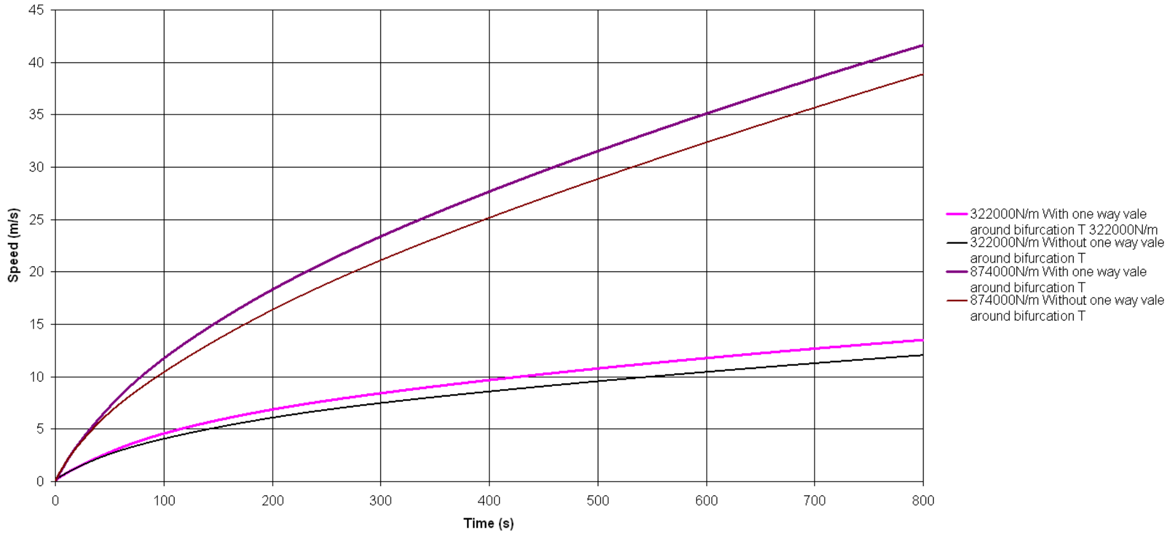


Figure 4: Speed of hybrid hydraulic vehicle.

From Figure 5 it can be observed that the pressure form the installation has a small fluctuation.

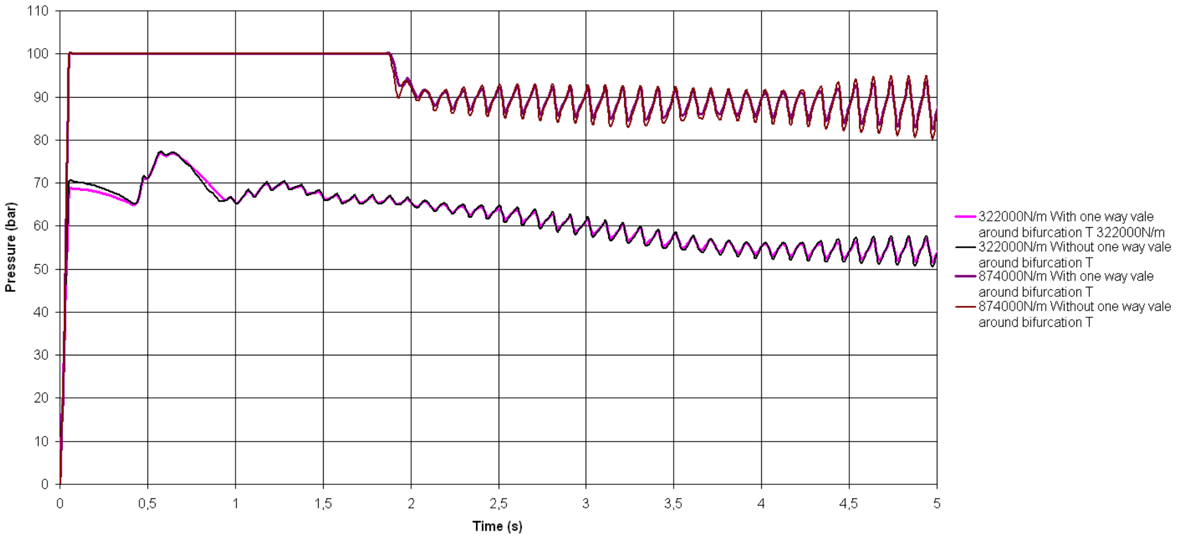


Figure 5: Pressure of hydrostatic motor.

As can be seen from Figure 6 the fluid flow in the recovery installation is directly proportional to the increase of the recovery speed, for a 41.6/s speed, the installation will debit 132.7L/m of hydraulic liquid for a vertical stiffness coefficient of 87400N/m. Compared with this value it can be stated that if rolled with a set of Bridgestone Turanza RFT tires with a vertical stiffness coefficient of 322000m/s the recovery speed will be only 13.5 m/s and the flow is only 43L/min.

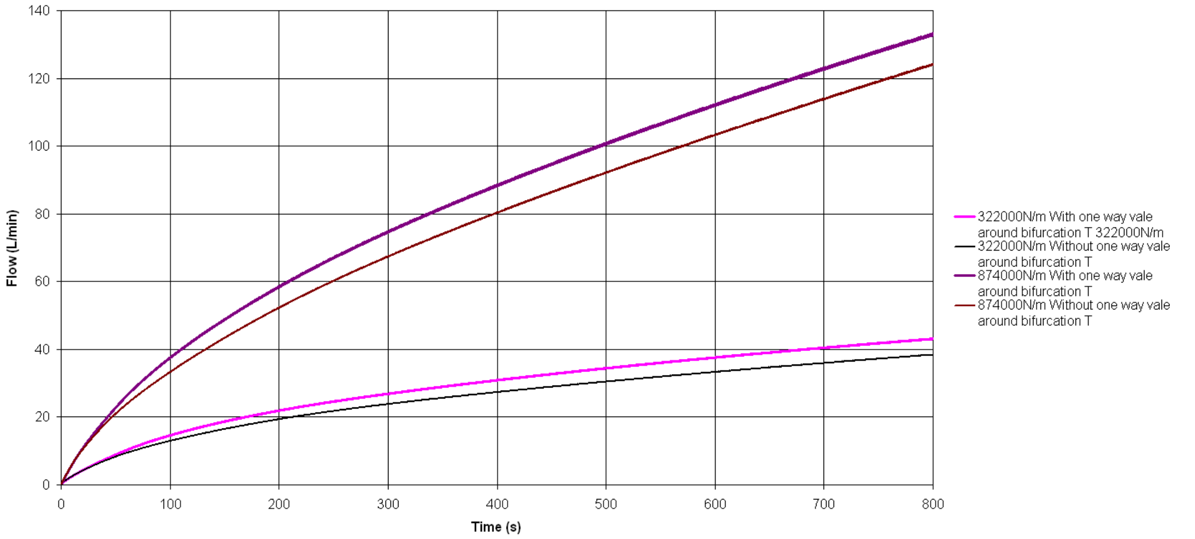


Figure 6: Flow of hydrostatic motor.

The vertical displacement, shown in Figure 7, of the vehicle is influenced in small extend by the vertical stiffness coefficient of the tire, the one-way valve has no influents on vertical displacement, and this because almost all the received energy from the unevenness of the road is captured with the help of the recovery system and transformed in mechanical work.

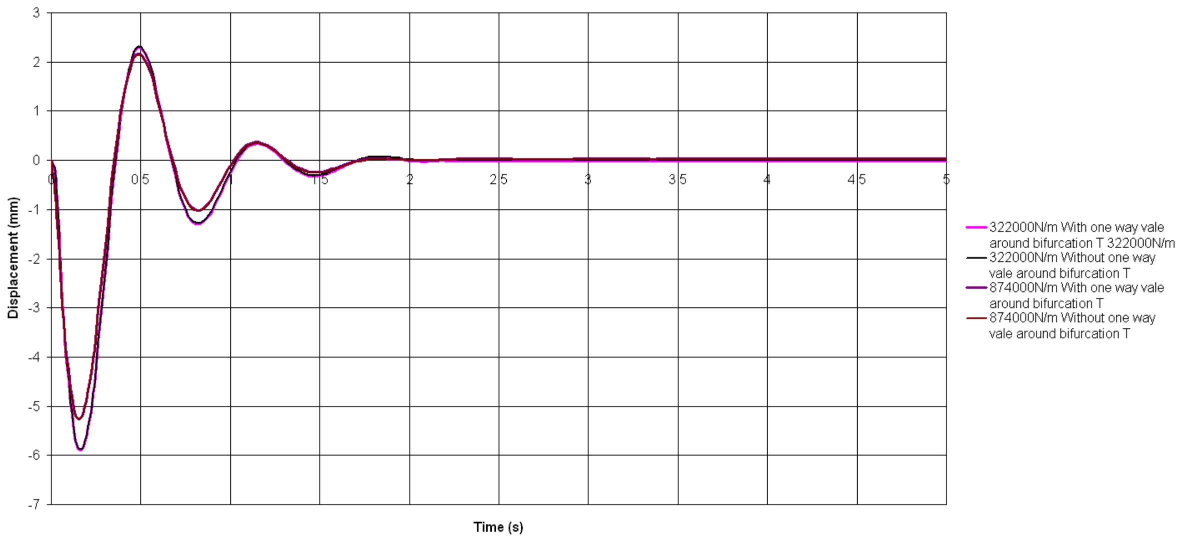


Figure 7: Vertical displacement of the vehicle.

## CONCLUSIONS

The research focuses on a hybrid hydraulic suspension energy recovery system. By introducing the one-way valves around the forks, "T" zone, of the hydraulic installation of a hybrid – hydraulic vehicle an increase of the speed with 10% was obtained, without influencing other parameters. Based on the simulations we can say that by using two tires with two different vertical stiffness coefficient it was observed that the rigid tire (874 000 Michelin Radial 11R22.5 XZA) recovers more energy from the road oscillation compared with Bridgestone Turanza RFT tire. In the case when using Turanza RFT tire and the recovery system has one way valve around bifurcation T the speed and flow is greater with 10.9% compare with case when no one way valve around T bifurcation was used. When using the Michelin Radial 11R22.5 XZA tire this difference becomes 6.7%. In conclusion we may say than one way valve around bifurcation T is very important for the correct direction of flow column.

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