OXFORD ANALYSIS CONSULTANTS

Car trailer dynamics

The effect of component variation and age

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Reference : C00-TR2-v1.0

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1.1 Forward

This article is not meant as a design guide but as an informative and interesting article. A little bit of Engineering 'playtime'.

The article is not meant to be 'watertight' and may be amended without any notice.

Oxford Analysis Consultants are presenting some of their capability in this article.

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1.2 Abstract

Designing something to last must consider the real life environment. How is the environment quantified and used as an input to the design process?

Not unreasonably, Engineers often design for single worst cases where, for example, a component is on 'bottom limit'. Problems really begin when trying to design for worst case forces. Designing against all the possible pessimistic numbers and producing a component that will not break would probably mean creating something too heavy, expensive and would be generally uncompetitive.

Design numbers for forces can come from many sources including standards and historical experience. But, as a competing component's performance begins to take market share, designs are made more and more efficient without any real knowledge of where the feasible design envelope really ends. Beyond the envelope, components either just break or they statistically fail prematurely along with reputation.

It is at this point that Engineers apply instrumentation and begin collecting real data against which to design and it is at this point that Engineers realise that the real forces involved can be much larger and more complex than realised. It is now that the component design company begins to learn about the real operating environment and about the statistical nature of applied forces.

Instrumentation requires real hardware, the results from which must be read across to new designs. Measurements taken from current designs are a valuable asset they may not so useful for a new or different design.

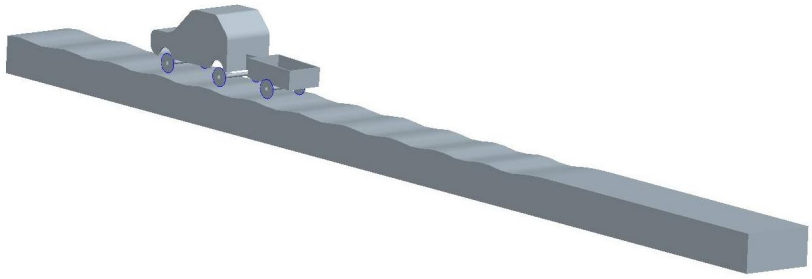
Whatever the force inputs finally used for design, trials instrumentation of real hardware helps to 'close the loop' and improve the inputs for the next design.

This article explores suspension forces for a simple towed trailer and how these forces are affected by 'aging' of the damper and spring. It shows that force 'envelopes' are possible in the virtual environment.

1.3 High level methodology

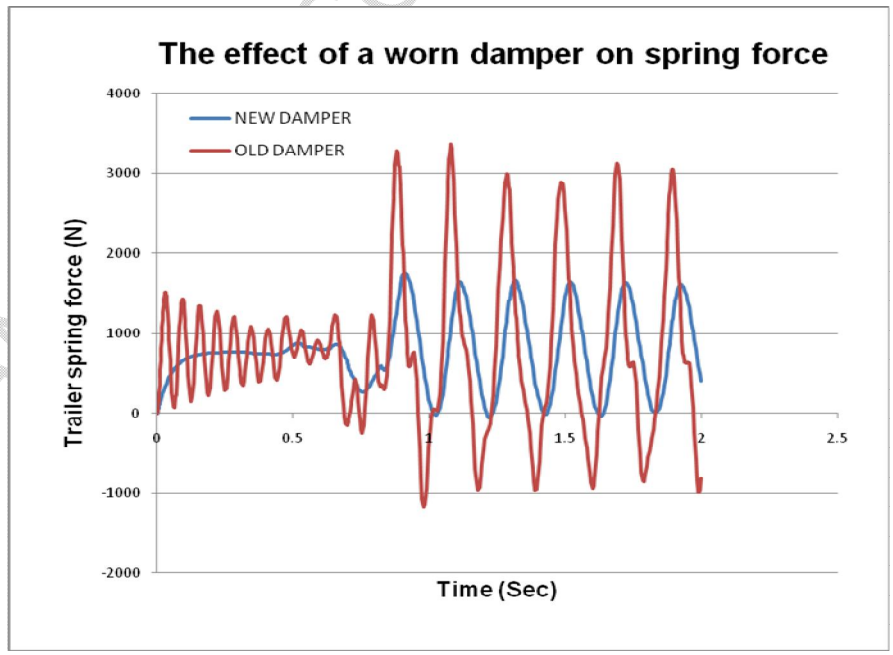
A simplified rigid body dynamic model of a car and trailer were created.

The model car and trailer was arranged to have an initial velocity on flat ground before approaching a road surface profile at a constant velocity.



During the motion, the forces experienced by the spring and the damper were recorded and for a fixed road surface profile, the trailer variables were modified.

Looking at the condition when a damper is poor, old or failed it is expected that the trailer will bounce and the spring will experience high forces during uncontrolled oscillations encouraged by the uneven road surface. The introduction of a damper tends to 'smooth' the response. This is not new knowledge.



The initial oscillations of the trailer for a worn damper are in fact damped out by the suspension of the towing vehicle. This view is of design input extremes.

1.4 Gradual performance decline

It is reasonable to assume that there will be some change in performance of both spring and damper over time. It was assumed that the car pulling the trailer was a constant but the following variables were available to study for each road surface:

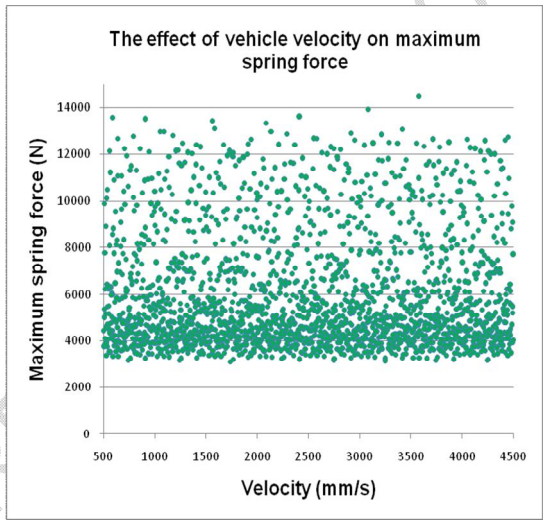
- Vehicle velocity
- Trailer damper rate
- Trailer spring rate

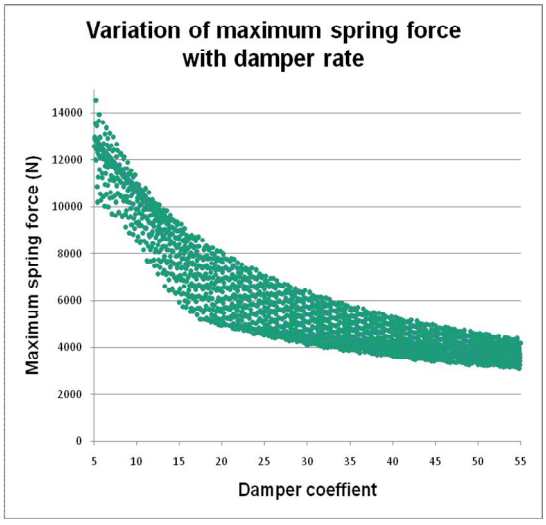
The same experiment was carried out a large number of times, each one having a different spring rate, damper rate and vehicle initial velocity as inputs. Spring and damper forces were plotted as outputs.

Table Data

Name: MASTER_TABLE Records: 2000

Record #	MIN_SPRING_...	MAX_SPRING...	MIN_DAMPER...	MAX_DAMPE...	CAM_MAX:M...	CAM_MIN:MO...	CAM_RMS:M...
0	-3.333754	5074.689236	-4480.611815	42792.744208	0.000000	-43241.50707...	3182.166974
1	-140.256005	7819.915993	-4566.400284	23314.070131	0.000000	-23552.50390...	3016.213159
2	-2.778128	3849.346355	-3974.762118	58135.178407	0.000000	-58705.95893...	3391.354984
3	-18.898232	5437.670282	-4464.026577	32842.587963	0.000000	-33238.39136...	3045.895090
4	-4.167192	4484.249087	-4286.707274	68016.277482	0.000000	-68483.94678...	3557.885459
5	-201.660120	10056.863998	-4981.200734	16500.260795	0.000000	-17777.18178...	2939.348828
6	-2.500315	3957.974988	-4088.258775	49735.855792	0.000000	-50278.45034...	3266.892556
7	-32.317747	5247.054879	-4412.486457	28088.053975	0.000000	-28460.44682...	2956.527117
8	-3.750473	4313.415487	-4232.734361	63492.072425	0.000000	-63969.70720...	3489.459188
9	-258.039449	12232.403393	-4816.277647	11240.917650	0.000000	-14699.71754...	2652.730330
10	-3.194847	4625.388220	-4431.977948	46789.569427	0.000000	-47229.72569...	3244.659554
11	-150.849773	7547.401793	-4244.794921	18768.190889	0.000000	-19004.87693...	2915.324029
12	-4.028285	5007.258032	-4421.139740	55639.398123	0.000000	-56063.44069...	3394.453462





The Engineer can begin to understand the distribution of the spring force population and how the performance of the damper affects the maximum spring force.

This will assist with the choice of design load for basic static structural integrity but more importantly could become an input to fatigue studies.

1.5 Brief notes

The model studied has the following main simplifications

- Effectively 2-Dimensional
- No tyre characteristic
- No friction
- Wheels do not rotate

The following is possible further study

- 3-Dimensional model to study lane changing
- Tow hitch forces
- The effect of different towing vehicles
- Effect of different road profiles
- Minimising the chances of trailer wheels leaving the ground

1.6 Review

Date	Reference	Revision	Actor	Comment	Company	Signature
10 Mar 2011	C00-TR2	v1.0	Charles Simpson		Oxford Analysis Consultants Limited	

1.7 Document history

Date	Revision	Author	Comment
10 March 2011	v1.0	Santosh Gannu	New document