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Development of an Experimental Active Suspension System *(Final Report)*

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DEVELOPMENT OF AN EXPERIMENTAL ACTIVE SUSPENSION SYSTEM

FINAL REPORT

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SUMMARY

This document is the final report for Contract Serial No. W7702-8-R033/01-SG entitled "Development of an Experimental Active Suspension System". The work was sponsored by the Defence Research Establishment Suffield (DRES) with D.M. Hanna as the Scientific Authority at DRES.

The ultimate goal of the project was to produce a working prototype of an active suspension mounted on a Canadian Forces Iltis 1/4 ton utility vehicle. The suspension has been designed, built and installed and is in the process of undergoing testing at DRES. The details of the system are described in companion reports which are referred to in the body of this report.

Contents

1 INTRODUCTION

The level of vertical accelerations experienced by the driver, passengers and payload of rubber tired vehicles is governed by two factors: the disturbing input arising from the terrain and the suspension system. The first of these is the direct cause of the accelerations and the second is designed to attenuate such disturbances in an effort to produce good ride quality.

It has been common practice over the years to think of a suspension system, composed only of elastic and damping elements, as providing a passive filter for the disturbing inputs. The level of attenuation is therefore a frequency dependent function with very large accelerations possible as terrain input frequencies approach the natural frequencies of the system. Only in recent years has there been an attempt to incorporate an active feature to the suspensions.

Ideally, an active suspension consists of sensors which can predict the occurrence of disturbances in time to cause actuators on the vehicle to respond in an optimal manner. This will result in minimal undesired motion being apparent onboard the vehicle. It is a relatively simple matter to visualize the concept but it is not easy to produce such a system in any practical sense.

The physical components of the ideal active suspension system must have large force capabilities and be able to respond very quickly to a perceived disturbance. The power requirements of this system would be immense. In addition, the on-board sensors would be required to have very quick response and to be able to make an intelligent choice between the different actions which are possible in response to an input.

The ideal system does not exist. There are many approaches to active suspension design currently being taken and, as yet, there is no clear direction seen as being better than all others. Yet it is apparent that active suspensions are definitely coming in one form or another. It is very likely that many competing systems will appear on the market in the next several years, each claiming to be superior. It is also likely that each claimant will have valid arguments to make but it is unlikely that any one system will be suitable for all vehicle types.

For those, like the Canadian Armed Forces, who have a requirement for many vehicles each with the best possible ride quality, it is appropriate to develop a means of comparing competing schemes for producing active suspension systems. The work described here was aimed at developing an experimental active suspension system for a 1/4-ton rubber tired vehicle, the Iltis. This was not an attempt to develop another active suspension concept, but rather to produce a system which has the flexibility to reproduce the action of a variety of commercial active suspension systems. In this way, their ability to control the ride quality of the Iltis could be compared objectively through full-scale testing.

2 THE APPROACH

An initial step in the project was to undertake a comprehensive survey of the literature in order to establish the state-of-the-art in active suspensions for road vehicles.

Next, the goal of producing a means for testing competing active suspension systems was addressed in two ways.

Firstly, the design and implementation of an active suspension system for the Iltis was undertaken. The system, as installed, has the ability to mimic the control schemes and performance of a variety of commercial systems. For the user, it is simply a matter of providing a software description of the control scheme to be tested. The hardware, both transducers and actuators, installed on the Iltis is very capable and able to accommodate almost any desired controller.

Secondly, it was necessary to provide a computer simulation capability for active suspensions. The simulation software provides a tool for understanding the results of tests performed on the Active Iltis and for evaluating systems which have capabilities beyond those of the experimental system envisioned here.

The active suspension system for the Iltis provides flexibility of use through micro-computer based data acquisition and control hardware. There are four hydraulic actuators consisting of packaged cylinders and servovalves mounted on the vehicle, one allocated to the suspension at each of the four wheel locations.

Development of the hardware and software package necessary to implement a flexible micro-computer based controller was a major component of this project. The system had to be capable of reading sensor information, deciding on appropriate control signals for the actuators, and sending the correct analog signals to the servovalves.

The following sections describe the project briefly and make reference to accompanying documents which contain detailed descriptions.

2.1 Review of the State-of-the-Art

A necessary first step in the project was a comprehensive survey of literature and current efforts by companies and laboratories in order to establish the state-of-the-art. This work revealed the goals set for active suspensions and many of the control schemes which were being used. It provided a solid basis for continuing with the development of the system for the Iltis using the knowledge developed by numerous other researchers. This initial effort resulted in the report by Tregenza [1] which gives details of the state of knowledge regarding active suspensions, both hardware implementations and control concepts.

2.2 Concept Design

This task was concerned with developing a concept design for the active suspension system. The conceptual design is described by Tregenza [2], covering all aspects of the hydraulic system, the transducers, and the computer interface. The conceptual design, once complete, gave a set of goals for the active suspension and a sense of which directions should be followed for the final design and implementation.

Using this approach, it was possible to determine the basic characteristics of the system in a well controlled environment. The frequency response characteristics of the active suspension were established and it was found that the combination of pump, actuators and controllers behaved well up to nearly 20 Hz. This is well above the frequencies of most interest for ride control and the system was considered to be excellent for its stated purposes.

2.5 Vehicle Installation

Once laboratory testing has been completed, the system was removed from the Engine Laboratory and installed on the Iltis supplied by DRES. The installation was performed at Queen's University and the vehicle was tested locally to ensure proper operation of the active suspension system.

Installation consisted mainly of moving the system from the lab to an equivalent mounting arrangement within the vehicle. Problems with onboard power supplies and the physical location and fixation of all components were addressed as part of this task.

Once the installation was complete, the test vehicle was operational and ready to proceed to field testing.

2.6 Field Tests

This was the final task in the experimental phase of the project and was undertaken to confirm successful operation of the system on the Iltis.

There were two types of tests. The first type used the actuators to provide a forcing input to the vehicle on level pavement. In this mode of operation, it was possible to use the control system to produce predetermined acceleration levels within the vehicle. Many of these tests were performed and all of the results have been previously provided to DRES in graphical form.

The results of the tests were to confirm that the installed system was as capable as predicted from laboratory tests. Both the step and frequency response tests gave excellent results. The system is capable of very quick response and is well suited to the needs of DRES in testing competing control schemes.

Due to the lack of a certified driver for the Iltis at Queen's it was difficult to conduct experiments with the vehicle in motion. Some testing was done at CFB Kingston during a visit by the Scientific Authority who is a qualified driver. This involved a control strategy having the roll angle of the vehicle tied to steering wheel motion. An appropriate choice of gain on the control could then lead to a vehicle which experienced essentially no roll angle when traversing a slalom course. A trial and error process was used to choose the gains and tests were conducted over a slalom course. Only qualitative results are available from those tests but there is no doubt that the active suspension performed as expected. It was found that the handling performance of the Iltis was much enhanced over the course through the use of the active suspension.

2.7 Simulation of Active Suspension Systems

The simulation of vehicles with active suspension systems was conducted using the A'GEM Road Vehicle Dynamics Software package. An early version of this software resides at DRES and the most recent version is being prepared for delivery at the time of writing this report.

The simulation of the Iltis required an accurate description of the vehicle in a form suitable for producing a dynamic model. Determination of the parameter values resulted in the production of the "Iltis Data Package" [5]. The data presented there are those used for simulation results.

In addition to vehicle parameters it was necessary to quantify the surface profile which would act as a forcing input for the dynamic simulations. The standard off-road NATO profile called APG31 was used as a test case. The profile was provided by the Scientific Authority and is used in both the time-domain and frequency-domain versions of the software. The conversion of the spatial representation of the profile to a PSD spectrum is described by Langlois [6].

Langlois [7] also performed a large number of simulation cases for the Iltis. These are described in [7] and [8] which were previously provided to DRES. Demonstrating the capability of simulating whole vehicles under the control of active suspensions was an advancement of the state-of-the-art in this area. Active suspension control systems were and continue to be designed on the basis of fairly simple 1/4 car models which cannot account for the coupling of roll and pitch motions with the heave of the vehicle.

The simulations could not be fully validated with the available experimental results. They did however give good qualitative agreement and demonstrated the ability to incorporate the full vehicle in the analysis of the controller using this simulation technique.

3 CONCLUSION

The goals of the original project have, to a large extent, been met by the work carried out under this contract. An Iltis vehicle with a very capable active suspension system has been delivered to DRES and is now being tested. They can now confidently test competing control schemes for active suspension systems. A simulation capability for active suspensions has been developed and continues to be modified for more complex non-linear suspensions and incorporation of four-wheel steering. CAD pre- and post-processors are the latest development in this area and they are nearly ready for delivery to DRES.

4 REFERENCES

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