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FUNCTIONAL CHARACTERISTICS OF ACTIVE SUSPENSION SYSTEMS FOR AGRICULTURAL TRACTORS

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ABSTRACT

Suspension systems are generally used to improve the comfort degree and to diminish or totally avoid injuries caused to drivers (and passengers) when the vehicle is moving on a regular road, usually having irregularities. Some other important functions of the suspension system of one vehicle are to provide driving stability, to maintain a permanent contact between vehicle and road surface, to protect the road surface from damages caused by excessive pressure forces of tires. Active suspension systems are in fact modern closed loop control systems that use all the elements of an automated system: electronic regulator, driving electro-actuators, electronic transducers and signal conditioning devices. Active suspension systems can be programmed to work as passive (classic) suspension systems, but the main goal is to achieve better comfort and improved overall handling of one vehicle at same time.

INTRODUCTION

Agricultural roads are generally uneven in terms of roughness and soil type, causing the vehicle (tractor) to vibrate, wobble and have poor handling capabilities, these all conducting on driver's side to excessive forces applied on his spine – leading to medical issues, to poor overall stability of the vehicle in terms of acceleration, braking and turning and to some damages of road's surface caused by excessive pressure forces of tires. Strong mechanical vibrations induced in the vehicle chassis are another negative aspect of an inappropriate suspension system.

Passive (classic) suspension systems have, initially, constant characteristics, but due to mechanical wear these vary in time, leading to weak driver comfort and low vehicle stability. A classic suspension system comprises a spring and a damper, mounted in parallel, and a linkage system to vehicle wheels and chassis. Agricultural road unevenness causes shocks that are absorbed by the spring, while the damper dissipates the energy of suspension's vibrations. A good suspension design must be located at the intersection of driver comfort and vehicle stability conditions, therefore a compromise.

One of the most important features of suspension systems, either passive or active type, is concerning the stability of the vehicle, here the agricultural tractor. Vehicle stability is strictly related to suspension's working parameters providing safety while having a close contact area between the agricultural road's surface and vehicle's four tires. In a worst case scenario, an agricultural tractor with poor stability can cause serious health issues to the driver (and passengers) while having weak maneuverability in terms of braking, accelerating or turning even when a simple, but fast, acceleration or braking is applied. Safety comes first all-time, therefore vehicle's stability can be considered as the most important parameter of a suspension system before driver (passenger) comfort. Furthermore, vehicle stability can be seen as a function of many variables such as: resistance against tractor's chassis motions, amount of weight transfer from back to front in tractor's chassis, amplitude of vertical vibrations of tires, agricultural road unevenness, centrifugal forces during turning and tire contact forces. As can be seen, developing the

ideal passive suspension system that can satisfy in the same time the optimum conditions in terms of comfort and stability, is very difficult.

When dealing with agricultural tractors, the development of an optimal passive suspension is even a bigger problem due to the higher center of gravity and total mass value resulting in low stability. Some of agricultural works need constant and increased tractor speed which adds another variable when developing the optimal suspension system.

Redesigning the suspension system of agricultural tractors and therefore stepping towards active suspensions assume using, at least, electrohydraulic closed loop control systems. New electronic technologies, especially microcontroller powered boards, can make an improvement in developing active suspension systems that provide flexible – programmable – working characteristics and new facilities.

ACTIVE SUSPENSION VS. PASSIVE SUSPENSION SYSTEMS

As written above, passive or classic suspension system for agricultural tractors comprises at least one spring and one damper used to store and dissipate vibrations' energy values. Features and working characteristics of passive suspensions are not flexible and cannot be modified according to constantly changing requirements that appear when performing agricultural works. Furthermore, these features and characteristics decrease due to mechanical wear and working environment characteristics, resulting in loss of comfort or stability or both.

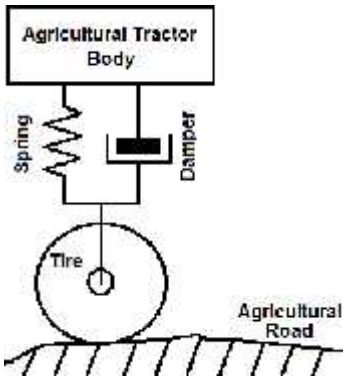

Fig. 1 *– Passive (classical) suspension system*

Taking the example of modern cars, agricultural tractors have adapted the concept of active suspension systems to their field of activity and demands. Classic mechanical spring and damper structure have been replaced by a similar structure developed using electronic controlled fluidic equipment, adding new adaptive and programmable features to suspension systems by means of electronic technology. It can be said that active suspension systems are the first step to intelligent agricultural machine control. This type of suspension systems have, in theory, unlimited performances in terms of stability, comfort and features but are limited by certain mechanical parameters.

Active suspension systems of agricultural tractors use the basic principle of electronic closed loop control, designed for compensating low or high frequency vibrations, according to application's needs, being able to dissipate suspension energy or to store, covert and consume the supplementary energy, somehow similar to energy recovery systems found in modern cars.

Returning to the passive (classic) suspension system, the spring – damper system can only store and dissipate vibration energy, while an active suspension system can perform these two and one more, namely adding an even more amount of energy to the one already existing in the system. The amount of added energy is calculated using an

electronic microcontroller programmed with proper control software, having as input information the signals given by electronic transducers of main functional parameters. Afterwards, the output, a computed electronic signal is applied to an amplifier and fed to an electromechanical actuator (or actuators).

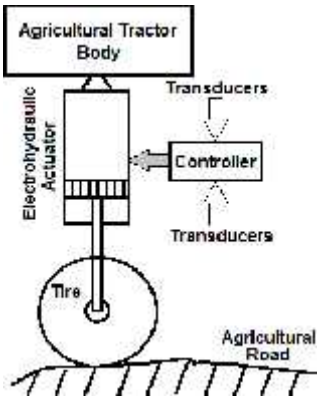

Fig. 2 *– Active suspension system*

The electronic controller used in Fig.2 has a dedicated management software designed to regulate suspension working parameters, according to a specific control algorithm and transducers' inputs, in the system's range of frequencies (natural frequencies of tractor's body and tires). Active suspension systems are designed in such a way that the electronic controller takes into consideration the entire range of frequencies of the suspension system, therefore achieving a full control of mechanical vibrations. However, the intersection of optimal driver comfort and high tractor stability control has to have a price to pay. This type of active control conducts to significant power consumption and will certainly lead to increased fuel consumption.

Another decent aspect to take into consideration is that accurate control needs fast actuators, furthermore leading to increased total costs of the suspension system and to a higher structural complexity that require specialized personnel to perform the installation and maintenance. Active suspension systems have high dynamic performances against passive suspension systems, but their development, installation and maintenance costs recommend them for special applications only.

Active suspension systems have an electrohydraulic actuator as the main equipment that controls suspension performances. Critical failure of the electrohydraulic actuator, electronic board failure or software errors lead to critical failures in meeting the conditions for driver comfort or tractor's stability, that in some particular cases can cause dangerous or potential life threatening conditions. The solution to overcome this drawback is to mount a passive suspension system in series with the active suspension. The passive system will act as a buffer when the active system will rarely encounter a failure, therefore reducing the risk of potential dangerous working conditions. The passive system mounted in series with an active system it is designated to improve only the dynamic response of the tractor's suspension in the range of natural frequencies of its chassis.

General practice of using passive suspension systems on agricultural tractors show that low frequencies range performance is somehow similar to active suspension systems. These systems have acceptable good stability during braking, accelerating and turning maneuvers against active suspensions systems, but the major gain is the lower energy use. Using these passive systems beside the active systems reduce the critical failure modes.

Active suspension systems designed to meet the requirements of controlling an agricultural tractor driver comfort and stability have high dynamic performances, but usually are not recommended due to the heavy weight of such vehicles – leading to high

energy consumption. One acceptable solution is that an agricultural tractor manufacturer can use the active suspension system only for the driver's (passenger) compartment, while the other is a passive (classic) suspension system.

CONCLUSIONS

Active suspension systems suited for agricultural tractors are probably the best solution for reducing vibrations caused by agricultural road unevenness and tractor's braking, accelerating and turning regimes, but the high energy consumption, high cost and complexity of development, installation and maintenance can be seen as major drawbacks.

There can be recommended that a hybrid solution made of an active and a passive suspension system shall be used due to the functional characteristics and features discussed above, but the passive part shall be used for the tractor's chassis suspension and the active part for the driver's compartment only.

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