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ABSTRACT

The objective of this work is to provide the engineering department with a simple and useful tool to predict the valve pieces to be used in a shock absorber during the design phase, in order to diminish the experimental work to be done during the vehicle ride test and prototype manufacturing. This tool is a group of equations that can predict the force behavior of the shock absorber and the corresponding valves according to the preliminary shock absorber force x velocity curve defined by the vehicle suspension engineers.

INTRODUCTION

This project about Shock Absorber Mathematical Modeling is concerned with equations that lead us to know shock absorber force related only to valve code, through measurements and experiments. Such model will support new valve codes creation. At first, we worked with 35-mm diameter piston but it is possible to extend that model for others, for example with P.T.F.E. piston ring.

We tried to isolate and to simplify the shock absorber real effects through boundary conditions in order to measure each effect separately and to compare real with theoretical behavior. The shock absorber with traditional design consists in three sets of valves. One group is in the piston assembly and another similar in concept in the base valve. The piston valves control mainly the rebound phase and the base valve the compression phase. (Fig.1).

As the bleeds, springs and blow-off present different energy dissipation, each one must be modeled separately and total effect in the shock absorbers shall be obtained by the “blending “ of the curves in the transition of the valve operation.

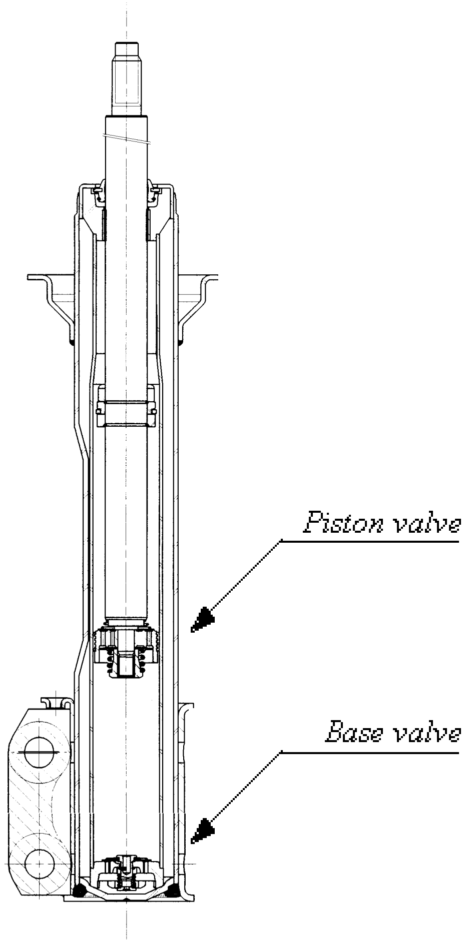
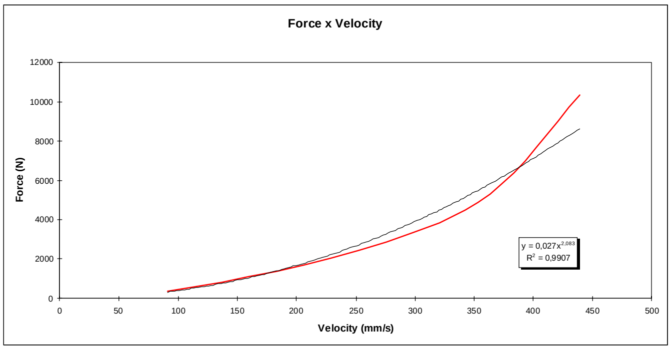


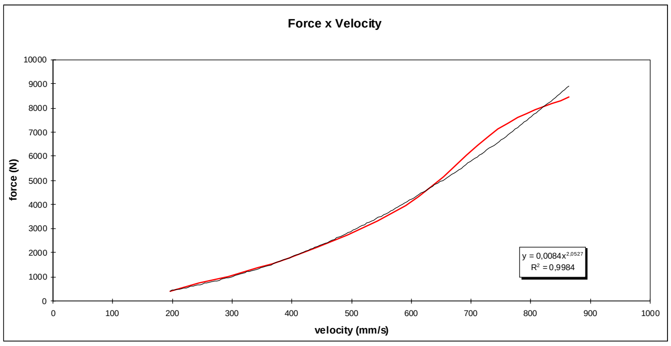
Fig.1 – Shock absorber components

BLEEDS VALVES APPROACH

We start with bleed valves measurements because that's the first effect when shock absorber is running at low velocity (below 100 mm/s theoretically). Before defining the experiments we must understand bleed valve features. Broadly speaking, bleeds are small passages (10^{-2} $mm^{2)}$ that control piston oil flow. The first problem was how to neutralize other variables that interact in shock absorber behavior. We changed the shock absorber structure blocking the disc movements (replacing the spring by a washer). That block would lead us to a stringent condition if we increase the velocity. Experimental calculations provided a maximum force value (9000 N), so we extended our tests to this critical value. Let us now summarize the procedure to the measurements. By the valves code table, we selected a piston and then choosen eleven bleeds samples which provide equations shown in table 1, where bleeds code is an item related to passage area, v is a velocity in mm/s and R^2 is a error factor that is better as it approaches to one (1 is perfect). After we tested the shocks and were obtained the following curves, where the thin line is the model and the thuck is the experimental result.



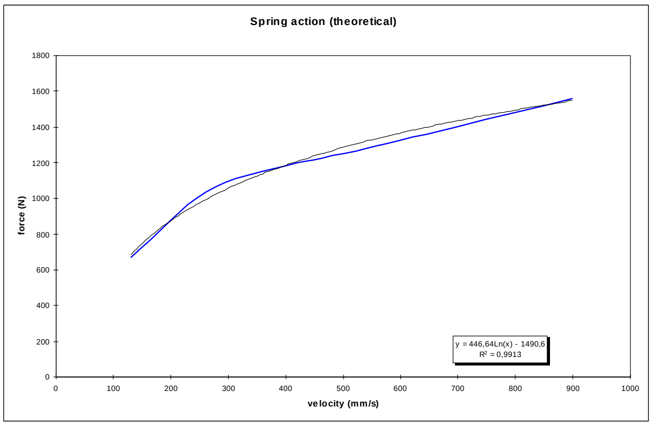
Graphic 1. Bleeds 8,0* in action



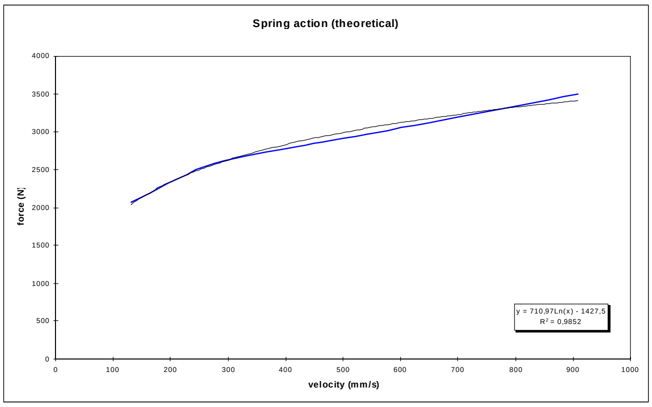
Graphic 2. Bleeds 17,0* in action

SPRINGS APPROACH

It's a hard task to isolate this component because its features are related to a large number of variables (composition, thermal treatment, diameters, etc), so we adopted a high quality spring ideal model. To complete boundary conditions we used the higher area passage piston and considered the useful velocity band 100-900 mm/s where influence of spring is maximum. Again, using the valves code table, we constructed table 2 with spring samples.



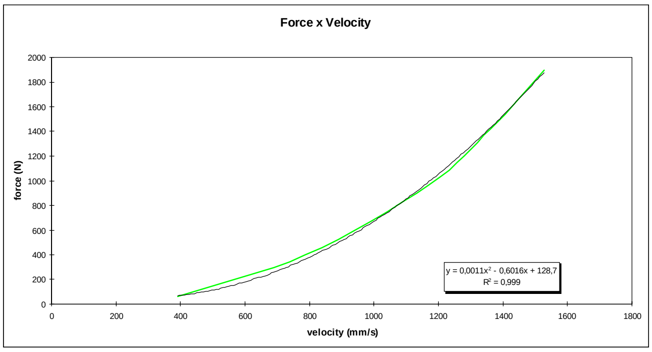
Graphic 3. Spring 35 lbs. in action



Graphic 4. Spring 100 lbs. in action

PISTON APPROACH

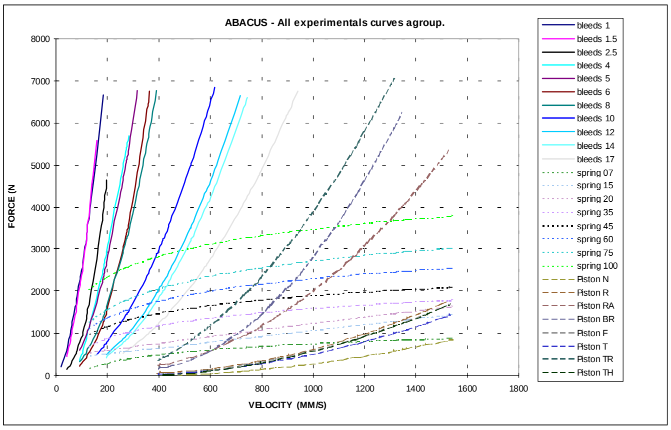
In discussing the shock absorber at high velocity, we are concerned with pistons, which have the greatest influence. This time all pistons available were used for calculations. We supposed the spring was totally compressed leading to a high velocity situation. The results in table 3 were obtained with 300, 900, 1050 and a 1200-cpm frequency with 50-mm stroke, where the main influences are the passages in the piston space reserved for blow-off.



Graphic 5. Piston R in action

ABACUS CONSTRUCTION

The project purpose was to build an abacus that helped us on a shock absorber elaboration, a first step towards its behavior. We constructed the abacus composing bleeds curves (low velocity), spring curves (medium velocity) and piston curves (high velocity) in a unique graphic, to analyze a certain valve code for rebound force.



Graphic 6. Shock absorber abacus.

RESULTS

The mathematical models can be used in two ways. When we have a proposed "valve code" we can predict the force x velocity curve using the equations developed. Another way is to take the proposed force x velocity curve given by the suspension engineers and describe it by a mathematical model for each valve operation region. With this curves we can define in advance which pieces shall be used in valve assembly in order to actually reproduce this curves in the prototype construction.
With this process we can design the shock absorber valves in less time and smaller cost in the prototype construction.

Bleeds code	Force	R^2	Equation
1,0*	$1,8934.v^{1,5673}$	0,9998	Potential
1,5*	$0,5830.v^{1,8131}$	0,9998	Potential
2,5*	$0,5341.v^{1,7255}$	0,9966	Potential
4,0*	$0,1980.v^{1,8238}$	0,9988	Potential
5,0*	$0,0922.v^{1,9455}$	0,9972	Potential
6,0*	$0,0038.v^{12,4403}$	0,9960	Potential
8,0*	$0,0270.v^{2,083}$	0,9907	Potential
10,0*	$0,0320.v^{1,9101}$	0,9999	Potential
12,0*	$0,0113.v^{2,0201}$	0,9998	Potential
14,0*	$0,0084.v^{2,0527}$	0,9984	Potential
17,0*	$0,0083.v^{1,9878}$	0,9992	Potential

Table 1. Bleeds equations.

Springs denomination	Force	R^2	Equation
AM 8-8	286,84.Ln(v) - 1223,3	0,9019	Logarithmic
AM 15-8	268,63.Ln(v) - 899,47	0,9093	Logarithmic
AM 20-8	315,35.Ln(v) - 1060,7	0,9227	Logarithmic
AM 35-8	446,64.Ln(v) - 1490,6	0,9988	Logarithmic
AM 45-8	452,51.Ln(v) - 1228,1	0,9972	Logarithmic
AM 60-8	583,39.Ln(v) - 1724,4	0,9960	Logarithmic
AM 75-8	719,10.Ln(v) - 2244,3	0,9907	Logarithmic
AM 100-8	710,97.Ln(v) - 1427,5	0,9999	Logarithmic

Table 2. Springs Equations.

Piston denomination	Force	R^2	Equation
N	$0,0005.v^2 - 0,211.v - 5,9471$	0,9993	Polynomial
R	$0,0011.v^2 – 0,6016.v + 128,7$	0,9990	Polynomial
F	$0,001.v^2 – 0,472.v + 64,859$	0,9995	Polynomial
T	$0,0008.v^2 –0,312.v + 26,734$	0,9987	Polynomial
RA	$0,003.v^2 - 1,2658.v + 268,85$	0,9942	Polynomial
BR	$0,0059.v^2 - 3,883.v + 785,86$	0,9983	Polynomial
TR	$0,0046.v^2 - 0,587.v - 126,65$	0,9999	Polynomial
TH	$0,001.v^2 - 0,446.v + 21,434$	0,9984	Polynomial

Table 3. Piston Equations.