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Suspension System Testing and Tuning with the Use of a Four-Post Rig

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ABSTRACT

One of the hidden aspects of the past Formula One season was the use of indoor road simulators as a mean of speeding up the springing and damping set-up over the race weekend. According to the rumours some teams can perform an indoor set-up optimization overnight by reproducing freshly acquired road profile data. The optimized set-up is then communicated back to the team and tested on-track the day after.

The optimization is carried out on a so-called hydraulic four-post rig (or seven-post rig), where a car is shaken at such frequencies and amplitudes to reproduce the same inputs and forces encountered during a typical circuit lap.

The Vehicle Dynamics Group of the University of Brescia has recently acquired a four-post rig by Servotest England. The paper aims to describe this facility while future papers will describe the first results obtained in research.

INTRODUCTION

At the Mechanical Engineering Dept. of the University of Brescia a research group has been involved in Vehicle Dynamics for quite a few years, with particular regard to racing cars.

All the work, which has been published in various papers and degree thesis, was carried out in conjunction with primary teams as well as car and component manufacturers like FIAT (the FIAT Research Centre), Dallara, Minardi Formula 1, BMS Scuderia Italia, Nissan Motorsport Europe, CF Gomma etc.

The design of racing cars is more and more undertaken with the help of mathematical models, which in general aim to the evaluation of the behaviour of the vehicle as well as of separate components on road and track. This is often done before the vehicle or the component in itself is designed and built. The same need is even stronger when designing a passenger car.

It should also be underlined that the time of approximate and “qualitative” models is now over; by now the difference between an average and a winning car is extremely reduced in percentage hence models must be extremely accurate i.e. with narrow tolerances. This means that any mathematical model should be calibrated and validated with the help of accurate experimental tests.

It is well known that the experimental validation takes time and needs proper tools and physical models, supported by experience and skill. Optimization of the resources is required to reduce time loss and the need for physical models to a minimum.

For this purpose the Department of Mechanical Engineering recently acquired a so-called Four-Poster Road Simulator, shown in Figure 1.

This paper aims to describe this tool and its purpose.

THE TESTING RIG PLANT - HARDWARE

The road simulator is substantially composed of four small platforms where the vehicle can be leant. As each platform is properly adjustable all the four wheels can be positioned in such a way to reproduce the running setup of the vehicle.

Each platform can be activated in a vertical vibrating mode to reproduce the vibrations induced by the road profile when running. As a matter of fact the platforms are fitted on special hydraulic actuators connected to a hydraulic power unit and driven by a complex computer controlled system. Figure 2 shows the system general layout.

The Hydraulic power unit is composed of a tank with a cooling system, an electric piston pump, a group of control valves and the related control panel and ancillaries. The performance is pretty high but it also involves various problems regarding vibration insulation, cooling, and sound proofing.

One high pressure, large section pipe runs from the power unit to the distributor while a similar one works as a return line. Other eight hoses take the high pressure fluid from the distributor to the actuators and back (figures 3 and 4).

It should be noticed that the actuators' motion control is performed by servo-valves fitted on the actuator cylinder body. This is necessary to guarantee a precise high frequency response and avoid any distortion induced by the hose elasticity. For instance, a sinusoidal motion could turn out to be asymmetrical producing resonance at certain frequencies.

A set of three high-performance Moog servo-valves -controlled by the PC- is fitted on each actuator. The PC can compare the desired position with a feedback signal and correct it in real time independently from any loads, thermal or dynamic disturbances.

The actuators are hydraulic servo cylinders. The feedback signal is supplied by high-precision position sensors (LVDT type) fitted in an oiltight compartment inside the shaft. There is no traditional sealing or shaft guide; there are instead no-friction, hydrostatic bearings.

Small pressurized, membrane-type plenum chambers can smooth eventual fluid hammering effects when sudden flow rate variations occur.

The operator can control the system via the software front-end, which allows either control of the power unit as well as programming, control and data processing. The only additional operations are turning the main switch on and opening the water cooling valve.

Control of the actuators can be operated in position, acceleration or force mode (load cells will be integrated in the system soon), while the implementation of three additional actuators to exert inertial load transfer and aerodynamic forces is being evaluated.

THE TESTING RIG PLANT - SOFTWARE

The control software has been specifically developed for automotive use within the MatLab package. It is equipped with a professional and effective interface, but it also has an open structure. This means it is possible to integrate user functions and routines.

Such a software architecture has been one of the main criteria when choosing the system among the other ones available on the market, since it was deemed that within the Department there were either skill and interest to explore innovative additions to the software.

The main software modules are:

- **DCS datalogger** - acquisition module
- **DCS scope** - virtual oscilloscope
- **DCS replay** - module for reproduction of outdoor recorded files
- **DCS filter** - data filtering module
- **DCS Wavegen** - signal generator
- **DCS Block Prog** - signal sequencing module
- **ICS (Iterative Control System)** - allows the generation of a road profile signal (in acceleration form) starting from outdoor recordings (e.g. acceleration of the unsprung masses).

APPLICATIONS

The road simulator allows to reproduce road inputs previously recorded on the road, as well as mathematically generated signals.

The last type of test aims at either taking the loads exerted on the vehicle to the extreme or at investigating peculiar aspects of the vehicle behavior. For instance, tests aimed at determining frequency response and transfer function of vehicle systems and components.

A typical use is suspension testing where the target is an improvement of either comfort and driveability. Load cases like riding over a step or a pothole can be analyzed with particular attention to how the impact propagates through the vehicle chassis components. This sort of testing is particularly suitable for validating and adjusting previously created mathematical and/or software models.

Fatigue testing is aimed at exposing machines and components to a stress level capable of showing eventual structural weaknesses quickly, while real life could make the same failure occur after months or years of everyday usage.

Another subject suitable for studying with the use of the Four-Poster is the so-called NVH (Noise, Vibration and Harshness) analysis, aimed at picking out noise sources and improve the global acoustic comfort level.

The above tests can be performed through sinusoidal forcing vibrations with variable amplitude and frequency, as well as with resonance tracking techniques; actuators can be moved with variable laws and phases or even with various random vibration sets.

Moreover, the test system can be used in other original ways. For instance at the Mechanical Engineering Dept. some research work was done on active suspension systems for road and racing cars. Testing such an active system would imply putting it in competition with the actuator. For this purpose a set of fixtures is currently being designed; Two hydraulic units will be used and they will be controlled by the above mentioned front end.

All the research and design work is carried out as a cooperation between teachers, researchers and students, and it is kept updated with the response of external teams and manufacturers.

The availability of this facility should speed up the research in the vehicle dynamics field and it should also prompt the cooperation with industry, with mutual advantages. Moreover, the students attending the Degree

Course in Mechanical Engineering will be able to experience real-life testing and development.

CONCLUSION

The Vehicle Dynamics Group of the University of Brescia has recently acquired a four-post rig by Servotest England. The paper has described this facility while future papers will describe the first research results.

REFERENCES

1. Four-poster and DCS user's manuals, Servotest England.

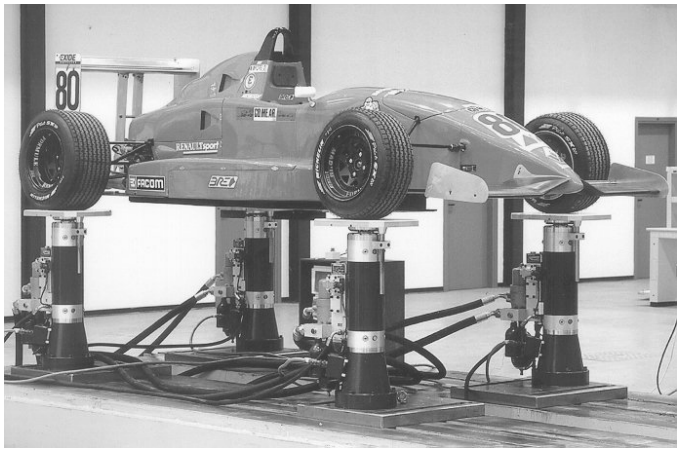

Figure 1. The Four-Poster test rig

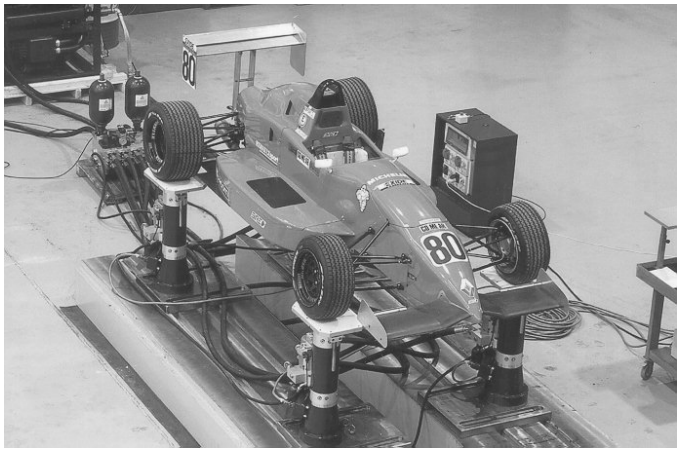

Figure 2. General layout of the system

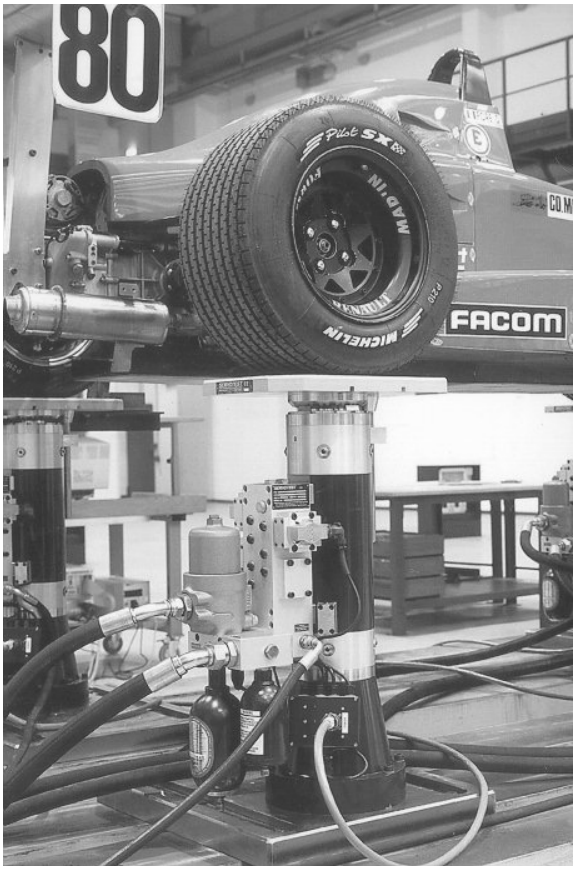

Figure 3. One of the hydraulic actuators

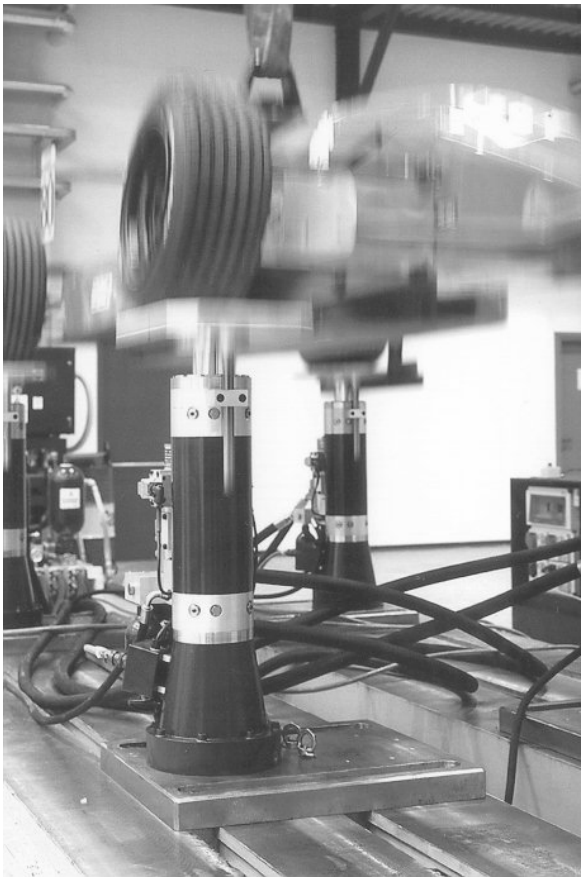

Figure 4. The four-poster at work